NORTHERN INSTITUTE
People. Policy. Place.

CHARLES DARWIN UNIVERSITY AUSTRALIA

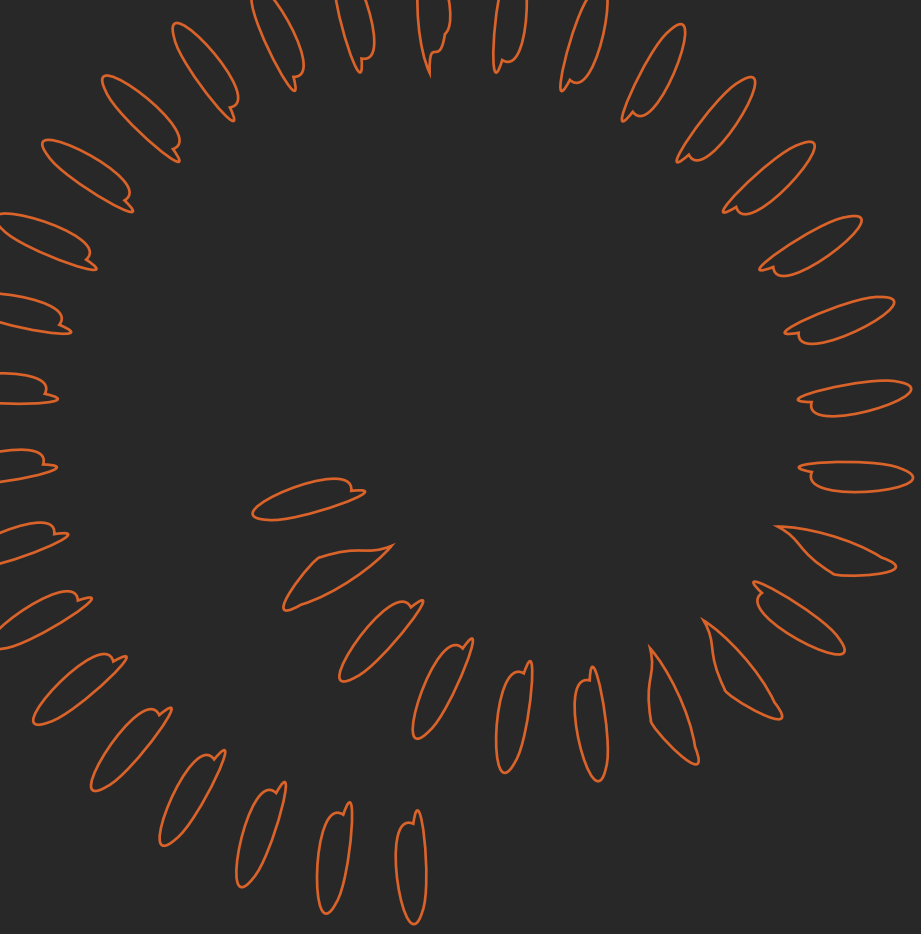
Regional Development Australia

Proudly sponsored by NORTHERN TERRITORY GOVERNMENT

Report authors
Dr. Deepika Mathur
Dr. Robin Gregory
Dr. Stephen Sutton

NORTHERN INSTITUTE REPORT

SCOPING REQUIREMENTS FOR NT REMOTE AND VERY REMOTE DISASTER WASTE MANAGEMENT



Disclaimer

The views expressed in this report do not necessarily represent the views of the funding bodies, the Commonwealth, Northern Territory Government or Charles Darwin University, including their officers, employees or agents.

Project Team

The project team comprised of Dr. Deepika Mathur (Northern Institute, Charles Darwin University, Dr. Robin Gregory (Regional Development Australia NT) and Dr. Stephen Sutton (Independent researcher). Collectively the team brings together expertise and good understanding of current issues in waste management, regional development and disasters.

Report title: Scoping requirements for NT Remote and Very Remote Disaster Waste Management
Authors: Dr. Deepika Mathur (Northern Institute, Charles Darwin University, Dr. Robin Gregory (Regional Development Australia NT) and Dr. Stephen Sutton (independent researcher)
First Published: 2023

Cover image: https://cc0.photo/2015/12/23/remains-of-a-burnt-down-house/

Contents

Abbreviations

ALPA	Arnhem Land Progress Aboriginal Corporation
BAU	Business as usual
C&D	Construction and Demolition
DW	Disaster Waste
DWM	Disaster Waste Management
EARC	East Arnhem Regional Council
FEMA	Federal Emergency Management Agency
JSMCWM	Japan Society of Material Cycles and Waste Management
LEMP	Local Emergency Management Plan
LGANT	Local Government Association of the Northern Territory
LEC	Local Emergency Committee
LRC	Local Recovery Committee
MSL	Mean Sea Level
NTEPA	Northern Territory Environmental Protection Authority
NTPFES	Northern Territory Police, Fire & Emergency Services
NTG	Northern Territory Government
PAWA	Power and Water Authority
PWA	Public Works Advisory
SLTT	State Local Tribal & Territorial
TEP	Territory Emergency Plan
WAC	Welfare Assembly Centres
WARC	West Arnhem Regional Council

List of tables

List of figures

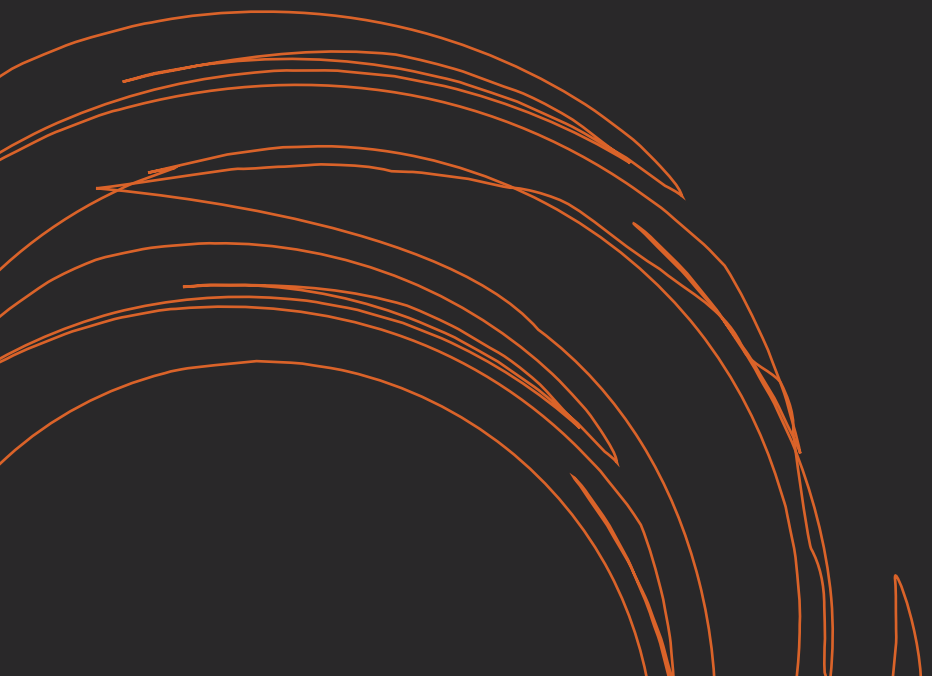
Acknowledgements

The project team would like to acknowledge the funding support provided by the National Territory's Risk Reduction Program (NTRRP) administered by the Department of the Chief Minister and Cabinet, and Regional Development Australia, Northern Territory (RDA NT). We would also like to thank all our stakeholders who participated in the interviews. We are grateful for their time and willingness to share their knowledge and information.

We would like to thank Bev Sithole, Honorlea Mangion (ARPNet) and the ARPNet trained community-based researchers, Christine Brown, Jenester Stewart, Maureen Redford, Maisie Cameron, Kelly Wilson and Ursula Campion for collecting data in Ramingining and Maningrida. We would also like to thank Anna-Feliz Stevens for interview transcriptions.

We are thankful to Local Government Australia Northern Territory (LGANT), Wesley Van Zanden (East Arnhem Regional Council) and Sara Fitzgerald (West Arnhem Regional Council) for supporting this research.

Finally, we wish to acknowledge the Traditional Owners of Arnhem Land who welcomed us to their Country and gave permission for us to conduct this research. We hope this report might help to protect the ancient land and sea country on which they live.



Executive Summary

The purpose of this study was to explore the importance of disaster waste management for remote and very remote regions of the Northern Territory. The project aimed to identify critical disaster waste management issues for a range of natural disasters, current limitations and challenges for disaster waste management in remote regions, and interventions required for effective disaster waste management in the future.

In order to address these aims, there were two key data collection activities: gathering data from existing literature on disaster waste management and conducting a series of stakeholder interviews regarding current policy practices, barriers and challenges and ways forward for improving disaster waste management. The review of literature from Australia and overseas allowed us to contextualise the study findings and inform on both the fieldwork and interpretation of the results. Both academic and grey literature highlighted the importance of early planning and having a disaster waste recovery plan before a disaster. It allowed us to list the types of waste generated in the remote communities during natural disasters, as well suggest ways of calculating volumes of that waste. The grey literature revealed that despite the urgent need to clear waste after an emergency, disaster waste management barely rates a mention in its own right, while essential services, usually referred to as encompassing telecommunications, power, water and sewerage, all receive considerable attention. Interviews with the stakeholders helped us explore the diverse perspectives of the stakeholders who play a role in disasters and disaster waste management.

The results identify the central and urgent need for the creation of a specific disaster waste management (DWM) plan for each community. These plans should be embedded within the 46 local Emergency Management Plans in the Northern Territory's two emergency management areas. The establishment of these DWM plans will provide an effective and straightforward way to deal with the practical issues communities face, while larger structural and statutory/regulatory issues are developed appropriately. Both the literature review and fieldwork strongly indicated that a "cookie-cutter" approach was not appropriate for the development of DWM plans. Each community has its own unique geographic and socio-economic characteristics, as well as Indigenous languages and cultural practices, that contribute not only to that community's capability and capacity to manage disaster waste, but also to the local cultural protocols that should be observed.

Data gathered for this study also suggests that the vertical integration of decision making for effective disaster waste management will be critical for risk minimisation when hazards strike. Given that 'all disasters are local' it is essential that key stakeholders are identified at the local level. In the three communities used as case studies there is an uneven spread of understanding of the DWM risk and the local capacities and responsibilities for dealing with it.

Investing in a DWM plan as part of a more comprehensive local Emergency Management Plan that recognises and supports development of that local capacity in business-as-usual (BAU) times will reduce vulnerability in times of crisis and contribute to more rapid response and recovery efforts. Including community nodes of competence, such as the Ranger groups that have developed in the last two decades, as well as other identified community members, in planning and practical activities such as pre- and post-cyclone clean ups is a positive step in engaging the local community. The degree to which residents can participate and feel empowered to be involved in a clean-up needs to be further explored.

Structurally, there is a shared recognition of the vagueness of the Local Government role in the EMPs. The 2008 Local Government reforms have not yet translated into a formal role explicitly recognized in the TEP. The inclusion of a clarified (and increased) role of Local Government in DWM plans would facilitate other measures important for response and recovery stages, including more strategic investment in both people (training, education, recruitment) and place (infrastructure and equipment).

1. Introduction

Despite the increasing frequency and scale of natural disasters across the Australian landscape, disaster waste management remains relatively poorly understood and largely occurs as a 'reactive' process that is costly and impacts upon the recovery and resilience of communities. The capacity and capability of communities to manage disasters and resultant waste varies; research to date has tended to focus on larger communities from the more populated areas of eastern and southeastern Australia. These areas exhibit geographic and socio-economic characteristics that are very different from those found across much of the Northern Territory.

According, the purpose of this study was to explore the importance of disaster waste management for remote and very remote communities of the Northern Territory. The project aimed to identify critical disaster waste management issues for a range of natural disasters, current limitations and challenges for disaster waste management in remote regions, and interventions required for effective disaster waste management in the future.

Drawing on information from academic and grey literature as well as the lived experiences of a range of stakeholders, the study addresses the National Disaster Risk Reduction Framework (NDRRF) priorities by:

- Establishing the need for disaster waste management plans as part of the local Emergency Management plans;
- Providing evidence for vertical integration of decision making;
- Identifying benefits of investing in disaster waste management planning that includes using existing resources; and
- Recognizing role of local government in governance, ownership and responsibility for disaster waste.

The information provided in this report is intended to assist a broad range of stakeholders and represents a starting point for further discussion and consideration.

Section 2 of this report presents a literature review of relevant academic and grey literature (including government reviews and inquiries), relating to the management of disaster waste and disasters more broadly. Section 3 describes the methodology, data collected and results of interviews. The implications of these findings, as well as those from the literature review inform the discussion that is presented in Section 4. Recommendations arising from this study are in section 5. Additional information that contributes to the final analysis and recommendations is included in the appendices.

2. Literature Review

This section reviews selected literature on waste management practices, emergency waste management arrangements and disaster waste preparedness. Specifically, it aimed to:

- Identify key themes relevant for disaster waste preparedness;
- Identify various waste streams generated during disasters and potential methods for predetermining waste volumes;
- Identify gaps in the existing knowledge base and areas which will require further investigation and analysis in the final literature review; and
- Inform on the scope and content of the field research component of the current study.

The findings arising from this literature review are presented below, following a brief description of the methodology. The review also includes critical commentary on the nature and scope of this knowledge base. It highlights some of the similarities and differences between research, reflected in the body of academic literature, and practical lived experiences, documented primarily through various reviews, inquiries and reports held in the aftermath of various disasters ('grey' literature).

2.1 Methodology

Relevant academic literature was sourced through an internet search using the term 'disaster waste management' and those relating to natural disasters were shortlisted for review. Impacts from human created disasters, such as nuclear waste or hazardous waste (oil spills) were not considered. The journal articles were categorized based on the type of natural disasters as well as overall themes they addressed. Grey literature was sourced through a search of the Bushfires CRC Disaster and Natural Hazards database using the search terms 'waste' and 'waste management' from which relevant reports were identified for review, as well as a direct internet search using the terms 'disaster', 'review', and 'inquiry'.

2.2. Review of academic literature

This section focusses on describing the main themes in the academic literature, types of waste generated and potential methods for quantifying volumes of disaster waste. It is important to note that because the current study adopts an "all disasters-all waste streams" approach, these findings are presented in terms of broad categories rather than being scenario/event specific.

Table 2.1 lists academic papers that discuss types of disasters and country in which the disaster waste study was undertaken. Two important points to note regarding this body of work are that firstly, virtually none of this research has been undertaken in Australia (with the exception of work by Brown et al. (2011) and Cheng et al. (2021) in relation to bushfires), and secondly, the extent to which this research has been undertaken in comparable settings, in terms of geography, demography and socio-economic contexts, requires further interrogation.

Some of the key themes identified from the academic literature were: lack of pre-planning for disaster waste; details of waste (composition and separation; quantities; management systems); waste treatment (temporary storage; recycling; open burning; landfilling; waste to energy); economic impact of disaster waste management (DWM) programs; social considerations (Victims; people in clean-ups; communities health risks); Organizational aspects (organizational structure; design of physical works associated with DWM program); and legal frameworks. Details of waste and potential quantification methods are described separately in section 2.3.

Table 2.1 Types of disasters and country studied for disaster waste (modified from Zhang et al., 2019)

Type of disaster	Academic literature
Earthquake	Japan: Sasao (2016), Asari et al. (2013), Tabata et al. (2017, 2016), Shibata et al. (2012), Kawamoto and Kim (2016 & 2019), Wakabayashi et al. (2017) , Saffarzadeh et al. (2017), Sakai et al. (2019), Pramudita and Taniguchi (2014), Koyama et al. (2016)
	China: Xiao et al. (2012), Hu and Sheu (2013), Zhang et al. (2016)
	Peru: García-Torres et al. (2017)
	Istanbul: Berktaş et al. (2016)
	Turkey: Sahin et al. (2016), Onan et al. (2015)
	New Zealand: Domingo and Luo (2017)
	Sri Lanka; Karunasena and Amaratunga (2016), Karunasena and Amaratunga (2015), Karunasena et al. (2012)
	Italy: Faleschini et al. (2017)
	Iran: Askarizadeh et al. (2016, 2017)
	Haiti: Raila and Anderson (2017), Pham et al. (2014), Hooper (2019)
	Nepal: Poudel et al. (2018), Memon (2015)
	Modelling: Çelik et al. (2015), Cheng et al. (2018a)
Tsunami	Japan: Asari et al. (2013), Tabata et al. (2017), Wakabayashi et al. (2017), Portugal-Pereira and Lee (2016) and Koyama et al. (2016)
	Indonesia: Prasetya et al. (2012)
Hurricane/Typhoon	USA: Fetter and Rakes (2011), Fetter and Rakes (2012)
	Modelling: Habib. et al. (2017, 2019), Kim et al. (2018), Lorca et al. (2017), Hu et al. (2019)
	USA: Fetter and Rakes (2013), Jiang and Friedland (2016), Thompson et al. (2011) and Szantoi et al. (2012)
Landslide	Japan; Tabata et al. (2017) and Wakabayashi et al. (2017)
Flood	Germany: Leader et al. (2018)
	Japan: Pramudita and Taniguchi (2014)
	Thailand: Phonphoton and Pharino (2019)
	Malaysia; Saat et al. (2016)
	Japan: Tabata et al. (2018)
	South Korea: Kim and Kim (2017)
	Modelling: Beraud et al. (2012)
Bushfire	Australia: Cheng and Thompson (2016), Brown et al. (2011b), Brown & Milke (2016).
	Modelling: Cheng et al. (2019, 2021, 2022)
Thunderstorm	Modelling: Cheng et al. (2018b)

2.2.1 Lack of Planning for disaster waste

It was identified that if there was pre-planning for disaster waste, it resulted in rapid clean up after disasters. Crowley (2017) surveyed 95 counties in the United States, who received major disaster declarations between 2012 and 2015, to examine the quality of their debris management processes. Forty-nine of these counties had debris management plans while the other 46 did not. The results suggested that counties with pre-disaster debris management plans were more effective and recycled almost twice as much disaster debris as counties without plans. The counties with pre-disaster plans also received over three times as much Public Assistance from the Federal Emergency Management Agency (FEMA). FEMA provides guides to help towards preparing and responding to disasters and the pre- disaster plans were done in consultation with FEMA, the State, and the EPA.

It has also been argued that planning for disaster waste should be done during normal times. Asari et al. (2013) identify that planners should determine the quantity of waste, temporary storage sites, and disposal or recycling options well before disasters strike. The guidelines put forth by the Japan Society of Material Cycles and Waste Management (JSMCWM) is summarised in their paper. These guidelines emphasize planning in the pre-disaster environment. The manual has guides on the identification of waste category and sorting for disaster waste; estimation of quantity generated; phases of recovery or reconstruction and waste management; flows for disaster waste separation and disposal; planning of separation and disposal strategy;¬¬ process of removing houses and temporary storage sites; examples of waste sorting and separation; addressing each waste material handling; and cautions for waste handlers (workers and volunteers).

While pre-planning for disaster waste is lauded, it is also evident that there are few instances where it is done. Reasons cited for this are: it is difficult to plan for the unknown; large scale disasters are perceived to be of low probability; and, in some instances, successful disaster waste management plans are being implemented without a pre-plan (Zhang et al., 2019, p.830).

2.2.2 Disaster waste management approaches

Geographical location (e.g. internal and coastal areas), urbanization level (urban and rural) and construction techniques impact types and quantities of disaster waste as well as management approaches. For example, Xiao et al. (2012) identified that construction in rural and urban regions was different. Houses in rural areas were mainly masonry structures while those in urban areas were concrete frame structures. As the concrete structures have a better seismic performance, these types of houses were less damaged during earthquakes. Therefore, recognising different types of construction systems was important when measuring quantities of waste generated in urban and rural areas.

Evaluating waste treatment scenarios for pre-disaster planning of DWM is important. Tabata et. al. (2017) propose a method to create inventory data which involves the following three steps:

1. estimation of disaster waste generation;
2. determination of temporary storage sites;
3. setting of system boundaries; and
4. data collection and inventory analysis.

The waste volumes were calculated taking into account the type of construction, overlaid with impact maps for tsunami, seismic activity and flooding. Based on the waste volumes, the area required for temporary storage sites were calculated. The system boundaries helped identify the catchment areas of waste. Initially, all waste is stored unsegregated at the temporary storage site. Next it is transported to a secondary storage site where it is stored and segregated. Finally, the segregated materials are taken for recycling, re-use or sent to landfill.

Zhang et al. (2019) have discussed programming models that allow for decision-making regarding allocation of funds, storage and processing of waste and route planning. Simulations of different waste management scenarios were also suggested as a way to provide decision-support inputs for improving resilience of the DWM systems.

2.2.3 Waste treatment options

Waste treatment options referred to in the DWM literature include **temporary storage**, recycling, open burning, landfill and waste conversion to energy. As discussed earlier (Tabata et al., 2017) temporary storage is required to store waste for a limited time and sometimes this is near the affected areas (Zhang et al., 2019, p.832). The secondary storage site, in contrast, needs to be located away from the affected location and the residential zones. Sorting is done at this site and materials are sent for recovery or to the landfill.

While **recycling** appears to be an eco-friendly option, some of the barriers for recycling disaster waste are lack of professional knowledge (Karunasena et al., 2009), lack of sufficient funds (Karunasena and Amaratunga, 2015), and large quantities of reusable and recyclable materials

continued to be disposed of in landfills and or via incineration, especially in developing countries (Brown and Milke, 2016). In addition to time and resources, Brown and Milke (2016 21) recommend seven disaster-specific factors to determine the feasibility of disaster waste recycling programs: volume of waste, degree of mixing of waste, human and environmental health hazards; aerial extent of the waste, community priorities, funding mechanisms, and existing and disaster-specific regulations. They highlight that pre-disaster planning and clear, well-enforced policies are necessary for implementing successful recycling programs.

While **open burning** is frowned upon due to toxic gases, many authors discuss the positive impact burning had during a time-pressure situation (Asari et al., 2013; Sasao, 2016). Similarly, **landfilling** has also been adopted to achieve efficiencies in disposing of disaster waste. Zhang et al. (2019) note that this would depend on finding a suitable space that is not close to water systems, has the capacity for landfilling the waste generated and is safe and well-planned.

Waste to energy is also suggested as another option for managing disaster waste. However, this involves high costs and access to particular technologies that might not be widely available (Portugal-Pereira and Lee, 2016).

2.2.4 Economic considerations

The literature distinguishes between economic impacts, that is direct and indirect costs and benefits, and funding mechanisms.

Direct costs tend to be captured under the headings of transport, classification, storage, opening of temporary sites, treatment of waste and disposal costs (Lorca et al., 2017; Hu and Sheu, 2013; Fetter and Rakes, 2012; Tabata et al., 2016).

There are a limited number of studies on indirect costs and benefits. Indirect costs would include disruption of critical infrastructure, risk to public health, delays in waste disposal and rebuilding, and road blockages. The benefits from efficient DWM would include job opportunities, the development of new technologies, or an increase in the scope of transport businesses (Zhang et al., 2019).

Zhang et al. (2019) identified that effective funding mechanisms (private, public, and insurance) for DWM were missing. They argued that access to funds for technology and equipment were closely related to the success or failure of a DWM plan (Karunasena et al., 2009, 2012). Often the funding providers required an implementation plan and the funding receivers (working on a short time frame) would opt for open burning or landfill. This caused a disconnect between the funding bodies and recipients (Crowley and Flachsbart, 2018).

2.2.5 Organizational aspects

Different organisations or groups (e.g. government agencies, non-profit organizations, volunteers and military) are involved when responding to disasters (Zhang et al., 2019) and their communication and coordination are highlighted in research by Karunasena and Amaratunga (2016). At the same time Zhang et al. (2019) noted that there was no literature on ways of achieving this coordination with respect to managing disaster waste. This is particularly true when no pre-disaster plans are in place (Brown et al., 2011b, Hooper 2019).

Since Zhang et al.'s (2019) review, there has been increasing academic attention on community participation in disasters and emergencies more broadly. Although not necessarily focused on disaster waste per se, this body of work does provide examples of potential approaches regarding community participation, engagement and consultation, which are relevant when considering disaster waste planning. For example, Rawsthorne et al. (2023) identified action across seven domains that support community action for disaster preparedness. In doing so, they also drew attention to the gap between policy and practice in community leadership and participation, and disaster preparedness and recovery. In another study, community members identified "community leadership and community-led action" as factors that contributed the most towards community recovery on the ground (Moreton, 2018). Moreton (2018) also notes that there were multiple perspectives on community recovery held by different people in the community and between the community and 'those at the top'. Nevertheless, the overwhelming message was that actions and responses should focus on the needs of the local community rather than imposing solutions or processes (Moreton, 2018). The study by Rawsthorne et al. (2023) also reinforces this message, cautioning that because communities are socially produced, rather than being "objects to be acted upon", a "cookie cutter" approach is unlikely to gain traction across locations and will be short-lived (Rawsthorne et al., 2023, p.49). Underpinning the success of any approach is genuine community engagement. Moreton (2018, 21) found that:

"Current consultation mechanisms and community reference groups are frustrating for many community

members, even when established explicitly to facilitate community engagement and community leadership in planning, response or recovery. The most suitable community representatives were not always invited to join these groups, and frequently, they are chaired or led by government or non-government organisations. Community members feel disempowered and frustrated by this approach to community engagement".

In Australia, academic research regarding community involvement in disaster/emergency management has also included Indigenous participation-resilience-responses in disaster contexts (e.g. Sangha et al., 2017; Veland et al., 2010), although this body of work mirrors that undertaken in Australia more broadly in that there appears to be very little focus on disaster waste management specifically. Much of the research relating to NT Indigenous communities and disasters has occurred in the Top End. For example, Morely et al. (2016) assessed the resilience of the Ngukurr and Gunbalanya communities, exploring the applicability of the Torrens Scorecard approach. They found that despite residents' previous experiences of disaster resilience activities in their respective areas, their knowledge of local plans and procedures was limited. They also found a strong disconnection between the local Indigenous residents and those people in positions of authority, despite the existing procedures in place at varying scales, including at the local level (Morely et al., 2016; see also Sithole et al., 2019). Similarly, Ali et al. (2021) highlighted an apparent mismatch between the top-down, government-driven Western approach to emergency/disaster management, and community-led and culturally appropriate approaches to managing and responding to risk in their research with Yolgnu people on Galiwinku. Such tension is not restricted to Indigenous/non-Indigenous relationships; Crossweller and Tschakert (2021) explored the 'culture clash' between the command-and-control approach of emergency service organisations and the self-organising, grassroots approaches enacted by local community groups.

Sangha et al., (2019) examined how people in remote Indigenous communities can contribute to emergency service mitigation and delivery through Indigenous Ranger groups in Borroloola, Hermannsburg (Ntaria) and Yuendumu. This work highlighted the importance of a collaborative policy framework to facilitate incident mitigation and management whilst meeting Indigenous cultural protocols and practices.

In the case of Galiwinku, Ali et al., (2021) documented the role of local Yolgnu people during the preparation, response and recovery phases of several cyclones, noting that this involvement was not formally recognized in the Territory Emergency Plan (TEP) or related documentation (Ali et al., 2021). The nature of this participation included activities such as disseminating information in language to the local community about impending cyclones, helping vulnerable community members (e.g. aged, disabled, kids) move to cyclone shelters, and respected community leaders acting as liaison officers between the community and government agencies. In common with findings from several inquiries following disasters (see section 2.4 below), the lack of appropriate training for local community members regarding emergency responses was seen as a barrier to local awareness and ability to prepare and respond to disasters (Ali et al., 2021). Ali et al. (2021) recorded that whilst government agencies engaged with Elders during the preparation and response phases, there was far less engagement during the recovery phase, with the community only involved in relatively minor activities such as cleaning up roads. Most of the recovery work was undertaken by non-Indigenous people, including FIFO workers, who did not always interact in culturally appropriate ways with local residents (Ali et al., 2021). Section 2.4. contains further examples of Indigenous participation in the NT in disaster response and recovery phases, derived from the grey literature.

2.2.6 Legal Frameworks

Lack of legal frameworks for regulating DWM has been flagged in the literature (Zhang et al. 2019), although it is recognized that often there are guidelines prepared by governments to guide the management of disaster waste. For example, *Planning for Disaster Debris* and *Planning for Natural Disaster Debris* by USEPA, and *Guidelines for post-disaster debris cleanup and waste management* by the Ministry of Environmental Protection, China. However, as such documents are guidelines they are not legally enforceable. Additionally, these documents could not resolve conflicts between environmental and economic concerns relating to disaster waste. For example, decision-making was difficult when deciding between environmental impact and economic costs in a situation where open burning was carried out (Wakabayashi et al., 2017; Lorca et al., 2017; Karunasena et al., 2012). Also, locating optimal waste disposal sites has its own challenges in terms of environmental justice/injustice (Allen, 2007).

2.3. Types of waste generated during disasters and potential quantification methods

2.3.1 Waste composition

Disaster waste can be classified into one of 15 categories (after Brown et al., 2011), which, for the current study, have been grouped as follows in Table 2.2. They have been further categorised as hazardous and non-hazardous, as this is the primary factor that dictates their treatment.

Table 2.2 Disaster waste streams (modified from Brown et al., 2011)

Non-hazardous

Natural wastes	Man-made
• Vegetative debris & green wastes • Sediment, soil, & rock	• Construction & demolition debris from damaged buildings & other infrastructure (e.g. masonry, concrete & cement, bars, timber, steel, clay, reinforced concrete brick, structural components, foundation materials debris from road damages) • Vessels & vehicles • Recyclables (e.g. plastics, metals) • Household waste (e.g. furniture other than electrical & white goods, clothing) • Excessive unwanted donations (e.g. clothing) • Emergency relief food & water packaging

Hazardous

Biological/health hazard	Chemical hazards	Other hazards
• Putrescible wastes (e.g. rotting food) • Human & animal corpses • Healthcare wastes • Rotten food from power outages	• Household waste (e.g. refrigerants, oils, pesticides, paints etc) • Industrial & toxic chemicals (including fuels)	• Construction & demolition debris from damaged buildings & other infrastructure (i.e. asbestos) • Electronic & white goods • Waste from pre-disaster waste/ landfill sites

2.3.2 Determining waste quantities

There are several studies examining ways of quantifying disaster waste. Marchesini et al. (2021) undertook a comprehensive analysis and comparison of 22 methods of quantifying vegetation debris, household goods waste, and construction and demolition debris and on this basis identified three main types of methods:

- 'historical data' methods (based on historical data from past disasters),
- 'database' methods that use local, regional and national databases (e.g. on building types, household goods etc), and
- 'imaging' methods that use satellite, aerial and radar images (this method is the most accurate but cannot distinguish between different types of waste).

The authors observe that volumetric quantifications are more practical (even when considering historical data) because they permit calculations of the need for temporary waste disposal sites. Imaging methods can only be used post-disaster, whereas historical data and data-based methods are mainly predictive. These methods are described below.

Historical data methods. Many estimation methods are based on historical events where the quantification of wastes is done after a specific disaster and may be combined with imaging methods. For example, satellite images from before and after hurricanes were used to develop statistical models of debris distribution (Thompson et al., 2011; Escobedo et al., 2009). Chen et al. (2007) developed a method based on the historical flood data in Taiwan, which can be replicated wherever there is enough historical data. These methods produce a per unit generation debris estimation for particular types of disaster.

Database methods. A second type of method is based on national or regional databases on household equipment (Tabata et al., 2018; Tabata et al., 2016) or on building types (García-Torres et al., 2017; Federal Emergency Management Agency, 2003), and may be supplemented by other sources of data. For example, Tabata et al. (2018) included a questionnaire survey to obtain additional information. The amount of material per building type can also be estimated through building codes, technical recording, or field recognition (Poudel et al., 2018). For vegetative debris, surveys on tree cover, canopy, land uses, etc., may be necessary (FEMA, 2003). A statistical analysis of the databases is generally performed.

Imaging methods. The third type of method is based on imaging. These methods do not require hazard or regional data and have proved useful in places where there is no historical data available (Yoo et al., 2017). However, they require the use of drones (Saffarzadeh et al., 2017), airborne sensors (Szantoi et al., 2012) or satellite and aerial imaging (Jiang and Friedland, 2016), as well as specific software to process the images and significant computing (memory) capacity.

2.3.3 Waste calculation methods according to waste type

Within the academic literature there are calculations for construction and demolition wastes, vegetation debris, household goods waste and mixed waste.

Construction and Demolition (C&D) debris. Two ways of constructing the methods appear for calculating C&D debris. On the one hand, there are methods based on statistical analysis of historical data, i.e., on waste quantities calculated on past disasters. In this case, calculations of C&D waste were done post-disaster, and this formed the basis of calculations that can be used for future projections. Different material wastes from collapsed and damaged buildings were calculated. These quantities were then used to calculate demolition waste per unit area generated by different materials, from different types of structures (Xiao et al., 2012).

On the other hand, some methods used current databases or building inventories; in these cases the material waste arising from the existing stock of buildings is calculated from materials used for construction. This heavily depended on the building construction type (for example, reinforced concrete construction vs masonry construction). Waste generated is measured as tonne per sq. m and cu.m waste per sq m. (Poudel et al., 2018).

Tabatha (2017) estimated potential disaster waste from seismic, tsunami and water damage. A residential map was created to visualize potentially damaged areas by overlaying a hazard map on a residential map. The hazard map provided the seismic intensity, inundation depth and so on, for the area. Next, a grid was created to visualise the number of dwellings by overlaying the residential map and the grid data. The potential disaster waste generation was calculated for each grid by multiplying the number of dwellings, damage functions and mass per unit of disaster waste.

FEMA has also developed a Hazus Earthquake Model User Guidance tool (FEMA, 2018). The Hazus Earthquake Loss Estimation Methodology provides state, local, tribal, and territorial (SLTT) officials with a decision support software for estimating potential losses from earthquake events. The tool enables users to anticipate the consequences of earthquakes and develop plans and strategies for reducing risk. The Geographic Information System (GIS)-based software can be applied to study geographic areas of varying scale with diverse population characteristics and can be implemented by users with a wide range of technical and subject matter expertise. It is a tool for developing earthquake loss estimates for use in anticipating the possible nature and scope of the emergency response needed to cope with an earthquake-related disaster; developing plans for recovery and reconstruction following a disaster; and mitigating the possible consequences of earthquakes. The use of this standardized methodology provides nationally comparable estimates that allow the US Federal Government to plan earthquake responses and guide the allocation of resources to stimulate risk mitigation efforts. The Hazus Earthquake Model comes with a large library of baseline nationwide inventory data, which can be updated with local data to increase the accuracy of the model. The data is available only for the United States and its Territories.

Vegetation debris. For vegetation analysis, most of the methods use statistical analysis of historical data or images. FEMA performs a mechanical analysis at the scale of the tree to define damage functions for trees, and Szantoi et al. (2012) have undertaken post-disaster waste detection using aerial images.

Szantoi et al. (2012) developed a tool to detect downed trees and debris volume to better aid disaster response efforts and removal of tree debris. The tool estimates downed tree debris volume in hurricane-affected urban areas using a Leica Airborne Digital Sensor (ADS40) and very high resolution digital images. The tool employs a Sobel edge detection algorithm combined with spectral information based on colour filtering using 15 different statistical combinations of spectral bands. The algorithm identified fallen tree edges based on contrasts between

tree stems, grass, and asphalt and colour filtering was then used to establish threshold values. Colours outside these threshold values were replaced and excluded from the detection processes. Results were overlaid, and an "edge line" was placed where lines or edges from longer consecutive segments and colour values within the threshold were met. Where two lines were paired within a very short distance in the scene, a polygon was drawn automatically, and, in doing so, fallen tree stems were detected. Tree stem diameter–volume bulking factors were used to estimate post-hurricane tree debris volumes. Images following Hurricane Ivan in 2005 and Hurricane Ike in 2008 were used to assess the error of the tool by comparing downed tree counts and subsequent debris volume estimates with post-hurricane photo-interpreted downed tree counts and actual field measured estimates of downed tree debris volume.

Household goods waste: The three methods dealing with household goods waste are based on a statistical analysis of databases on household equipment, associated with a weighting for each type of waste (Tabata et al., 2016, Tabata et al., 2018). A hypothesis is made for conditions that transform the good to waste (e.g. the threshold for water height in case of flooding, building damage state for an earthquake, etc.). Tabata et al. (2018) used a survey to estimate the quantity of consumer goods in households. Material intensity coefficients (MIC) regarding the weight of consumer goods were calculated based on web–based and statistical surveys in units of kg/item and kg/USD. This was then used to estimate waste per housing for detached houses and complex housing.

Mixed wastes: Most methods that quantify mixed wastes are post-disaster imaging methods established to assess the quantity of debris resulting from earthquake and flood disasters (Jiang and Friedland, 2016; Koyama et al., 2016; Saffarzadeh et al., 2017; Yoo et al., 2017). For example, per unit generation of earthquake disaster debris was examined based on observed debris discharge from the 1995 Great Hanshin Awaji Earthquake and the 2004 Niigata Chuetsu Earthquake. In addition, the per unit generation of disaster debris from flood damage above floor level was estimated at 4.6 t/household. It was shown that this procedure would allow an estimate of the amount of debris so that disaster management and operation systems could be established for not only emergency response in the aftermath, but also pre-disaster planning" (Hirayama et al. 2010).

Hazardous waste: Management of two types of hazardous waste discussed in the literature are for asbestos and other hazardous materials in the built environment such as warehouses and factories (Zhang et al., 2017). Baek et al. (2016) used the Delphi technique to identify asbestos management through a process that consisted of (1) the location of the ACBM-containing buildings; (2) types and quantities of ACBMs; (3) cost of ACBM disposal cost; (4) amount of asbestos fibre during normal times and during post-disaster periods; (5) the optimum order in which ACBM-containing buildings should be dismantled. Kim and Hong (2017) added the greenhouse gases generated when removing the ACBM. At the time of a disaster-the buildings with ACBM are dismantled first, using a tailored process.

2.4. Findings and observations on the 'grey' literature

For the purposes of this section the 'grey' literature primarily consisted of the reports following various inquiries and reviews into disasters. This body of work is extensive: the 2020 Royal Commission identified at least 242 inquiries/reviews into disasters in Australia, mainly bushfires (Commonwealth of Australia, 2020a). Only the results from more recent reviews have been considered below, except where the review directly relates to DWM.

The first and most salient point to make regarding the grey literature, is that DWM barely rates a mention in its own right, even though essential services, usually referred to as encompassing telecommunications, power, water and sewerage, all receive prominent coverage. For example, the 2017 *The Cyclone Debbie Review: Lessons for delivering value and confidence through trust and empowerment, Report 1*, includes the word 'waste' only three times. It notes that Councils used Facebook to push messages regarding essential services, including waste collection and clean-up activities, as soon as they were able to, i.e when communications systems were restored (Office of the Inspector General Emergency Management 2017, p.46). Of particular relevance to the current study is the observation that there was high demand from the public for advice regarding the clean-up of hazardous waste, along with other issues such as food and water hygiene, mental health, and power outages (Office of the Inspector General Emergency Management 2017, p.11, 71).

The 2020 Royal Commission into *National Natural Disaster Arrangements*, held in the wake of 2019-2020 bushfires in south-eastern Australia, also only briefly considered disaster waste. This consideration was undertaken within a discussion framework specifically

relating to recovery plans. The Report included the following observations:

21.37. *"Problems also arise when establishing new arrangements for recovery services during a crisis. This was particularly apparent in the clean-up process following the 2019-2020 bushfires. In areas hardest hit we heard that the scale of the clean-up was enormous, complex and costly. It required the identification and management of vast volumes of hazardous waste, particularly asbestos which had been used in the construction of homes and other structures. The time taken to finalise clean-up arrangements resulted in uncertainty and delays in debris removal and added complexity to the resolution of insurance claims – see Chapter 20: Insurance. The delays in the removal of debris were compounded by perceptions of poor communication and unclear eligibility – points of significant frustration in affected communities".*

21.38. *"The coordination of issues such as clean-up would benefit from additional planning before a disaster. Standing recovery plans help relevant organisations understand roles, processes and thresholds in addressing particular recovery needs. These plans can also support the establishment of core features of a recovery program (such as eligibility and whether an 'opt-in' or 'opt-out' process is used) before a disaster."*

21.39. *"These arrangements could be supported by additional coordination tools and platforms. We have been told that there would be value in developing apps that can be used to match an identified need with offers of support and access to panels of pre-identified suppliers of particular services (such as Victoria's Clean-up Panel, which Victoria used to execute its state-coordinated clean-up program following the 2019-2020 bushfires). In combination with standing plans, these additional supports can reduce the lag in responding to recovery needs in communities."*

21.40. *"All levels of government should establish standing recovery plans before a disaster. These plans should focus on known recovery needs, such as clean-up and debris removal, and clearly identify the entities responsible for addressing particular needs and outline their service coverage. Pre-established and appropriate arrangements, such as supplier panels, could further support effective and coordinated recovery."* (Commonwealth of Australia, 2020b, p.438).

Even the more recent *2022 NSW Flood Inquiry Volume 2: Full Report* (State of NSW 2022a) devotes only three pages out of a massive 335 page report, to a specific discussion of DWM. Nevertheless and despite this brevity, the issues raised are of relevance to the current study and are summarised in more detail elsewhere in this section.

Arguably, one of the most recent reports to consider DWM arrangements which then led to the development of an actual DWM Plan, was the Burns et al., (2017) *Independent Review of the Extreme Weather Event South Australia 28 September – 6 October 2016 Report*, presented to the Premier of South Australia. This review noted that the Local Recovery Committee (LRC) held meetings to discuss key priorities and issues which included de-watering, and waste management issues such as debris, green waste, garbage, septic tanks and biohazard waste. It also noted that the State Recovery Committee established a Waste Management Working Group; its focus was on managing agricultural waste and specifically that related to the market gardens in northern Adelaide. At that time, options to address the waste were collection and disposal in licensed landfill, and collection and processing of organic matter at licensed composting operations. The review report noted there was no set framework for managing disaster waste, that the arrangements and responsibilities for managing various aspects of DWM were not clear and that traditionally, it was largely managed and disposed of using local government resources (Burns et al., 2017, p.129). The report recommended that a Disaster Waste Management Plan be developed, to form part of the State Emergency Management Plan that describes participating agencies and responsibilities for various aspects of waste management during and after emergencies.

The SA Disaster Waste Management Capability Plan that was subsequently developed, is incorporated into that state's State Emergency Management Plan (SEMP). It has specific objectives linked to each emergency phase and, together with the accompanying guidelines, aims to support decision-making processes, noting that the scope of DWM activities will vary according to the nature of the event, types of waste created and associated issues (Government of South Australia 2018, p.7). Accordingly, the Plan and Guidelines are based on an "all hazards" and "all waste types" approach but excludes biosecurity events not linked to natural disasters. The Plan outlines basic principles, key roles and responsibilities, but more detailed advice regarding specific waste types, handling and treatment options is found in Part C: Technical Guidelines. Notably, the Capability Plan has an expectation that

local governments' responses will be "scalable" if "appropriate and practical to do so", an expectation that would be beyond the capacity of most remote NT local governments to meet, without a substantial injection of resources (money, expertise).

As part of the Green Industries SA (2015) *Disaster Waste Management Scoping Study* (cited in WALGA nd), a disaster debris calculator was created, which provides order-of-magnitude estimates of waste volumes for different types of waste. Users of the tool are prompted to enter data into the following input fields:

- Disaster type (bushfire, flood, severe storm, earthquake);
- Square kilometres (km^2) of urban area affected by the disaster;
- Average vegetation density (low, medium, high) across affected urban areas;
- Number of low-rise buildings in the affected area; and
- Total floor area (m^2) of damaged high-rise building.

The output table provides estimates of debris generated (in tonnes and cubic metres) by waste stream (masonry, metals, vegetative waste, hard waste, whitegoods, e-waste, soil and sediment, and vehicle bodies) (WALGA nd). According to the Office of Green Industries SA (2015, p.105) it is their intent to refine the tool so that it can be used by stakeholders across SA (and potentially Australia-wide).

As noted left, the 2022 NSW Flood Inquiry specifically considered DWM. The brief discussion regarding the impact of the floods on waste disposal centered on the following themes:

- The volumes of waste produced, which exceeded business-as-usual (BAU) and the capacity of local Councils to manage;
- Issues relating to waste sorting, specifically treatment of hazardous waste and lack of kerbside waste sorting; and
- Efficacy of existing processes in place to divert waste to other locations following a natural disaster to ensure that local Council facilities are not overwhelmed and can manage their annual limits (State of New South Wales, 2022a, p.165-167).

Local Council submissions to the Inquiry described the volumes of waste as being six times their community's annual contribution to landfill, how local waste transfer stations were overwhelmed within the first week and had to close to the public, and in the case of one Council, how it had to manage its waste unaided (e.g. over 430t of flood waste from 1,430 properties) because the PWA (Public Works Advisory), which manages the waste diversion process in the event of natural disasters, was itself overwhelmed and lacked the capacity to provide any further waste management support.

In terms of managing hazardous materials such as asbestos, local Councils highlighted the lack of timely advice regarding its management and lack of available landfill sites capable of accepting volumes of asbestos.

Lack of kerbside sorting was also an issue with residents placing all waste, unsorted, on the kerb for collection. "Consequently, many otherwise recoverable materials went to landfill, resulting in more landfill than necessary. Community-led groups wanted to assist with this problem but had no available mechanisms" (State of New South Wales, 2022a, p.166).

As noted above, despite there being processes in place to divert waste to other locations following a disaster, this service was also unable to meet the high demand. These processes included arrangements with commercial waste facilities to take Council waste, which saw an estimated 220,000t of flood waste transported from the Northern Rivers region to commercial facilities in SE Queensland, in addition to the establishment of 17 temporary waste transfer stations across the region (State of New South Wales, 2022a, p.167).

Notably, despite the vast amounts of waste generated by this flood event, no specific findings or recommendations on waste disposal were made in the report, in contrast to recommendations regarding power, water treatment, and telecommunications.

Two further themes that were strongly evident throughout the Inquiry report that are relevant to the current study, are the role of local government and the community as first responders. With respect to the role of local government the report stated:

> "As the level of government closest to community, local councils are well placed to facilitate community preparedness through engagement, resourcing, plan development and emergency risk management. Although local involvement in preparedness is critical, the Inquiry has heard "the roles of local government under the current NSW emergency arrangements are unclear, unfunded, and as a result, fail to integrate local context"

(State of New South Wales, 2022a, p.183).

The Inquiry noted that within local Councils, the Local Emergency Management Officer (LEMO) position was akin to a "passion project" for those staff members,

being an additional responsibility on top of their normal service delivery role (State of New South Wales, 2022a, p.85). One Council managed the risk posed by having only one person with the corporate knowledge and experience of emergency management, by establishing a LEMO team with the lead role rotating amongst the staff (State of New South Wales, 2022a, 85). In contrast, Queensland Councils employ full-time disaster coordinators (State of New South Wales, 2022a, p.183).

During the Inquiry a distinction was drawn between the community as first responders, and formal volunteering, such as members of the SES. The former consists of informal, spontaneous networks that develop prior to, during and after a disaster. In contrast, the Inquiry noted declining levels of volunteerism, including in organisations such as the SES (State of New South Wales, 2022b,p.16). Regarding community as first responders, the Inquiry noted that many communities felt abandoned by Government during the 2022 floods, and whilst these communities wanted support from Government, they did not want Government to interfere or try to run community-led initiatives that had worked well (State of New South Wales, 2022b, p.16). It is beyond the scope of this report to discuss this matter in more detail, but it should be noted that the Inquiry concluded that because Government, at all levels, will never be able to meet all needs during or after disasters, future planning must recognise and support the central role of communities, "which will always step up to help their own when the occasion requires" (State of New South Wales, 2022a, p.323).

Of relevance to the current study, is that the Inquiry included a recommendation for Indigenous involvement in emergency management arrangements through the inclusion of Aboriginal Community Liaison Officers on Local Emergency Management Committees, and development of an Indigenous first responder program. These recommendations recognised that within Indigenous communities there are matters of cultural safety and networks that need to be taken into consideration (State of New South Wales, 2022b, p.16-17).

Although the NSW Government supported the recommendation regarding the community as first responders (including greater Indigenous involvement through the mechanisms referred to above) and that communities receive training and resources to enable them to become first responders in the event of future disasters (New South Wales Government Response to the NSW Independent Flood Inquiry, p.3-4), others have raised concerns that such a proposal places an unfair burden on the local community and that it may result in perverse outcomes by exacerbating the existing confusion regarding roles and responsibilities, poor communication, and lack of resources and co-ordination (Vahanvati and Kuligowski, 2022).

Vahanvati and Kuligoski (2022) raise a number of issues to be considered, including liability for injuries to community responders, responsibility for maintaining equipment, extent to which community responders may be placed at risk by being encouraged to remain in disaster areas, and distinguishing between formal and informal volunteers regarding responsibilities. Based on their research in Australian and Pacific communities to build resilience and reduce disaster risks (e.g. Vahanvati et al., 2022), they recommend that training programs for community first responders should "build upon any existing community organised strategies and approaches" and be co-designed with the communities, including Indigenous community members "who are most knowledgeable and active in disaster risk management" (Vahanvati and Kuligoski, 2022).

The recognition of the key roles of local government, non-government organisations and the local communities themselves in the disaster management process was a theme also identified in other reviews and reports (e.g. Office of the Inspector General of Emergency Management, 2017). These recommendations, which essentially advocate for a place-based and strengths approach towards disaster risk planning, echo similar advice provided by other researchers and practitioners.

One example where the role of community organisations in the recovery phase was formalised is the Meander Valley Council in Tasmania. Following the 2016 winter floods, the Council worked with its six local service clubs to develop a MOU to enlist their help in future public emergencies. The MOU sets out the parameters of the role the service clubs will take, which is limited to low-risk tasks such as door knocking, rubbish disposal, delivery of supplies and simple repairs (Tasmanian Government, 2017, p.28). The impetus for this MOU was the realisation by Council that "anxious and vulnerable residents want regular contact, good information, and in some circumstances, prompt practical action" (Tasmanian Government, 2017, p.28). The Clubs are also able to provide feedback on significant issues. Through the MOU the Council assists the Clubs with costs and provides an opportunity for annual training. The MOU is reviewed every two years (Tasmanian Government, 2017, p.28).

Burns (2017) noted that the Red Cross has capability and capacity in relation to emergency relief and

recovery. At the of end of his review, there were two formal MOUs between the Red Cross and SA Government; one for emergency relief with Housing SA and one with the Relief Functional Service regarding psychological first aid, outreach programs and support at community meetings. Burns (2017) noted that they provided a range of other services that could also be utilized in the post-disaster phase, but none relate to DWM.

There is surprisingly little in the way of formal reviews or inquiries relating to disasters in the NT that are available in the public domain. Of the 242 inquiries/reviews identified by the 2020 Royal Commission, only three were specific to the NT; two related to the 2012 Review of Bushfires NT Operations and the other was a 1974 report, also related to bushfires (Commonwealth of Australia, 2020a, Appendix B). Meanwhile, Surjan et al. (2018) documented the impact of Cyclone Marcus on the Greater Darwin region in 2018 and highlighted the potential waste issues, particularly the massive amounts of green waste that this event generated.

Altman and Jordan (2009) documented the Maningrida community's response to Cyclone Monica (2006) in the context of considering the risks arising from climate change upon Indigenous communities across tropical northern Australia (Green et al., 2009). They recorded that the community, as well as outstations, were warned of the danger and organisations and individuals spent the four days prior cleaning up loose material and stockpiling fresh water (Altman and Jordan 2009). After the cyclone, local agencies and individuals were involved in the clean-up. There were some perceptions in the community that the Government response was slow, and that the local community was largely left without assistance. Among the observations recorded was that food-security in the aftermath of future cyclones would need to improve (Altman and Jordan 2009, p.104-105).

Indigenous Ranger groups played a role in the preparation and recovery efforts associated with Cyclone Lam in 2015. Dhimurru Rangers ensured that residents from remote homelands/outstations were transported to towns with cyclone shelters, as well as that adequate supplies of water, diesel and opal fuel were stored ready for use in the clean-up phase. Post-cyclone, they worked with Police and other service providers to assess damage and prioritise clean-up activities. They cleared tracks, took supplies of water and fuel to remote homelands, ensured they had power (i.e. generators were working) and removed trees from power lines (National Indigenous Australians Agency, 2015). On Milingimbi and neighbouring homelands, the Crocodile Island Rangers helped patch roofs and clear fallen trees. Given the clean-up work required, the Tjuwanpa Women Rangers from Ntaria (Hermannsburg) in Central Australia travelled to Miligimbi to help the Crocodile Rangers (National Indigenous Australians Agency, 2015).

The authors of this report are also aware that there exists a report documenting the processes that were adopted with regard to the response and recovery phases in relation to the 2023 flooding of Kalkurindji, Daguragu and Nitjpurru, (Pigeon Hole) however this report is not available in the public domain.

2.5. Knowledge gaps and implications for the current study

In reviewing the academic literature and reports from a range of inquiries and reviews into the management/response of various disasters, it became apparent that there was a disconnect between the two broad datasets. The reports of the inquiries and reviews held in the aftermath of disasters predominately focus on the lived experience and practical lessons from those involved: i.e. various levels of Government, volunteer organisations such as the SES and other not-for-profits, and local communities and affected residents. Recommendations are thus framed primarily based on this knowledge set, rather than being driven by the results of academic research into DWM. For example, of the 1,498 written submissions received by the NSW Independent Flood Inquiry, only 2% were from an academic/researcher, compared to 66% from flood-affected residents (State of New South Wales, 2022a, p.4) and most of these related to hydrology, flood mapping and modelling, weather and climate change. The reasons for this disconnect are unknown but may relate to issues regarding the accessibility/availability of research (i.e. in academic journals that require paid subscriptions to access), perceived relevance of this research (it was noted in section 2.1 that relatively little DWM research has been conducted in Australian contexts); and/or trusted sources (i.e. organisations at the 'coal face' may be more likely to trust in the advice and experience of other similar organisations who have been in similar situations, than place their trust and resources in theoretical research). The disconnect between the academic and grey literature reinforces the 'fitness' of the approach adopted in the current study: a combination of theoretical and practical, desktop and in-community fieldwork to combine the lived experience is needed to achieve practical outcomes on the ground.

This literature review has also identified knowledge gaps that need to be bridged as well as reinforcing the need for the current study and that DWM planning should be undertaken well prior to a natural disaster, a finding evident in both the academic and grey literature. Knowledge gaps to be filled include types of waste generated in remote communities during natural disasters (expanding on the broad categories identified in Table 2.1 of this document), as well as volumes of that waste. For example, there is little documentation on historical waste generated in the remote communities.

Importantly, the literature review has directly informed on the types of questions to be asked of government and non-government organisations, as well as community residents regarding disaster waste. Interview questions need to include questions of both fact and opinion, and relate to existing waste and waste management, waste types and amounts likely to be generated during disasters, existing disaster preparedness activities specifically related to waste, nature and type of any pre-arrangements in place to address disaster waste and clean-ups, as well as a series of questions relating to lessons learnt from past experience, and future planning and opportunities for a more considered approach to DWM in these communities.

The following section describes the methodology employed during fieldwork, followed by the results and analyses of interviewee responses.

3. Data collection and analysis

This section reports on the results from interviews, focus groups and surveys of stakeholders associated with DWM in the Northern Territory as well as residents of three Arnhem Land communities. The latter were selected as case studies for gathering real-life contextual data about waste practices during disasters. Questions were aimed at understanding waste management during BAU times; roles and responsibilities of stakeholders' organizations during disasters; understanding of disasters and their impacts; disaster preparedness, response and recovery practices; lived experiences and lessons learnt from previous disasters.

3.1 Methodology

Various Australian Government and Northern Territory Government agencies, Local Government, non-government organisations, and residents of three remote Arnhem Land communities (Maningrida, Milingimbi, Ramingining) were invited to participate in the research (Appendix B). Some invitations were declined because invitees felt there was little they could contribute to the study, whilst others did not respond.

Most of the interviews with Northern Territory Government and Local Government staff were conducted online through the Teams App (Table 3.1). In-person interviews were also held in the three communities. Interviews with Indigenous residents and Aboriginal organisations in the communities were conducted by two ARPNet staff and six local Indigenous researchers (trained by ARPNet) and research team members. The team conducted five focus groups (senior ladies, Women, CDEP, Rangers, and Bush food team), 15 interviews with Indigenous residents, including women, men, young people, Traditional Owners, djunkai (land caretaker), Aboriginal Corporations, outstation residents and community leaders. Copies of the questionnaires for different stakeholder groups are at Appendices C, D and E. Additionally, a short online survey via Survey Monkey was also sent to the email addresses available for organisations in Raminginging and Maningrida. Twelve responses were received. A copy of the Survey Monkey questions is at Appendix F.

Data collected from the interviews, surveys, focus groups, and documents was reviewed and analysed to gain an understanding of the degree of preparation and waste management practices during a natural disaster. These results are presented in the following sections.

Table 3.1: Data collection from stakeholders

Stakeholder type	Data collection method	Number
Northern Territory Government	Online interviews	6
Local Government (including LGANT)	Online interviews, In-person	13
Remote communities		
Residents & organizations	Focus groups	5
Non-Government Organizations	Online survey	12
Government Organization	In-person Interviews	4
Indigenous residents	In-person Interviews	15

Note: For this section of the report, "Local government staff" is used inclusively to refer to participants from either local government councils or LGANT.

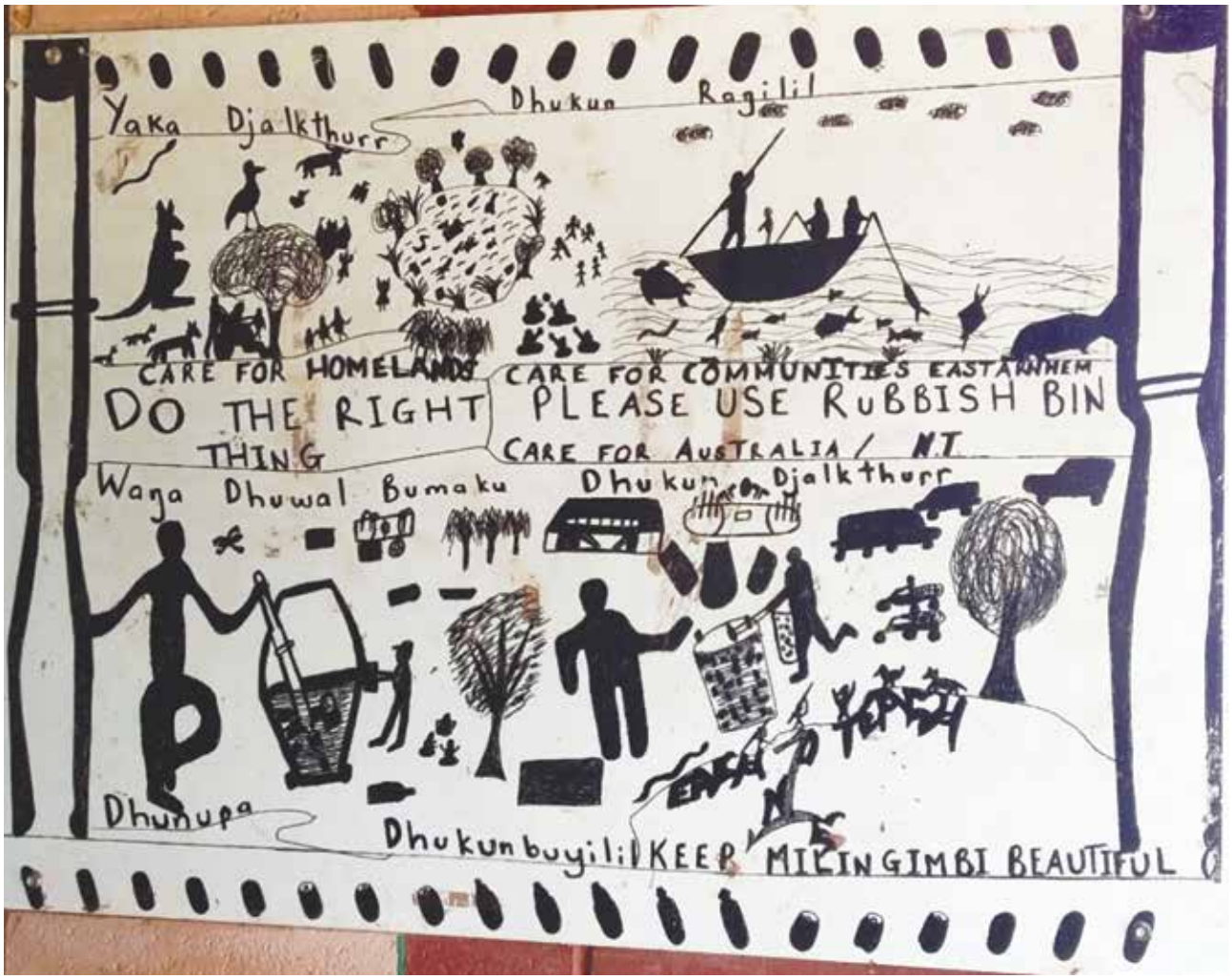


Figure 1: Public education messaging regarding waste, on the wall of the East Arnhem regional Council office in Milingimbi, September 2023

3.2. Business-as-usual waste management in remote NT communities

Waste management is the responsibility of Local Government (local Council), including in remote regions. This ranges from rubbish bin collection from households, running the landfill, exploring recycling initiatives, disposing of waste and educating community about waste and littering.

Bin collection schedules differ in each community, but each household gets a 240L bin and commercial organisations get a larger 660L or 1100L bin. Commercial bins are mostly picked up once a week. One interviewee described the household bin pick up and hard waste collection services provided by their local council as:

"So there is a daily bin service here that goes out to the tip, that's done five days a week and that's a full five days a week. There's also an ongoing and when I say ongoing, probably at least once or twice a week, a truck will go out with three workers and they will pick up hard rubbish. So if anyone has got beds or fridges or washing machines, that's a community service they do, pick it up and take it out to the tip" (Local Government staff).

The collected waste is taken to the local waste management facility. Waste from household bins is put in a pit and periodically burned. Hard rubbish is sorted and stockpiled on the landfill site. Commercial operators can take their waste directly to the landfill and deposit it by paying a fee. Most landfill sites are unmanned, but some have cameras installed to monitor commercial drop-offs and then invoice those organisations.

Figure 2: Landfill site in a remote community

Waste streams segregated at the landfills are “hard rubbish”, which includes cans, white goods, tyres, metal (from construction and cars), timber, plastics, oil (waste and cooking), paints and batteries. The purpose of segregating waste is to reduce waste going into landfill and exploring better avenues for removal from the community by sending sorted materials for recycling. Waste management facilities do not accept asbestos, and contractors need to take it to the nearest licensed facility, which in the case of the Top End of the NT will be Katherine or Darwin.

Interviewees identified several barriers when managing waste such as high transport costs to move recyclable waste, lack of staff, difficulty in acquiring land for landfills and lack of appropriate machinery. High transport costs for moving waste from remote communities to cities where recycling occurs, is a major barrier for recycling waste. This results in materials (such as metals) being stockpiled till a metal recycler collects them or the materials are compacted and sent on a truck or a barge to a recycler.

Car wrecks are a huge problem for the local Councils. Council staff are not permitted to pick up wrecks or defective vehicles until the paperwork allowing the car pick has been completed by the car owner. Sometimes this process takes a long time and the car wreck sits within the community indefinitely. Once collected the car bodies are taken to the landfill, where they remain until a metal recycler comes to compact and take them away. Other metals may also accumulate rapidly at the landfill. Even when the metal recyclers pick them up, another pile of metal goods builds up fairly quickly.

“We’ve had Sell & Parker come out and they pretty much took all the scrap metal and all the car bodies, 30 years’ worth from out there and they compacted them up and sent them off. They cleared all the washing machines and everything out and within three months later, now it’s the Mount Everest of whitegoods out there again”
(Local Government staff).

The research team consistently heard that workforce issues impacted upon BAU waste management operations. Lack of staff and lack of accommodation within communities meant that positions were unable to be filled.

Figure 3: Derelict vehicles at a waste management facility await the arrival of the metal recycler, September 2023

"There's just not the staff to do it, three positions open now and it's like, there's no one to fill them with" (Local Government staff).

Some communities do not have the right machines to manage large waste volumes and/or experience difficulties getting them fixed when they break down, which then impacts upon BAU activities. For example, when machinery such as the garbage truck breaks down, it is taken to the nearest town to be fixed, but in the absence of a replacement vehicle, staff resort to picking up rubbish by hand and putting it in a trailer, which poses a health hazard.

"So if the garbage truck is not working, the garbage truck then has to go on the truck, get freighted all of the way to Katherine. If Katherine can't fix the truck, it goes down south. That garbage truck could be out of circulation for 8 to 12 weeks, depending on what's going wrong with it. Then I've got staff, picking rubbish with hand with a trailer and taking that to the dump. And again, it causes another health issue" (Local Government staff).

A waste management facility can only be licensed if it has a lease from the landowner. Currently only three landfill repositories across the Territory are licensed: Darwin, Alice Springs and Katherine. Over 50% of the NT is Aboriginal Land under the *Northern Territory Aboriginal Land Rights Act.* Under Section 19 of the Act, government, businesses, organisations and individuals may apply to the relevant Aboriginal land council for a lease over a specific area of Aboriginal land. There are no legislative timeframes regarding this process and the time taken to obtain a lease depends on the region, area of interest, nature and extent of the impact of the proposed use for which a lease is sought. Owing to these challenges, some smaller communities are finding it harder to get leases for landfill sites.

As noted in section 2 of this report, a waste event greatly impacts the life of a landfill since a huge volume of waste is generated quickly, and this is no different in remote communities. One interviewee explained how an emergency event shortens the life of a landfill:

"I saw the...Council dump lose 20 years of its life from that flood event. I think one of the big things with emergency waste is really looking at what a single event can do to the longevity of a facility like a regional waste center" (Local Government staff).

The information describes a range of waste related services carried out by the local Councils as well as some of the existing challenges experienced during BAU times. Managing waste arising from disasters adds another, significant, layer of tasks for these organisations.

3.3. Territory Emergency plan: processes, roles, and responsibilities

The Territory Emergency Plan (TEP) describes the NT's emergency and recovery operations approach, including the governance and coordination arrangements, and lists the roles and responsibilities of agencies. It establishes principles for prevention, preparedness, response, and recovery for emergency management. It also identifies the lead agency responsible for controlling response to different forms of hazards. As described in the TEP (NTES, 2021), governance arrangements in response to an emergency event are shared by the Northern Territory Police, Fire and Emergency services (response) and the Department of the Chief Minister and Cabinet (recovery coordination). Table 3.2 lists the lead agencies for the natural disasters that are discussed in this report while Table 3.3 summarises the roles and responsibilities of different government organisations against the cross-overs with waste issues.

Table 3.2: Lead agencies for selected natural disasters (Source: NTES, 2021, p.19)

Hazard	Controlling authority	Hazard management authority
Cyclone	NT Police Force	NT Emergency Service
Earthquake	NT Police Force	NT Emergency Service
Fire	Bushfires NT, Dept of Environment, Parks and Water Security	Bushfires NT, Dept of Environment, Parks and Water Security
Flooding	NT Police Force	NT Emergency Service
Heatwave	Department of Health	Department of Health
Storm surge	NT Police Force	NT Emergency Service
Tsunami	NT Police Force	NT Emergency Service

Four activities form the comprehensive approach to emergency management in the TEP. These stages are referred to using the acronym PPRR:

Prevention/mitigation activities: these are "activities and measures aimed at reducing exposure and vulnerability to hazards, to reduce or eliminate risk" (NTES, 2021, p.26). Examples of such measures are those that are taken in advance, including land use planning, engineering (structural works), building codes, public education, increasing infrastructural resilience, providing enhanced warning systems and modifying behaviour. The development of local emergency management plans also falls into this stage.

Preparedness activities: these arrangements are listed "to ensure that, should an emergency occur, all those resources and services that are needed to cope with the effects can be efficiently mobilized and deployed" (NTES, 2021, p.28). These include community education and engagement to empower communities to act in a timely and safe manner during an emergency event; planning to reach agreements between people and organizations about their roles and responsibilities during emergencies; training and education agencies who will be involved in emergency management activities; and exercises to test the effectiveness of emergency plans.

Response activities: these activities are defined in the TEP as ones "taken in anticipation of, during, and immediately after an emergency to ensure that its effects are minimised and that people affected are given immediate relief and support" (NTES, 2021, p.30). Governance arrangements are put in place so that the emergency is efficiently, effectively, and appropriately managed, and various organisations involved work cooperatively and achieve the response operation goals. Response activities also include ways information will be disseminated publicly (secure NT website, ABC) and steps for closing offices and schools if that is required; opening of short-term (max 48 hours) emergency shelters (for fire, cyclone, flood or tsunami) whose responsibility lies with the Emergency Shelter Group (Department of Education); provision of Evacuation Centers and Welfare Assembly Centers (WAC) following the impact of the hazard which is led by the Welfare group (Dept of Territory Families, Housing and Communities) as well as the Welfare Recovery Centre which is a one-stop-shop providing a range of support services to the affected community. A comprehensive impact assessment is carried out as part of the response coordinated by the NTPFES.

Recovery activities: this is a coordinated process to support "emergency affected communities in reconstruction of the physical infrastructure and restoration of emotional, social, economic and physical well-being" (NTES,2021, p.38). Recovery operations are also coordinated across local, regional and territory levels and have governance structures in place. Recovery efforts focus on the impact on the social, built, natural and economic environments due to a particular hazard and the scale of the impact. The TEP states that planning for recovery will occur concurrently with the initial response and may include assessment of the impacted area against the four environments; gap analysis of capabilities; understanding the community context and development of a Recovery Action Plan. Five phases are identified as key phases to recovery: transition to recovery (activation), relief, early recovery, medium to long term recovery and transition to BAU. Recovery efforts and time frames for each phase depend on the impact of the event, level of disruption to the community and the capacity and capability to recover.

Table 3.3: Roles and responsibilities during emergencies and intersection with waste

Organization	Role	Responsibility under Territory Emergency Plan in Remote communities	Crossovers with waste issues (from the TEP and data collected
NT Police Force		Local Emergency Controller: In charge of the Response	Having access to local council staff and equipment (?)
Department of Infrastructure, Planning and logistics (DIPL)	Leading transport and engineering functional groups	a. Clearing essential traffic routes b. Coordination, inspection & advice in relation to roads & government c. Waste management d. Facilitating a additional equipment/resources e. Clearing storm water drains f. Facilitating the restoration of public infrastructure g. Provision of advice re capacity of the engineering group h. Provision of advice on response and recovery measures i. Managing the temporary closure of roads j. Assistance on repair costs to houses and building k. Assist, fueling and testing generators at public shelters as requested l. To procure, mobilise and manage contractors and consultants subsequently deliver rectification works.	a. Waste management during disaster response and recovery b. Transporting rubbish and debris to designated tips c. Hiring contractors for identifying extent of damage, cleaning up waste, rebuilding & repairs d. Responsible for functional arrangements in temporary shelters e. Moving assets f. Looking after infrastructure at the evacuation shelter
Department of Health	Lead the Medical and Public health functional groups	As the lead agency for Medical group: a. To co-ordinate and control the mobilisation of all health responses to emergencies. This includes medical, nursing, pre-hospital care, first aid, pharmaceutical supplies, laboratory services and public mental health services b. As the lead agency for Public Health Group: To monitor and preserve public health and hygiene standards, provide an environmental health service, provide a disease control service and provide public health information	a. Providing expert public health advice and monitoring of drinking water quality, food safety, personal hygiene, disinfection, sewage disposal, radiation hazards, hazardous waste management of medical waste and radiation sources, inspection of evacuation centres and assisting b. Medical Entomology with vermin and vector control c. Can shut down a shelter or evacuation facility if the health requirements are not met d. Directives over food serving. For example, evacuees can only be served packaged food and bottled water. While this ensures hygiene conditions (less transmission of disease?). This results in food packaging and plastic waste. e. Have to provide house safety clearance before residents can return to their homes.
Department of Territory Families, Housing and Communities	To co-ordinate and implement responses operationalised by its member organisations, to meet the immediate essential needs of individuals and families and promote self-efficacy during the response to and recovery from emergency events.	a. Provide assessment of the needs of residents affected by disaster b. Provide advice on appropriate responses and recovery strategies c. Coordinate the establishment and operation of evacuation centres and/or welfare centres d. Coordinate access to support services to meet the immediate essential needs of affected people during response and recovery. e. Facilitate Disaster Recovery Funding Arrangements for affected individuals f. Work with individuals, families and the community to build people's capacity to recover g. Contribute to broader operational planning and activities h. Provide advice to the Territory Emergency Management Council on measures to improve provision of welfare support in the event of a disaster	a. Manage evacuation centres and shelters. There is considerable food packaging and plastic (water bottles) waste associated with evacuation centres b. Managing provision of nappies, female hygiene products and condoms to evacuees and finding ways of disposing these items

Organization	Role	Responsibility under Territory Emergency Plan in Remote communities	Crossovers with waste issues (from the TEP and data collected
DM&C	Coordination of Disaster response agencies and head the Public Information functional group	Key responsibilities are: a. Lead the development and release of all NTG public messages during an emergency event; b. Ensure timely, accurate, consistent public messages c. Provide advice on measures to improve media arrangements and public information dissemination d. Liaise with external agencies involved in the response or recovery to ensure agreed national protocols e. Ensure appropriate physical and human resources are allocated to achieve the group's responsibilities.	Provide physical and human resources
Power and Water Corporation	To lead the development and implementation of Territory-wide policies and plans for the prevention, reparation, response and recovery to, emergency events relating to public utilities.	a. Protection, maintenance and restoration of power, water and sewerage services b. Provide advice on measures to improve the availability and robustness of public utilities in the event of a disaster c. Provision of advice on public utilities issues impacting on response and recovery measures.	a. Loss of power during and after a disaster leads to food waste homes and stores
Department of Industry Tourism and Trade	Provision of NT wide capability, coordination and control to biosecurity, animal welfare and agricultural emergencies. And to work with internal and external stakeholders to assure the supply of critical goods and services following a disaster or an emergency event. Depending upon the emergency, this may include the supply of food, groceries, ice, bottled gas, cleaning products, building/hardware supplies, camping equipment and bank services.	1. In an emergency plant or animal disease and pest incursion into the NT, as lead agency: a. ensure early detection b. effectively and efficiently respond to the emergency incursion c. have an effective legislative framework to respond d. enable the declaration of freedom from the pest and/or disease through surveillance e. provide advice on issues that may be impacting on response and recovery measures f. lead coordination with interstate agencies to biosecurity incursions 2. In a disaster situation affecting the NT: a. Coordinate the care, treatment and reuniting (where appropriate) of domestic and commercial animals and wildlife 3. The prime responsibilities of the Critical Goods and Services Group are to: a. advise on the availability and durability of supply of critical goods and services from suppliers, manufacturers, wholesalers and major retailers b. liaise with industry and other stakeholders to assist with the restoration and/or provision of critical goods and services c. assist with the sourcing of critical goods and services to support the other group leaders during emergency activities d. provide advice on improving the robustness of supply chains for critical goods and services and any issues impacting on response and recovery measures.	Reduce waste in emergency shelters through sustainable procurement. Liaise to find pathways from emergency shelters.

Organization	Role	Responsibility under Territory Emergency Plan in Remote communities	Crossovers with waste issues (from the TEP and data collected
Department of Education	Overall coordination of the provision of emergency shelters and development of NT operational policies and plans in the preparation, response and recovery phases of an emergency	a. Coordination of buildings designated as emergency shelters b. Coordination of personnel to staff and operate emergency shelters when they are activated c. Maintenance of effective liaison with other organisations with responsibilities relating to emergency shelters d. Assisting with the staffing and operation of such shelters as may be designated evacuation centres and welfare assembly centres in a post event phase. Provide advice on measures to improve shelter arrangements in the event of a disaster f. Provide advice on shelter and emergency accommodation issues impacting on response and recovery measures. Note: It is the responsibility of shelter owners to provide the personnel to both manage and operate the shelters when they are activated	a. Responsible for emergency shelters.
Local councils	No mention in the Territory Emergency Management plan as being responsible for any operations		Are responsible for waste management during BAU times. Own staff, machinery and other assets to assist with waste recovery

Based on the interview responses, it was clear that NT and Local Government employees had a good understanding of the process they need to follow during an emergency or disaster. In remote communities, there is a Local Emergency Committee (LEC), headed by the Local Emergency Controller (Officer in Charge of the local Police Station). The other members of the LEC are from NTG and non-government organizations with a presence in the community. In case of an emergency the Local Emergency controller takes charge of the response and directs the LEC members. While it is stated in the TEP that Bushfires NT, and Department of Environment, Parks and Water Security are the controlling authority in case of bushfires and the Department of Health in case of Heatwaves, this distinction was not recognized by the interviewees, most likely because they described more familiar scenarios they had experienced such as cyclones, storms, and flooding.

3.4. Lack of Disaster Waste Management (DWM) Plans

While the LEC members and other organizations knew the processes to be followed during a disaster, they all commented on the lack of a Disaster Waste Management plan.

"And all the images that come out of floods are of piles of waste and still we have no plan really. They're not included in the disaster management plans" (Local Government staff).

The priority in existing Emergency Management Plans is on keeping people and property safe; waste is much lower down in the hierarchy of such plans. As one Local government staff member stated:

"I think it's a priority but that it's a low priority. People don't think about it till after the fact. Things like waste are ignored in the planning process because we're worried about human life or infrastructure. That's our concern and we don't worry with clean ups and preventative measures or anything when we're doing these sorts of plans. It is the same with like, bushfires. Like all our strategies around fire management are related to infrastructure protection and human health, there's no concern about environment" (Local Government staff).

Most interviewees agreed that a DWM plan was required, and it should be linked in some way to the existing Emergency Management Plans so that everyone knew the processes that needed to be followed and their roles, regarding waste management during emergencies. It was also acknowledged that it couldn't be a "cookie cutter" approach and the DWM plan needed to be tailored for each community, depending on its location, the natural disasters that were likely to occur in that region, and the cultural practices of the residents. One interviewee specifically identified the need for the DWM plan to also include a community profile that identifies the key stakeholders and the leadership in the region.

"I think that's where those roles of the local emergency committee and being prepared, knowing their community, knowing their strengths and vulnerabilities and their hazards and the role of the Council on that committee is kind of critical to what it's gonna look like for whatever circumstance impacts them, you know"
(NT Government staff).

Roles of key stakeholders such as Local Government (Councils), Ranger groups and the residents should be clearly stated in the DWM plans. Local Councils are responsible for BAU waste management for the community, but according to the TEP, during an emergency, waste management falls under Engineering Functional Group and the Department of Infrastructure, Planning and Logistics (DIPL) take over that responsibility, including the landfills and available machinery. Council staff believe they have a role to play which should be acknowledged in DWM plans and protocols put in place, because when their landfills are used for the disposal of disaster waste, it greatly decreases the life of the landfill.

"DIPL is the lead but we're basically, they just take over everything of ours anyway as engineering group. They would take over our waste management facilities and hopefully there would be some level of protocol around how we behave in that instance"
(Local Government staff).

"I don't think we have the authority. Once the command is stood up, and that's why we need to make sure that the plan and the protocols and the communications are correct and well understood because we don't, I don't think we have any authority. We just get told [what to do][sic]"
(Local Government staff).

Some interviewees noted that Ranger groups were not represented in the Emergency Management Plans despite having the capacity to help during an emergency. They are familiar with the land, and some have certificates to use heavy machinery. It was reported that Rangers used chainsaws to help clean up after Cyclones Monica and Lam.

Some interviewees described how in the recent flooding at Kalkarindji, Daguragu and Nitjpurru (Pigeon Hole), that local community residents helped in sorting items from houses of residents who had been evacuated. In addition, some residents returned earlier to help with cleaning up before the rest of the community could return. Including local residents in the cleaning up process meant that it could be carried out in a culturally appropriate manner i.e. ensuring that only people who had an appropriate cultural relationship with the occupiers of the houses, were the people who could enter and assist in the clean-up of those houses. It was suggested that identifying those residents who would have such cultural authority and willingness to help, and preparing them for disaster, needs to be done during the preparation phase.

"I think we probably have to get better in preparation in the preparedness phase at engaging those people from the start. So not just in emergencies but at the beginning of the year. And you know when it's the quiet time we can work with each of those councils or the Aboriginal corporations or whoever that you know the land councils for example, we might say who are your people in that community that are best able to help, and we might build a list of names. So that might be a ready reserve of people"
(NT Government staff).

3.5. Lived experiences of disasters and waste

Unsurprisingly, disasters that were more frequently discussed were those based on interviewees' lived experiences. From the list of identified hazards in the local Emergency Management Plan, these included flooding, cyclones, tropical storms, fire and heatwaves. However, most of the interviewees tended to focus on cyclones or flooding.

Tsunami's were considered a low risk due to Australia's geography and topography;

"Australia could get a Tsunami. It is pretty unlikely. And Darwin itself is well protected by the Tiwi Islands. It's also about that a lot of the active areas are a fair way away from Australia"
(NT Government staff).

Heatwaves were considered a real threat across the Territory. High heat in the "build up" was considered a serious issue which could have worse impacts when

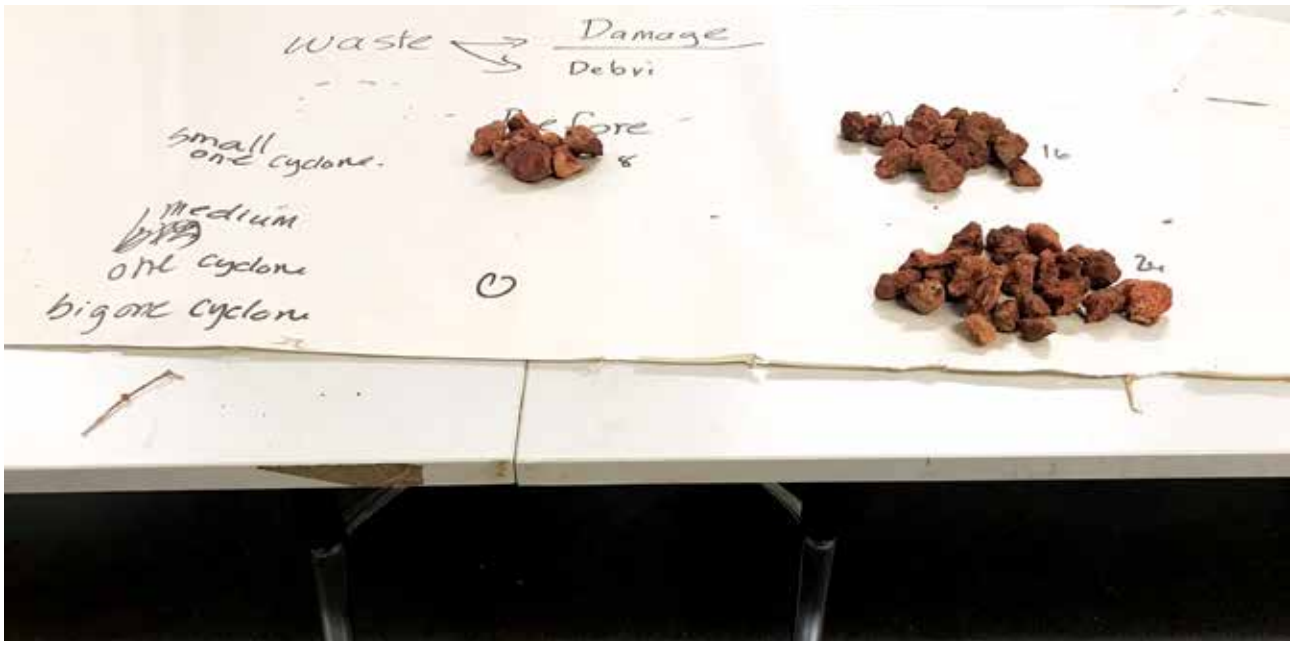


Figure 4 :Focus group with Indigenous rangers

compounded with a power failure. It was also stated that a power failure would lead to more waste generation, for example through food spoilage at the local shop and in people's fridges.

Earthquakes were of some concern but less so than cyclones, storm surges and flooding. One interviewee thought that education campaigns and new building codes would be able to address this issue. Although some interviewees had experienced minor earthquakes (earth tremors), because they had not resulted in any physical damage, planning for preparedness for these types of hazards was not considered as important as planning for other hazards such as cyclones. Nevertheless, it should be noted that another interviewee stated that the asbestos cement water mains would be the first thing to break in the event of an earthquake, thereby impacting the community's water supply.

"If it was going to break anything, it would break an AC water main in the ground"
(Local Government staff).

Covid was discussed by one resident in one of the communities, in particular the impact it would have had if more people had died from it. Local Government staff also raised this issue, expressing concern that remote communities have limited capacity to manage a large number of bodies.

Fire was considered a real risk in some regions. One interviewee stated that firebreaks were not enough, and fires can do significant damage. In contrast, another interviewee from a different Local Government Area said that firebreaks and back burns were adequate. He added that fires impacted the health of the residents (through smoke), more than it impacted infrastructure.

Cyclone and floods can have a considerable impact on infrastructure. Depending on the event, this impact can result in damaged roofs or collapsed houses. Strong cyclonic winds can result in spreading the construction waste (which could be contaminated with asbestos) around the community. Asbestos was found to be spread across some areas of the community at Galiwinku several years after cyclones had damaged several houses. Flooding can damage roads as well as cutting off the access to the community. This slows down getting help to the affected community.

"Most of our angst here, whether it's accessibility or whether it's actually damage, its just that we have a lot of the times we have to airlift food and supplies into some of our communities because we just physically can't get a truck in there and things like that with the roads"
(Local Government staff).

Describing the impact of cyclones, a group of Indigenous rangers said,

"Big rubbish after cyclone. Gas bottles, fallen trees block up the road, rivers too high in wet season, can't go anywhere, roads too bad. Ghost net sometimes, after big winds, get stuck in mangroves and cause problem for turtles and gets stuck everywhere"
(Indigenous ranger group).

Waste from fallen trees contributes significantly to disaster waste during cyclones. Cyclone Lam and Cyclone Marcus generated a lot of green waste.

"During Cyclone Lam, the main thing that was blown down were trees"
(Local Government staff).

Many interviewees talked about the real and potential impacts flood events could have on communities, including access, food security, public health related matters such as food waste, waste from evacuation centers, and landfill capacity. For example, interviewees in the remote Arnhem Land communities described flooding and heavy wet season events, which impacted access to the barge. In the case of Ramingining should the road to the barge flood, the community would be totally dependent upon air drops for food. Another resident of Ramingining described an incident where it was so wet that one of the Caterpillar machines got bogged up to chest-height (i.e. at least a metre) on the road to the barge landing.

The coastal communities and islands are dependent on the barge for food; if the barge is delayed by even a few days, it creates a food security issue.

"The weather was too bad to get the barge through to assist in that manner. It was wet season roads were completely cut. For the most part large scale recovery efforts weren't just available because of access issues. So it was food, before any real recovery efforts could make it to the community, the community was running out of food"
(Local Government staff).

If access to the community landfill is cutoff it creates a public health hazard. One interviewee gave an example of Borroloola, where the community could not cross the overflowing river to access the landfill and had to build a temporary landfill on their side of the river.

"They've got two communities Garawa 1 and Garawa 2, which is on the other side of the MacArthur River. Now, after a major flood event, they can't get into the waste facility or Borroloola. Can't [get] [sic] across the river. So they actually construct a dump on the other side of McArthur River. Then, after a period of time when the river goes down, they go back and take all that rubbish back. It's not conducive to public health, it's just litter, dogs, birds and all those public health issues are there"
(Local government staff).

This situation is not isolated and other examples (e.g. Wadeye and Tiwi Islands) were described, where access to the waste facility was cut off during events. This highlights the importance of roads as enablers during a disaster. It was suggested that this needs to be considered when deciding road hierarchies, i.e when determining to what standard a road is built (gravel vs all-weather bitumen).

An interviewee pointed out that after floods, the pooled water can lead to public health concerns if it becomes a breeding ground for mosquitoes, or conditions lead to a spike in gastroenteritis. Other wastes after a flooding event, such as food waste, animal carcasses and asbestos can also compound the situation. Rotting food and animal carcasses are disease vectors and asbestos is hazardous waste and they can impact residents' health significantly.

Large volumes of food waste may arise from the community store after a flood. This can occur because either the store has flooded and/or there has been a significant power failure:

"The stores were flooded themselves, and that's an enormous amount of waste that is generated through that event"
(NT Government staff).

Loss of power due to trees falling on power lines, other unforeseen power failures, or power being cut off for safety reasons, can also trigger more waste generation from stores with shelves full of perishables food or food in houses.

Flooded houses risk being contaminated by sewage water. Once household goods are contaminated, they become a health hazard.

"You know when floods happen, it tends to come up through the sewage systems and things like that, which then makes the households worth of contaminated waste. That is then, becomes a public health risk"
(Local Government staff).

Disaster events also result in displacing people from their houses. Whether they are moved to a nearby shelter or evacuated to another community or town, it impacts their wellbeing and mental health. Waste generated at evacuation centers is discussed in more detail in section 3.6.

Events such as flooding can create large volumes of household waste, compared to their regular BAU waste that can be accommodated in the municipal bin. As explained by staff from one local Council:

Figure 5: Milingimbi, showing the proximity of the salt flats (on the right) to the road and houses, September 2023.

"We had lots of family and friends on the riverbank who literally had to wipe their whole existence out, wash their house out and start again. So we're looking at thousands of households in Katherine, thousands who are emptying a whole house full of furniture and waste compared to a 240 litre bin that doesn't get full on a weekly basis" (Local Government staff).

As previously indicated in this report, large volumes of waste arising from disasters impacts the landfill life of the local waste facility when it is deposited there. One interviewee recounted that a single flood event reduced the life of their local landfill by 20 years. They added that in most circumstances, contaminated waste arising from the floods is not sorted, but dumped in the landfill and capped.

"It goes into the landfill and is capped and literally reduces the age or lifespan of your waste management facility. So it gets treated the way it usually would. You wouldn't have scavengers or anything because of the bulk amount, you would just sacrifice every recyclable whether it's a tyre or a can or whatever and put it into general waste. That would even increase the load on the landfill. You'd just cap and seal as you usually would" (Local Government staff).

The management of disaster waste after the recent Daguragu, Kalkarindji and Nitjpurru (Pigeon Hole) floods showed great initiative by the government departments and the private contractor to reduce the waste burden for the local landfill. The contractors dug a pit and lined it to temporarily store the putrescibles. This waste was later moved using road trains, back to Darwin. Similarly recyclable waste was temporarily stored and sorted at the local landfill and was subsequently sent to Darwin. Despite this there was waste that could not be trucked out and ended up in the local landfill pits. Dealing with additional waste implies their having to make space for this waste by digging new landfill pits.

Some interviewees identified the potential for future flooding events. For example, it was pointed out that Umbakumba would have significant issues with a 1 in 100-year flood, while other interviewees commented on events that were much more likely to occur.

"The way it's designed is there's a big sand dune across the front of the town [Umbakumba][sic] and you have about 20 houses in front of that sand dune. So they would all get flooded. And then there's a little inlet that comes through the sand dune and around to the school. And there's quite a low area right in front of the school and in a one in 100-year flood, because there's an inlet, all the water flows through there and rises up to above sort of, to the ground level around the school. And the houses around there as well. That impacts the Oval and a few other sort of public infrastructure places" (Local Government staff).

"The flood [2023 flood of Kalkarindji, Daguragu] [sic] was completely foreseeable. It was only a matter of time before it flooded" (NT Government staff).

In Milingimbi, the potential for a regular reoccurring flood event was also highlighted. Interviewees described how in the last 12-18 months king tides have regularly filled the salt flats adjacent to the community, spilling over onto the road and in some cases coming up to the hub caps of vehicles. This water does not drain away immediately but can remain in place for several days. A Local Government staff member said that this resulted in the sides of the road crumbling as well as potholes. It was flagged that if there was a strong cyclone or other big storm surge coinciding with a king tide, it would have a devastating impact on Milingimbi.

Another impact of disasters is the long period of time required for all waste to be dealt with, after the initial recovery processes are finished. The consequence of this is that other Council business falls behind as recovery takes priority.

"Some councils, depending on how significant the event is, might spend years in recovery mode and business continuity just doesn't occur for years. So new works or new projects, all your money goes into recovery. Goes just back into getting back to where you were before, let alone getting ahead"
(Local Government staff).

Table 3.4 summaries the impacts of different natural disaster types described by interviewees and the associated implications for waste management. Given the location of the three case studies it is not surprising that the impacts of cyclones and floods were described in greater detail than for other disasters and have significant waste management implications.

Table 3.4: Impacts discussed from various disasters

Event type	Perceived impact	Range of impacts	Waste implication
Flooding	High	Evacuation; houses filled with water; household goods contaminated; access roads cut off; power failure; pooled water leading to public health concerns; no access to landfills	High waste volumes generated; all contaminated household goods become waste; waste build up with no access to landfill sites; large food waste; carcasses a health hazard; reduced life of landfill
Tsunami	Low	Was dismissed by the interviewees	
Earthquake	Low	Could break underground water pipes; collapse houses	Building and construction waste; infrastructure waste
Heat Wave	High	Health risk; power failure	Food wastage with power failure
Fire	Medium/high	Houses burnt down; power failure; burning of hazardous waste	Landfill fires releasing toxins in the air; more waste from burnt structures
Cyclone	High	Damaged roofs, collapsed houses; fallen trees, loss of power	Large volumes of waste; spread of contaminated waste (for example, Asbestos); food wastage with power loss; reduced life of landfill
Covid	Medium	Dead bodies	Large number of bodies to be taken care of

3.6. Disaster Preparedness, Response and Recovery

This section discusses the processes followed by different stakeholders for Preparedness, Response and Recovery, followed by recollections of some specific disaster events that were frequently referred to by interviewees.

3.6.1. Preparedness

The coastal communities and the islands prepare for cyclone season by carrying out a seasonal cyclone clean up. Local councils organize hard rubbish collections leading up to the cyclone season and they remove everything that has "flight potential". One interviewee described this process as:

"So every, coming into cyclone season now which we are starting to think about, there's a big preparedness goes on, so all the businesses, including us will go around and make sure that we're removing stuff that's going to be potentially damaging in high winds and cause damage

to people and property. That's a big drive and that will happen for 4-6 weeks and there will be a big community cleanup during that time"
(Local Government staff).

The community residents are aware of this process and know what is required. For example, one said that:

"Before cyclone, Shire mob say to do big clean up before cyclone"
(Maningrida Resident).

Another resident described the Council cyclone clean-up activities as:

"Balanda clean up street. Council starts picking up motorcar, they're doing a pretty good job. They take rubbish to the Tip and cover it up. That's what they do before a cyclone came, so it doesn't blow again"
(Ramingining Resident).

Another resident highlighted the difference in the amounts of waste before and after the cyclone clean up:

"The situation before the cyclone was like now. But if a cyclone is coming it should be cleaned up. If a cyclone comes I will do a big clean up. The council sometimes does a good job" (Ramingining Resident).

It appears that in some instances pre-cyclone clean-ups are not solely undertaken by Councils but may also involve other organisations. For example, one Indigenous ranger explained that before a cyclone, there is an announcement by the Traditional Owners to clean up. Sometimes the CDP workers also help in this process. The rangers also help in the pre-and post-cleanup activities since they usually spend time in the communities during these periods, as opposed to the middle of the Dry season when they are more likely to be out on country.

One of the Local Government staff described the waste streams that need to be cleaned up around the community before a cyclone. This included cars on the footpath, hard rubbish in peoples' yards, roofing sheets, mesh, tins, and steel, whilst another said that they actively document the condition of assets before and after a disaster event. This is beneficial since funding bodies for recovery funds require proof of the damage to assets before dispensing any funds.

"So, we do a couple of things to protect ourselves. We do a drive around on all roads pre-wet and we photograph all assets pre-wet season. So, we would have data to compare post-event, you know, volumes or damage. So, we're prepared"
(Local Council staff).

Councils also do a post cyclone season clean up so that the waste deposited during the wet season does not go into the waterways, but this is considered an environmental management activity, rather than preparation for a disaster.

It is clear from our interviews in the three remote communities that there are no plans for DWM arising from cyclones (or other disasters), nor other documentation detailing how disaster waste would be consolidated, sorted and dealt with. Some Councils do not even have the equipment to deal with green waste even after a small storm.

"We had a bit of wind here not too long ago and it brought a lot of trees down, it actually brought down a tree on top of a house at bottom camp. They asked us to come and remove it. I looked at it and said we can't, I'm not game to remove it. If we had something like a 20 tonne excavator that could grab, pick it, pluck it off but we don't have anything like that here"
(Local Government staff).

However, the importance of a having DWM plan prepared ahead of time was reiterated:

"So the waste plan and the stuff that you're doing from a remote community perspective, the better the plan, the faster the plan can go, the better it is financially for the NT because we are hitting costs that no one really understands how much we cost when we care for a population"
(NT Government staff).

When responding to questions relating to disaster preparedness, interviewees also raised other issues such as lack of planning for temporary landfill arrangements and provision of adequate emergency shelters or evacuation centers. Some interviewees said that they had not given any thought to the potential need for temporary landfills/sorting areas.

One interviewee gave the example of Cyclone Markus and the difficulty of finding a temporary storage space for initial stockpiling. The spot where the waste from Cyclone Markus was temporarily stored was on the way to the airport and this created traffic issues with long queues of cars wanting to deposit green waste, while people were trying to get to the airport. Identification of suitable sites for temporary storage of disaster waste need to be identified well prior to any disasters.

In some communities, the local landfill is large enough to accommodate temporary storage. In places where it is not, new locations need to be identified that are large enough to temporarily store and sort the disaster waste generated. In remote communities, access to such am

area would require permission from the Traditional Owners, Land Council and potentially, would need to go through the formal s19 process under the NT Land Rights Act.

With several stakeholders involved in response and recovery, it is not clear which agency would be responsible for organising a temporary location beforehand.

"There would be enough space to receive a fairly big problem here, like a big disaster. I think, as you probably know, that if you start to look for another space, it becomes very, very political and TOs and government departments"
(Local Government staff).

In addition to land access issues and ensuring that temporary landfill/sorting areas do not impact upon sacred sites or other culturally significant areas, a temporary landfill would also need to be located so that the leachates don't contaminate the ground water. Care also needs to be taken to ensure that temporary landfills/sorting areas are cleaned up as soon as possible after the disaster to avoid any potential health hazards.

"The other thing even with location, a temporary emergency waste facility. We're gonna be very careful where that is, especially in the top end, if you get heavy rains or the water table rises, which then gets into your, especially if you got a landfill site. And then you got all that leachates problems and they go into the storm water, into bore water fields and things like that"
(Local Government staff).

"I think the biggest risk is when there's the waste facilities are shut down and we look at alternate [sites?] and the fact that sits there all the time and that's the biggest issue of Borroloola. It sat there for months and months. And it became putrid, you've got birds, dogs".
(Local Government staff).

Several interviewees reported that in a few communities, the council building, school, or a dedicated shelter are identified as cyclone shelters. These buildings provide protection during a cyclone but are not intended to provide accommodation for extended periods of time. In one remote community, the cyclone shelter was built on high ground and away from the sea, but it could only accommodate a quarter of the population. Further it had limited toilet facilities and no drinking water.

"It takes around 200 to 250 I think. That's the capacity, legal capacity. If you're under duress, you'll have more in there. There's only like four men's, four women's' toilets, it's only got water that's rainwater. You can't drink it"
(Local Government staff).

In some previous disasters, tent cities have been erected in or nearby communities to temporarily house residents until such time that their houses are repaired and certified as fit for habitation. In other cases, residents have been evacuated to another community or Darwin.

Although there are about 573 homelands (outstations) across the Northern Territory, only two interviewees raised concerns about DWM on homelands. One was a resident from a remote community and the other a Local government staff member.

"So one of the gaps I think is when we're talking about waste and there's just not local government, but looking at their homelands and resource centres. I know their population is a lot smaller, but the risks to individual constituents is still there like any other major populated area"
(Local Government staff).

3.6.2. Response

The TEP clearly states the level of hierarchy for response in an emergency event:

"In terms of the territory emergency plan, you've got the NT police fire and emergency services, they do the emergency response. Once it transitions, it sits with Chief Minister in terms of recovery"
(NT Government staff).

The priority in the response stage is to preserve human life and infrastructure, in that order. The only impact a "response decision" might have on waste, is whether people are allowed to stay in their homes or are moved to an evacuation center or other location. If residents remain in their homes during a weather event, then the local Council has the burden to clean up the waste from disasters as well as operate its regular BAU waste management functions as well.

"While you're cleaning up after an event, how do you maintain business continuity for your general services while you're now focusing on the event? And who cares about local government and what they have to do because nobody actually does, we are like the poor cousins of government"
(Local Government staff).

Interviewees described the evacuation process during a few cyclone and flood events. In one example the community's residents were evacuated to Darwin in anticipation of the cyclone. The cyclone didn't hit the

community and the residents returned to their community when the flood subsided and it was safe to do so.

However, when residents are moved to another community or location, Government agencies are also responsible for organising sanitation facilities for human waste as well as waste arising from food and drinks. In cases where residents are moved to an evacuation center in Darwin, the sanitation waste streams were directed to the regular waste management systems and facilities. However, the waste arising from everyday practices had to be dealt with and was said to be huge. This is discussed in sections 3.6.4 and 3.6.5.

3.6.3. Recovery

The Recovery stage occurs after people have been taken care of and marks the beginning of the clean-up process and transition back to normality. This can be a long process that may take years.

In remote communities, the recovery process only starts after the police have given authorisation. A Local Government staff member explained that residents need to stay indoors until the police tell them it is safe to do otherwise. Once authorities have ensured that there are no live powerlines, Council staff proceed to clear the roads.

Once power is safe, we've been able to turn that off, municipal services get involved and our job now is to clear the roads. We clear the roads particularly from here to the airport because we want to make sure that if anyone is injured, we can get them airlifted out. That's the first job. So power, and then, yeah, the roads, and then it's trying to get electricity and water restored if that's been broken down. We then, we just follow the guidance of the police. After that, once we've got those main things done, we then start to do a cleanup" (Local Council staff).

"After the primacy of life is dealt with and the immediate needs of the humans is taken care of the next bit is to clean up. And so waste management and the categorization of waste into various types and what to do next with them is, is probably because of the attention on environmental management. The waste management component of Emergency Management is going getting more and more important"
(NT Government staff).

According to the TEP responsibility of waste management during disasters lies with DIPL. As remote communities do not generally have a DIPL representative based in their community, this means that DIPL teams from Darwin or other larger regional center need to travel to the community. Meanwhile, local Council is often the first responder, clearing roads to air strips and to the barge landings so that DIPL and other outside emergency service personnel can access the community. It also allows essential services to resume as soon as possible.

"I know that for the Council, the first thing they do is obviously getting rid of debris off the road and stuff like that, access so we can open the town up and get access everywhere for all vehicles and emergency services and things like that. That would obviously be the primary goal for the council and then from there, it would be work under direction"
(Local Council staff).

Various stakeholders highlighted the importance of working together for cleaning up. For example, in one community, Council staff said that local construction contractors and a local Aboriginal Corporation help in cleaning up. However, this was an informal arrangement, and based on relationships within the community.

Some residents said that they participated in cleaning up, while others described the work of various organisations.

"After cyclone (Lam) I helped with the (general) clean up. The town was messy. I did it because everyone was doing it together, to get the feeling of the land. To get to like it was before the cyclone. We have feelings for the land before cyclones. As to we have feelings for our land"
(Ramingining Resident).

"After a cyclone the SES work to clean up. The Council is the main one, and Police, sometime CDP. At outstation the rangers do the clean up"
(Ranger group staff).

Another interviewee explained that as one of the first steps, the buildings get assessed for damage and the local Council is asked for equipment and staff to assist with cleaning up. External contractors are also asked to help with cleaning up.

In contrast to these examples of a collaborative approaches, some residents expressed the view that it was the work of non-Indigenous people (Balanda) to clean up:

"More rubbish after cyclone, wait for someone else to clean em up, balanda mob"
(Ramingining Resident).

Additionally, despite the collaborative approaches described above, during some interviews it became apparent that there was greater scope for collaboration between local organisations, both during the preparedness and response phases but that this

collaboration was either lacking or not as strong as it might have been. This was attributed to systemic failures within the organisations which had seen relationships between different organisations break down.

3.6.4. Recollections of some specific disaster events

During the interviews, certain disaster events were referred to repeatedly. The participants gave examples of how these were handled and ways in which waste was dealt with. These events were Cyclone Lam (2015), the Jilkmiggan flood (2021), Timber Creek floods (2022-2023), and the flooding in Kalkarindji, Daguragu and Nitjpurru (Pigeon Hole) (2023).

Cyclone Lam (2015)

In 2015, Cyclone Lam made landfall between Milingimbi and Elcho Island. Local Council staff said that it impacted Galiwingku, Milingimbi and Ramingining. In Galiwinku, it severely damaged roofs of houses and destroyed houses (Vanovac, 2015). It was a fairly significant event which saw residents living in tent cities on the community ovals for a period of time. The tents were sourced from NSW Rural Fire Service (Hope, 2015).

Owing to the extensive damage in Galiwinku, the local Council brought in heavy machinery such as bulldozers, to clear remote tracks since the backhoes and loaders they had were not large enough to move the volumes of waste generated. While some of the green waste such as large mahogany tree trunks were reusable, a large amount of green waste was splintered. This was either composted or the community members took it for using in cooking fires.

One Local Government staff member said that the Asset Asbestos register (updated in 2014) allowed them to identify buildings that contained asbestos. After the cyclone, asbestos handling professionals from Darwin gathered the asbestos and sent it to a South Australian facility for further processing. It was only later, in 2018 during the construction of houses, that asbestos was found spread over several areas of Galiwinku (Ashton, 2021). In 2019, an external environmental consultancy was contracted to carry out surveys and establish asbestos management plans over the next five years (EARC, 2021). It was suggested that one of the reasons for the spread of asbestos was during Cyclone Lam which had destroyed several homes (Ashton, 2021). It was only when cleaning up after the cyclone, that there was recognition about the lack of understanding of the capacity of organisations to respond with equipment and people.

> "That was one big thing back in Lam, and that no one knew each organisation's capacity and what they had in place. You know what resources they had to deal with anything. It was very much reactive - Oh Gee, something's gonna happen tomorrow. What have we got? Oh we've got chainsaws! Do we actually have chainsaws that are working? And people trying to use them?"
> (Local Government staff).

In Ramingining, a courthouse and police offices were damaged, but mostly trees had fallen down. A resident of Ramingining recalled:

> "There was a big mob rubbish from Lam. Trees everywhere. Only one house damaged fortunately. The meeting room at the police station door was torn off like a person did it. A tree fell on the back of a car. The banyan was all twisted up"
> (Ramingining resident).

Several power lines were also brought down by falling trees. In Ramingining the rangers helped to clear fallen trees since they said they had training in using chainsaws. They did not clarify whether they had certified training, or more informal training with no certification provided.

Jilkminggan Floods (2021)

In 2021, rising waters near the community of Jilkminggan, prompted an operation to evacuate the residents. The residents were evacuated to an existing community centre in the nearby town of Mataranka. An interviewee described the support provided to the evacuated residents:

> "We had cooking facilities; outside barbecues were going for every man and his dog. We had victim impact people, we had Centrelink here, you know, they were helping during the time of the disaster and after the disaster"
> (Local Council staff).

However, the toilet facilities were inadequate for the large number of evacuees and this overwhelmed the sanitation system. Fortunately, since the river at Jilkminggan did not break its banks, the residents returned within three days, following an inspection of the houses.

Timber Creek floods (2022-23)

In December 2022, Timber Creek's surrounding homelands experienced a 1-in-50-year flood event as ex-Tropical Cyclone Ellie moved inland. Given that an important ceremony was taking place in the area, it was decided that the community would be evacuated to a

nearby location, rather than to Katherine or Darwin. The Local Emergency Committee (LEC) worked with the elders to find a solution.

"But the difficulty there is that actually would have interrupted a very significant ceremony, which would have had an impact to multiple people in that community and also those who came to the community"
(NT Government staff).

It was also a smaller community on the Victoria Highway, which allowed the Red Cross to provide support and get supplies to the impacted residents. Some 200 residents from the surrounding homelands were brought into the community. The small council had to handle extra people in addition to their regular residents, which in turn impacted the existing infrastructure of the Timber Creek communities.

"The Timber Creek scenario where the population remained, waste became an actual massive issue for the Council. Evacuated population out of the homelands, were then in Timber Creek and the population overwhelmed the infrastructure of the Council. The waste that was being created was just massive. The Council actually got significantly overwhelmed by the day-to-day waste that occurred"
(NT Government staff).

These evacuees were accommodated in demountables and sanitation became a huge issue for the community.

"So in Timber Creek, they had actually toilets on the back of trucks. So I'm going into a dump point that quickly became overwhelmed. Plus, the local caravan park where the sewage should run through, had been impacted. Also overran by floods itself"
(NT Government staff).

A Local Government staff member explained that (even during disasters), waste from the flooded outstations was the responsibility of the Ngaliwurru-Wuli Association, an Indigenous outstation resource center that provides essential services to several outstations in the region, and was not managed by the local Council. After the floods, waste was deposited outside Vic-Daly Council's fenced off Waste Management Facility. This anecdote highlights that DWM Plans should also be consider disposal of disaster waste from homelands and outstations.

Flooding at Kalkarindji, Daguragu and Nitjpurru (Pigeon Hole) (2023)

In 2023, three communities of Kalkurindji, Daguragu and Nitjpurru (Pigeon Hole) were devastated by flood waters and were evacuated. Some communities were moved to Darwin and residents from Nitjpurru were moved to Yarralin so that they were closer to their community. A tent city was set up for them there.

Before the residents could return, the communities needed to be cleaned and the houses certified for occupation. DIPL worked with contractors NTEX, to prepare a plan for cleaning. This was done in three stages: the first stage was removing perishables (and other non-salvageable goods) from houses. In the next stage all personal belongings were removed, put in boxes and labeled. This was done with the help of local community members who were flown back to the community from Darwin. They advised the contractors and communicated with other community members in the evacuation center. The third stage of cleaning was removing sludge and complete decontamination. Again, some community members were flown back to help during this stage. The houses were then repaired so that they were liveable.

3.6.5. Evacuation center waste

While waste from the disasters is huge, significant waste also arises from the evacuation centers. While the waste generated at the Howard Springs Evacuation Centre was significant, it fed into the established waste infrastructure of Darwin and Palmerston. In the case of tent cities and remote locations, management of this waste poses challenges.

The interviewees mentioned several types of wastes from the evacuation centres. The residents in the tent cities and the evacuation centres are provided with packaged meals (3 times a day), bottled water and snacks (24-hour availability). With a usual population being over 500 in an evacuation centre, this generates enormous waste from individually packaged food containers and bottles of water. It was stated that:

"We are not in a position where we can separate waste in an evacuation centre except for plastic water bottles. And plastic water bottles are the biggest killer. We go through so many"
(NT Government staff).

A large number of Aboriginal community members are under the age of 18, and two-minute noodles are a favorite with them for snacking. While this was not measured, anecdotally this generated substantial waste.

The disposal of other items, such as tampons, baby nappies, condoms, person hygiene and similar products routinely used by large evacuation populations in a communal living environment, can also be problematic. While providing access to these products is part of the responsibility of the emergency services crew, less thought is given to their disposal after use, particularly when a large population is accommodated in short-term living arrangement outside of the urban or regional locations.

3.7. Lessons learnt for future disaster waste management

Collectively, the interviewees indicated that the way forward must include planning for disaster waste as part of preparation activities prior to disasters. This will help in managing the waste in an efficient and effective way. As one local Council staff member put it, "is better to be proactive rather than reactive in emergency situations". The need for strategic planning at all levels and across jurisdictions (Australian, Territory and Local governments) was identified as a priority in improving disaster preparedness.

"I think what the NT suffers from most of all is probably a lack of strategic management of emergencies and I mean that from top to bottom. I mean from the national level, taking all of those national priorities and probably even global priorities and bringing them down to the territory level. So everyone's working in their own particular space, they're not really aware of what the other people are doing. We don't have a central office or a central agency that does that. So we've got police for emergency services. They're responsible for a little bit of preparedness, fair bit of planning and all of the response part…but no one looks across all of the phases and all of the responsibilities and thinks about the bigger picture at the national level"
(NT Government staff).

Having a DWM plan for each community was proposed as an important first step towards preparing for disasters. Such plans need to be tailored for each community, keeping in mind their particular location, natural environment, demographics, buildings, other assets and cultural practices. Interviewees emphasized the need for a subcommittee, that prioritized waste management during emergencies, within the Local Emergency Committee.

"Then part of that group should be designing and working out where disaster waste can be held and for how long, and then having a plan in place, a pre-plan of what to do once you've gotten the waste long term"
(Local Government staff).

LEC members know the strengths and vulnerabilities of their community and residents, which is invaluable intelligence when planning for disasters. They can also help identify and prepare residents who can help during an emergency.

Several stakeholders said that acknowledging the role that Local Government plays or can play, in disaster waste management is important for improving waste management practices. Having this clearly stated in the local Emergency Management Plans would make what is expected from the local Council clearer and more transparent. As one interviewee argued:

"What are the expectations of government agencies for local government? And don't say "Nothing", because there is something. We've got the graders, we've got the loaders, the roads, the airports, you know, got the parks and gardens, we've got the community buildings, you know, that could be cyclone shelters. It's not nothing. We do have a role, and we should be acknowledged accordingly, and so we know what our role is and who we should be talking to and answering to"
(Local Government staff).

Part of this role should include participation in a mechanism that would see a DWM Plan fall within the remit of the existing LEC. An one interviewee stated:

"There is absolutely a role for the Council. How do we build it into, how we connect that then in with the LEC so that the LEC then can use the resources of the local emergency committee and actually plan for the hazards that the LECs identify"
(NT Government staff).

Understanding the availability of equipment and staff capacity in different organizations before an event was also suggested. This should be a focus before the cyclone season when an inventory should be prepared which lists working equipment and available staff during the expected cyclone period as well as listing staff who have the training to use equipment. Giving an example, an NT Government interviewee explained that after an emergency event had begun, they had to start trying to identifying residents who had training for using equipment such as forklifts, chainsaws and boats. Collating this information during the preparation stage would save time during the response stage.

Ranger groups can also help in cleaning up, as the examples provided earlier in this report demonstrate. As Rangers they can also be renumerated for this work, unlike some other volunteer groups.

It was pointed out that having disaster waste management in Emergency Management Plans might provide the impetus required for licensing existing

remote landfills. In the NT, an EPA license is required for a waste management facility serving a population of over 1000 persons or more. One of the prerequisites of the license is evidence of consent for the land use by the landowner, where the owner is not the local Council. Land in communities is generally owned by an Aboriginal Land Trust under the NT Aboriginal Land Rights Act. Accordingly, consent for the landfill needs to be negotiated with the Traditional Owners before a licence can be issued, which may take some time.

In case of a disaster, a large volume of waste is generated which requires quick removal. Most often this waste is removed to a safe site away from households. If this is put in the existing landfill, it reduces the life of the landfill by anywhere between 10 to 20 years. However, in recent years best practice is to remove it to a temporary location for sorting. Only waste that can be reused or recycled is then put in the existing landfill. For this, a temporary landfill/sorting site needs to be identified and consent for this use also sought from the Traditional Owners ahead of time, through the s19 process under the NT Aboriginal Land Rights Act.

One Local Government staff member stated that the biggest improvement for communities would be investing in "category-rated" housing and infrastructure. Since construction and demolition waste constitutes a considerable volume of waste, ensuring housing can withstand cyclones would prevent waste arising from damaged houses and greatly reduce the flying debris and asbestos during these events. Housing built on higher ground away from flood-prone areas, would also greatly reduce the amount of waste generated in these events.

As noted above, stocktaking of buildings, equipment and available personnel was suggested to improve preparedness for disaster waste. Assessing existing infrastructure and ensuring it is rated for the highest category of cyclones expected in the region, would be an essential part of planning process.

"So, this forward planning in emergency waste management is essential for government to have that strategic conversation to say look, in the event of an emergency. You know that, for example, with Roper Gulf, Borroloola, Numbulwar, they're going to get hit, and those towns are literally going to get wiped out because they've not ever been built to standard"
(Local Government staff).

It is very important to understand that different communities have different cultural practices and this needs to be addressed when writing specific DWM plans. For example, the research team were told how community residents became upset when Council staff went to remove loose c.g.i sheeting lying around in peoples' yards as part of the pre-cyclone season clean-up. The residents were upset because these pieces of c.g.i sheeting were being used to mark the graves of loved ones and were not to be removed. In another community, the household items after a disaster could not be touched and removed by just anybody. They could only be removed after consultation with the residents, who had already been evacuated. It was suggested that such practices should be documented so that new staff, and visitors that come to communities to help in the recovery process, are aware of what constitutes appropriate behaviour and local cultural practices.

A Local Government staff member pointed out that documenting all actions taken during disasters will be beneficial to new staff. When there is no historical or corporate knowledge, new staff make decisions based on the limited information available to them. Documenting and recording the waste management actions taken after a disaster will also be useful to reflect upon and improve measures taken subsequently. Documenting the conditions before a disaster event is also important as part of being able to provide a record of the damage incurred during that event and can be used as supporting evidence in funding applications or for insurance claims.

Regarding funding, it was suggested that disaster waste funding should include funding for transporting waste from the community to a waste management facility where it could be further processed. In fact, one interviewee suggested that this should be written into the Emergency Management Plan. The key point here is that preplanning should include how disaster waste will be dealt with, what waste streams need to be removed from the community and who will pay for that removal.

Several interviewees highlighted the need to empower communities to help themselves. Whilst some felt that an over-reliance on emergency management assistance takes away the residents' sense of control, others felt that communities needed to be proactively encouraged to become more resilient:

"You know there needs to be this joining up through either our planning frameworks, our funding arrangements or something, that puts community resilience back into communities rather than waiting for government to always sweep in"
(NT Government staff).

Improved communication with communities was identified as a need by several interviewees. This included getting information to residents about processes to be followed during an emergency event. If people have not been through a cyclone or other disaster it may be hard for them to comprehend what the impact on the ground may be in terms of likely damage

and amount of waste. As explained by one interviewee:

> "So, it's how do we get that understanding and the education within communities. What does it actually mean when cat 4 cyclone hits here? This is how much waste you're gonna have" (NT Government staff).

Given that English is not the first language for the vast majority of community members, this messaging needs to be in local language(s). Better engagement with community residents was identified by many interviewees as an essential element of improving disaster waste management.

Planning for backup power generation was another important aspect identified by interviewees, given it impacts upon the provision of essential services (water, sewerage, electricity) as well as communications. As previously noted, stores and households generate large volumes of food waste when they lose power during an emergency event.

The following section discusses the key findings from this study and identifies practical steps that can be taken towards addressing DWM in the NT more effectively.

4. Discussion

The previous section indicates that the problems associated with DWM in remote communities in the NT is, at present, inadequately understood but also that there is a strong appetite in all community sectors to take steps to improve the prospects in future disaster scenarios. Here we discuss the key investments that can be made to bring about step-changes in DWM.

It is a truism that 'everything relates to everything else' in small communities. At the same time Indigenous cultural settings tend to holistic approaches rather than segmented responsibilities. The following discussion reflects these drivers of effective DWM insofar as no single component of an improved model stands alone, rather they are inter-related.

4.1. A Disaster Waste Management Plan as part of the Emergency Management Plan

The central and urgent need is for the creation of a specific disaster waste management plan for each community. Sensibly, these plans should be embedded within the 46 local Emergency Management Plans in the Northern Territory's two emergency management areas (TEP, 2021, p.17). The establishment of these DWM plans will provide an effective and straightforward way to deal with the practical issues communities face, while larger structural and statutory/regulatory issues (see below) are developed appropriately. The research results frame the nature of the process of developing these DWM plans and their content.

The DWM plans should be developed through a devolved community engagement process with a prominent role allocated to the Local Government agency in each community. In addition to establishing the local parameters of DWM, the engagement should grow a waste subcommittee of the local LEC. The content of a DWM plan should be an extension of the existing local EMP. For example, the Maningrida Emergency Management Plan (EMP) describes the local context (geography, climate, culturally significant sites), infrastructure (building codes, land use, water services, Health and emergency infrastructure, communication and transport networks) as well as Preparation, Response and Recovery arrangements in the event of an emergency. A section on waste in the EMP that includes content as described in Table A.1. would allow preparing and responding to disaster waste as part of disaster planning, rather than as an afterthought.

Planning DWM considerations also reach into aspects of disaster response such as evacuations. The research results indicated that when the residents were evacuated to a distant location, it impacted the community's well-being and created anxiety amongst the residents, particularly about others touching and removing their personal belongings. As seen in one of the remote communities, when all the residents were evacuated, there were little or no staff for the Council to help in cleaning up operations. In other situations, where the local residents were temporarily relocated close by, often the toilets were overwhelmed by the number of residents, creating a sanitation problem. Equipping the tent cities or the evacuation centres with adequate facilities for sanitation and waste disposal is critical for maintaining hygienic conditions.

The interviewees pointed out that waste from evacuation centres became huge. The most problematic waste streams are food packaging (for example, individual meals, water bottles, instant cup noodles) as well as nappies, tampons and condoms. Some of the ways this could be handled better would be to instill a procurement process that either uses less packaging or more sustainable options, have specific and marked bins for sanitary products, and identify early where the waste will be taken post-disaster. The Container Deposit Scheme has led to several charities accepting bottles and cans marked with the 10-cent refund. Having an adequate number of toilets at cyclone shelters, evacuation centres and tent cities will also help in maintaining hygiene conditions.

Preplanning for disaster waste would also include estimating waste volumes from various disasters. The disaster waste management plan for each community would need to estimate possible waste volumes from various disasters. This would then help them estimate the area required for temporary landfill sites, as well as waste streams to expect from each disaster. Guidelines on separating waste and strategies for disposing waste streams would also need to be formulated during non-disaster times. Academic literature (Marchesini et al., 2021) provides 3 options for quantifying disaster waste based on historical data, using databases and imaging using aerial images. Since there is virtually no historical data available for historical disaster waste in remote communities, the other two methods will probably be more useful for quantifying waste. Further there are different ways for calculating debris from construction and demolition (Xiao et al., 2012, Poudel et al., 2018, Tabatha, 2017, FEMA, 2018), vegetation (Szantoi et al., 2012), and household goods (Tabatha et al., 2016, Tabatha et al., 2018) as well as from mixed (Jiang and Friedland, 2016; Koyama et al., 2016; Safffarzadeh et al., 2017; Yoo et al., 2017) and hazardous wastes (Zhang et al., 2017, Baek et al., 2016).

To reduce disaster waste ending up in landfill, it is critical to identify sites for temporary storage of waste nearby these communities. When all waste from disasters is mixed, it gets contaminated and can't be repurposed. A site where waste can be sorted would allow later recovery of some waste streams. Planning for where the sorted and unsorted waste is kept is essential and ideally should occur before the disaster. Putting disaster waste in landfills has the potential to reduce the life span of landfills by 10 to 20 years. In addition, it should be identified which organization will pay for handling and disposal (including transporting) of disaster waste.

The DWM plan should include accessible documentation. This means information about decisions and actions taken during disasters that is readily available and in a form that can be understood by people involved in planning, preparation, response and recovery in subsequent disasters. The need for this information is valuable everywhere, but in remote communities with the high turnover of staff, recording corporate knowledge and making it available is essential. The high rotation of staff in local Councils and the NT Government means that any lessons learnt responding to disasters tends to be lost. In the next disaster event, staff have to start from scratch again.

During our research, it was noted that unlike some other jurisdictions, in the NT there are no public records that review or evaluate disaster actions. For example, in Queensland the 2017 Cyclone Debbie Review report considered the timeliness and efficacy of preparation, response and recovery actions by different agencies (Office of the Inspector General Emergency Management 2017). NSW and Tasmania evaluated preparation, response and recovery regarding significant flood events in 2022 and 2016 respectively (State of New South Wales 2022a, 2022b; Tasmanian Government 2017). These documents are important for ensuring that learnings from past events can be shared not just between government agencies, but also with the local community, and thus helps mitigate the loss of both corporate and community knowledge. Such documents also form part of the accountable decision-making process and can also usefully identify areas where greater investment is required. (See Appendix G for sample community disaster waste checklist)

4.2. Accountable decisions

The vertical integration of decision making for effective disaster waste management will be critical for risk minimisation when hazards strike. Given that 'all disasters are local' it is essential that key stakeholders are identified at the local level. What we have seen in the three communities studied is that there is an uneven spread of understanding of the DWM risk and the local capacities and responsibilities for dealing with it.

The current arrangements provide for accountable decisions within the limits of the organizations engaged in the EMPs. However, significant capabilities and competencies within each community are not recognized in the EMP and the effectiveness of decisions is likely to be sub-optimal. Suitably established roles for Local Government agencies and community organizations such as Ranger groups, augmented with the inclusion of culturally appropriate community members will optimize the DWM function within EMPs. The agreement of roles and responsibilities will spread the burden of decision implementation while the act of inclusion will improve relationships between NTG and community.

4.3. Enhanced Investment

As stated above, while improvements in DWM planning can be made, there is an appetite and enthusiasm in communities to take the appropriate measures to make themselves more resilient to future hazards. Investment in a process for the generation and establishment of local DWM plans that includes all sectors of the community proffers a range of benefits to both government and community itself. Investment in disaster planning and preparation activities at the scale of the

village has been shown to practically improve hazard risk while bolstering capability and social capital (Sutton et al., 2022).

The remoteness of these communities and especially their isolation in times of disaster requires that every ounce of local capacity is optimised. Investing in a DWM plan as part of a more comprehensive EMP that recognises and supports development of that local capacity in BAU times will reduce vulnerability in times of crisis and contribute to more rapid response and recovery efforts.

Including community nodes of competence, such as the Ranger groups that have developed in the last two decades, as well as other identified community members, in planning and practical activities such as pre- and post-cyclone clean ups is a positive step in engaging the local community. The degree to which residents can participate and feel empowered to be involved in a clean-up needs to be further explored. Also, since cultural practices vary according to language groups, there are variations between communities on the specifics of the procedures that need to be followed with household objects. This again reinforces the need for individual DWM plans for each community.

Further investment opportunities exist in the area of communication of training and response mechanisms to the residents in language and during the non-disaster period. In addition, making the community aware of how each disaster (cyclone, flooding, fire) would impact the community is important. It was clear from the research that there is a very uneven understanding of disaster risk and disaster waste. Interviewees who had not experienced a disaster, had little comprehension of the range of impacts it could have. On the other hand, the interviewees who had experienced disasters described its impact on houses, roads, trees and generation of waste. Communication of this information needs to be in the local language(s) since for many residents, English is their second or even third language.

When developing and implementing DWM Plans, it is important to be cognizant that funding opportunities may exist in streams outside of the existing natural disaster funding mechanisms, for example, amongst education and training grants and programs, safer communities programs, road funding programs, as well as bodies such as the Foundation for Rural and Regional Renewal. However, as the grant and program space is an ever-shifting landscape, any list of funding opportunities provided here would become out-of-date within less than 12 months. The key challenge is to be sufficiently creative and nimble to be able to respond to these funding opportunities when they arise. Thinking outside of the box and working collaboratively with a range of stakeholders about ways in which elements of a DWM can be implemented will be critical. For example, communication about the potential impacts of different types of disasters in a community, might best be presented visually and in language, in posters or animated videos, that could be developed as arts and culture projects, delivered in conjunction with local art centres and/or Indigenous media organisations. However, the downside of this approach is that it does not address the real and pressing need for DWM Plans as soon as possible across all communities. A significant investment of time and resources is required to kick start the process. Realistically, this is most likely to be achieved through a specific once-off budget allocation in the NT budget with cash contributions from the Commonwealth. Areas requiring specific/additional investment in different communities would become apparent in the course of developing each DWM Plan, and from that position, it will be easier to identify and target particular funding programs in order to achieve specific community outcomes.

4.4. Governance, Ownership and Responsibility

This study has found that there are structural similarities, but also significant unique local challenges in DWM in the three communities. Interviewees in each community highlighted specific issues relating to their particular cultural, geographic and economic context and often provided ideas and insights into strategies that would enhance community self-efficacy.

Structurally, there is a shared recognition of the vagueness of the Local Government role in the EMPs. The Local Government reforms in the NT in 2008 have not yet implemented the formalisation of the role of local government in the TEP. In other Australian jurisdictions local government is recognised for its vital grass-roots role in emergency management and this is codified in legislative responsibilities not seen in the NT (NTES, 2021, p.22). There is an acknowledgement that “municipal and regional councils play a key role in emergency management activities, particularly at the regional and local level” (NTES, 2021, Section 1.13), but as we have learned, much of the potential for fulfilling this role (in DWM at least) remains uncoordinated and unrealised. In BAU times it is the local Council that is responsible for waste management. In the event of a disaster, there is great reliance on the Council or the external contractors to clean up. There is a sense in the general community that Local Government has a central responsibility for DWM noting that in general ‘they do a good job’. However, there is a clear mismatch between these perceptions and the codified responsibilities of the Councils. In the short term this can be managed by the establishment of DWM plans and subcommittees within the local EMPs. In the mid-term it will be

necessary to reconsider the legislative basis for Local Government's role in DWM, as well as wider issues of disaster preparation and response.

The inclusion of a clarified (and increased) role of Local Government in DWM plans would then lead to other measures important for response and recovery stages such as stocktaking of Local Government assets before a disaster. Stocktaking of available equipment and staff across organizations during cyclone season would help in responding to emergencies. Local council staff have the capacity to use machines and tools (for example, forklifts, chainsaws) that are required to clear fallen trees and remove debris. Checking before the cyclone season whether the machinery is in working condition and there are people available with skills to operate the equipment will make the response more efficient.

Establishing 'ownership' of the DWM role by Local Government might also practically lead to the identification and formal listing of all buildings containing asbestos within a community. While at present there is list of all the government buildings (with asbestos) on a public website, this does not include non-government properties. Documentation of the houses with asbestos is also necessary for the Council records. As seen during Cyclone Lam, in one of the remote communities the asbestos from damaged houses spread across several areas and in now undergoing remediation at a great cost.

4.5 Conclusions

There is a real and pressing need for the development of DWM plans for remote communities. The development of these plans requires a collaboration process between the three levels of government, non-government organizations and community residents. The DWM should be inked to the existing LEMPs. Done right, the DWM plans will significantly bolster community capacity to respond and resilience during recovery.

5. Recommendations

The following recommendations have arisen from the research and are referred to in various sections of the report.

Recommendation 1

Local Government agencies should have formally recognized roles and responsibilities for DWM (among other things) in the TEP.

Recommendation 2

All communities have a pre-disaster debris/waste management plans. The DWM plans should:

a. Be a formal component of existing emergency management plans, including a Waste Management sub-committee on the Local Emergency Management group.
b. Recognise that Government at all levels will never be able to meet all needs during or after disasters, and therefore they must work with communities "which will always step up to help their own when the occasion requires".
c. Be prepared during normal 'BAU' times.
d. Focus actions and responses on the specific needs of each local community, rather than imposing a single 'cookie cutter' solution or process.
e. Clarify cultural authority and practices including establishing protocols for access to private (residential) properties during the disaster clean-up phase.
f. Integrate the resources and actions of governments at all levels.
g. Broaden the scope of organisations and personnel allocated responsibilities in the plan, including Local Government, Ranger groups and local residents.
h. Identify residents who would have such cultural authority and willingness to help, and assist in preparing/training them for disaster waste management response.
i. Establish a program of up-to-date staff and skills audits for all local organisations.
j. Establish a regular review of equipment requirements for each community.
k. Establish training programs for community first responders that "build upon any existing community organised strategies and approaches". Training programs should
    i. Be co-designed with the communities, focusing on including Indigenous community members.
    ii . Include clear instructions about what is to be done with different forms of waste and by whom.
l. Establish regular stocktaking of buildings and equipment (for disaster waste estimation, but also for post-disaster change of situation reporting).
m. Establish regular stocktaking of hazardous wastes that will require removal from the community in the event of a disaster.
n. Pre-plan nature and location of evacuations and provide opportunities for community input into this.
    i. If evacuations to remote locations (Darwin, Katherine etc) plans need to be made re: cultural authority for waste removal
    ii. If evacuations are to near local facilities (tent cities etc) these need well planned for waste management.
    iii. Be communicated and implemented during the non-disaster period.
o. Include estimates of the quantities and types of waste.
p. Include design and location of disaster waste sites including what material can be held and for how long.
q. Establish a simple visual checklist/guide to waste types and their disposal.
r. Include a listing of all buildings (not just Government structures) with asbestos.
s. Include a listing of all buildings not built to cyclone code.

Recommendation 3

Access to waste facilities after a disaster needs to be acknowledged when deciding road hierarchies, i.e when determining to what standard a road is built (gravel vs all-weather bitumen).

Recommendation 4

Cyclone shelters need adequate toilet facilities (i.e. oversized from BAU) and must include feminine hygiene bins.

Recommendation 5

Disaster waste funding should include funding for transporting waste from the community to a waste management facility (this should be written into the Emergency Management Plan).

6. References

Section 2: Literature review

ALI, T., BUERGELT, P.T., PATON, D., SMITH, J.A., MAYPILAMA, E.L., YUGURRA, D., DHAMARRANDJI, S., & GUNDIARRANBUY, R.
Facilitating Sustainable Disaster Risk Reduction in Indigenous Communities:Reviving Indigenous Worldviews, Knowledge and Practices through Two-Way Partnering. *International Journal of Environmental Research and Public Health* **2021**, 18, 855. **https://doi.org/10.3390/ijerph18030855**

ALLEN, B. L. 2007.
Environmental justice and expert knowledge in the wake of a disaster. *Social Studies of Science*, 37, 103-110.a

ALTMAN, J. & JORDAN, K. 2009.
Maningrida Region, Arnhem Land, Northern Territory. In Green et al. (eds). *Risks from Climate Change to Indigenous Communities in the Tropical North of Australia*, pp. 99-106. Department of Climate Change and Energy Efficiency: Canberra

ASARI, M., SAKAI, S.-I., YOSHIOKA, T., TOJO, Y., TASAKI, T., TAKIGAMI, H. & WATANABE, K. 2013.
Strategy for separation and treatment of disaster waste: a manual for earthquake and tsunami disaster waste management in Japan. *Journal of Material Cycles and Waste Management*, 15, 290-299.

ASKARIZADEH, L., KARBASSI, A. R., GHALIBAF, M. B. & NOURI, J. 2016.
Management of post-earthquake construction debris in Tehran Metropolitan. *International Journal of Environmental Science and Technology*, 13, 639-648.

ASKARIZADEH, L., KARBASSI, A. R., GHALIBAF, M. B. & NOURI, J. 2017.
Debris management after earthquake incidence in ancient City of Ray. *Global Journal of Environmental Science and Management*, 3, 447-456.

BAEK, S.-C., KIM, Y.-C., CHOI, J.-H. & HONG, W.-H. 2016.
Determination of the essential activity elements of an asbestos management system in the event of a disaster and their prioritization. *Journal of Cleaner Production*, 137, 414-426.

BERAUD, H., BARROCA, B. & HUBERT, G. 2012.
Functional analysis, a resilience improvement tool applied to a waste management system – application to the "household waste management chain". *Nat. Hazards Earth Syst. Sci.*, 12, 3671-3682.

BERKTAŞ, N., KARA, B. & KARAŞAN, O. 2016.
Solution methodologies for debris removal in disaster response. *EURO Journal on Computational Optimization*, 4, 403-445.

BINSKIN, M., BENNETT, A. & MACINTOSH, A. 2020.
Royal Commission into National Natural Disaster Arrangements Report. *Canberra: Commonwealth of Australia*.

BROWN, C. & MILKE, M. 2016.
Recycling disaster waste: Feasibility, method and effectiveness. *Resources, Conservation and Recycling*, 106, 21-32. **https://doi.org/10.1016/j.resconrec.2015.10.021**.

BROWN, C., MILKE, M. & SEVILLE, E. 2011.
Disaster waste management following the 2009 Victorian bushfires. *Australian Journal of Emergency Management, The*, 26, 17-22.

BURNS, G., ADAMS, L. & BUCKLEY, G. 2017.
Independent review of the extreme weather event: South Australia 28 September-5 October 2016. *Report Presented to the Premier of South Australia.. Accessed,* 17, 2017.

CHEN, J.-R., TSAI, H.-Y., HSU, P.-C. & SHEN, C.-C. 2007.
Estimation of waste generation from floods. *Waste management*, 27, 1717-1724.

CHENG, C. & THOMPSON, R. G. 2016.
Application of boolean logic and GIS for determining suitable locations for Temporary Disaster Waste Management Sites. *International Journal of Disaster Risk Reduction*, 20, 78-92.

CHENG, C., ZHANG, L. & THOMPSON, R. G. 2018.
Reliability analysis for disaster waste management systems. *Waste Management*, 78, 31-42.

CHENG, C., ZHU, R., COSTA, A. M. & THOMPSON, R. G. 2021.
Optimisation of waste clean-up after large-scale disasters. *Waste Management*, 119, 1-10.

CHENG, C., LU, J.-W., ZHU, R., XIAO, Z., COSTA, A. M. & THOMPSON, R. G. 2022.
An integrated multi-objective model for disaster waste clean-up systems optimization. *Transportation Research Part E: Logistics and Transportation Review,* 165, 102867.

CROSWELLER, M. & TSCHAKERT, P. 2021.
Disaster management leadership and policy making: a critical examination of communitarian and individualistic understandings of resilience and vulnerability. *Climate Policy*, 21, 203-221.

CROWLEY, J. 2017.
A measurement of the effectiveness and efficiency of pre-disaster debris management plans. *Waste Management*, 62, 262-273.

ÇELIK, M., ERGUN, Ö. & KESKINOCAK, P. 2015.
The Post-Disaster Debris Clearance Problem Under Incomplete Information. *Operations Research*, 63, 65-85.

COMMONWEALTH OF AUSTRALIA. 2020a.
Background Paper: Australian inquiries and reports concerning natural disasters. Royal Commission into National Natural Disaster Arrangements. Available at **https://apo.org.au/sites/default/files/resource-files/2020-05/apo-nid303949.pdf [accessed 24/1/2024]**

COMMONWEALTH OF AUSTRALIA. 2020b.
Royal Commission into National Natural Disaster Arrangements Report. Report dated 28 October 2020. Royal Commission into National Natural Disaster Arrangements. Available at **https://www.royalcommission.gov.au/system/files/2020-12/Royal%20Commission%20into%20National%20Natural%20Disaster%20Arrangements%20-%20Report%20%20%5Baccessible%5D.pdf**

CROSSWELLER.,M & TSCHKERT, P. 2021.
Disaster management leadership and policy making: a critical examination of communitarian and individualistic understandings of resilience and vulnerability. *Climate Policy*, 21(2), 203–221. doi:10.1080/14693062.2020.1833825

CROWLEY, J. 2017.
A measurement of the effectiveness and efficiency of pre-disaster debris management plans. *Waste Management*, 62, 262-273.

CROWLEY, J. & FLACHSBART, P. 2018.
Local debris management planning and FEMA policies on disaster recovery in the United States. *International journal of disaster risk reduction,* 27, 373-379.

DOMINGO, N. & LUO, H. 2017.
Canterbury earthquake construction and demolition waste management: issues and improvement suggestions. *International Journal of Disaster Risk Reduction,* 22, 130-138.

ESCOBEDO, F. J., LULEY, C. J., BOND, J., STAUDHAMMER, C. & BARTEL, C. 2009.
Hurricane debris and damage assessment for Florida urban forests. *Journal of Arboriculture,* 35, 100.

FALESCHINI, F., ZANINI, M. A., HOFER, L., ZAMPIERI, P. & PELLEGRINO, C. 2017.
Sustainable management of demolition waste in post-quake recovery processes: The Italian experience. *International Journal of Disaster Risk Reduction,* 24, 172-182.

FEDERAL EMERGENCY MANAGEMENT AGENCY 2003. Hazus-MH 2.1 – Earthquake Model Technical Manuel. *In:* FEMA (ed.). Washington, DC.

FETTER, G. & RAKES, T. R. 2011. A self-balancing CUSUM approach for the efficient allocation of resources during post-disaster debris disposal operations. *Operations Management Research,* 4, 51-60.

FETTER, G. & RAKES, T. 2012. Incorporating recycling into post-disaster debris disposal. *Socio-Economic Planning Sciences,* 46, 14-22.

FETTER, G. & RAKES, T. R. 2013. An equity approach to contractor assignment in post-disaster debris disposal operations. *International Journal of Emergency Management,* 9, 170-186.

GARCÍA-TORRES, S., KAHHAT, R. & SANTA-CRUZ, S. 2017. Methodology to characterize and quantify debris generation in residential buildings after seismic events. *Resources, Conservation and Recycling,* 117, 151-159.

GOVERNMENT OF SOUTH AUSTRALIA 2018. State Emergency Management Plan - Part 4 - Disaster Waste Management Capability Plan.

GREEN D, S JACKSON AND J MORRISON. 2009. *Risks from Climate Change to Indigenous Communities in the Tropical North of Australia.* Department of Climate Change and Energy Efficiency: Canberra

GREEN INDUSTRIES SA. Disaster Waste Management. Available: **https://www.greenindustries.sa.gov.au/disaster-waste-management** [Accessed 3/3/2022].

HABIB, M.S., SARKAR, B., 2017. An integrated location-allocation model for temporary disaster debris management under an uncertain environment. Sustainability 9

HABIB, M. S., SARKAR, B., TAYYAB, M., SALEEM, M. W., HUSSAIN, A., ULLAH, M., OMAIR, M. & IQBAL, M. W. 2019. Large-scale disaster waste management under uncertain environment. *Journal of Cleaner Production,* 212, 200-222.

HABIB, M. S., MAQSOOD, M. H., AHMED, N., TAYYAB, M. & OMAIR, M. 2022. A multi-objective robust possibilistic programming approach for sustainable disaster waste management under disruptions and uncertainties. *International Journal of Disaster Risk Reduction,* 75, 102967.

HIRAYAMA, N., SHIMAOKA, T., FUJIWARA, T., OKAYAMA, T. & KAWATA, Y. 2010. Establishment of disaster debris management based on quantitative estimation using natural hazard maps. *Waste Manag Environ,* 140, 167-178.

HOOPER, M. 2019. When Diverse Norms Meet Weak Plans: The Organizational Dynamics of Urban Rubble Clearance in Post-Earthquake Haiti. *International Journal of Urban and Regional Research,* 43, 292-312.HU, Z.-H. & SHEU, J.-B. 2013. Post-disaster debris reverse logistics management under psychological cost minimization. *Transportation Research Part B: Methodological,* 55, 118-141.

HU, Z.-H. & SHEU, J.-B. 2013. Post-disaster debris reverse logistics management under psychological cost minimization. *Transportation Research Part B: Methodological,* 55, 118-141.

HU, Z.H., SHEU, J.B., WEI, C., ET AL., 2019. Post-storm Debris Removal Considering Traffic and Psychological Impacts. **https://doi.org/10.1080/** 838 F. Zhang et al. / Journal of Cleaner Production 235 (2019) 822e840 23249935.2019.1567618.

JIANG, S. & FRIEDLAND, C. J. 2016. Automatic urban debris zone extraction from post-hurricane very high-resolution satellite and aerial imagery. *Geomatics, Natural Hazards and Risk,* 7, 933-952.

KARUNASENA, G. & AMARATUNGA, D. 2015. Capacity gaps in post disaster construction & demolition waste management. *Engineering, Construction and Architectural Management.*

KARUNASENA, G. & AMARATUNGA, D. 2016. Capacity building for post disaster construction and demolition waste management: A case of Sri Lanka. *Disaster Prevention and Management,* 25, 137-153.

KARUNASENA, G., AMARATUNGA, D., HAIGH, R. & LILL, I. 2009. Post disaster waste management strategies in developing countries: case of Sri Lanka. *International Journal of Strategic Property Management,* 13, 171-190.

KAWAMOTO, K. & KIM, K. 2019. Efficiencies of bonding, bridging and linking social capital: Cleaning up after disasters in Japan. *International Journal of Disaster Risk Reduction,* 33, 64-73.

KIM, Y.C. & HONG, W.H. 2017. Optimal management program for asbestos containing building materials to be available in the event of a disaster. *Waste Management,* 64, 272-285.

KIM, T. & KIM, T. 2017. Smart and resilient urban disaster debris cleanup using network analysis. *Spatial Information Research,* 25, 239-248.

KOYAMA, C. N., GOKON, H., JIMBO, M., KOSHIMURA, S. & SATO, M. 2016. Disaster debris estimation using high-resolution polarimetric stereo-SAR. *ISPRS Journal of Photogrammetry and Remote Sensing,* 120, 84-98.

LEADER, A., GAUSTAD, G., TOMASZEWSKI, B., 2018. The consequences of electronic waste post-disaster: a case study of flooding in bonn, Germany. Sustainability 10 (11)

LORCA, Á., ÇELIK, M., ERGUN, Ö. & KESKINOCAK, P. 2017. An Optimization-Based Decision-Support Tool for Post-Disaster Debris Operations. *Production and Operations Management,* 26, 1076-1091.

MARCHESINI, G., BERAUD, H. & BARROCA, B. 2021. Quantification of disaster waste: Review of the available methods. *International Journal of Disaster Risk Reduction,* 53, 101996.

MCSHANE, I. & COFFEY, B. 2022. Rethinking community hubs: community facilities as critical infrastructure. *Current Opinion in Environmental Sustainability,* 54, 101149.

MEMON, M. A. Disaster waste recovery and utilization in developing countries-Learning from earthquakes in Nepal. 15th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering, ARC 2015: New Innovations and Sustainability, 2015. 143-147.

MORELY, P., RUSSELL-SMITH, J., SANGHA, K.K., SUTTON, S. & SITHOLE, B. 2016. Evaluating Resilience in Two Remote Indigenous Australian Communities. *Australian Journal of Emergency Management, 31*(4), 44-50.

MORETON, M. 2018. 'We needed help, but we weren't helpless': the community experience of community recovery after natural disaster in Australia. *Australian Journal of Emergency Management,* 33(1), 19-22.

NATIONAL INDIGENOUS AUSTRALIANS AGENCY. 2015. "Indigenous Rangers at forefront of Cyclone Lam recovery". **https://www.indigenous.gov.au/news-and-media/stories/indigenous-rangers-forefront-cyclone-lam-recovery** [accessed 11/1/2024]

O'KANE, M. & FULLER, M. 2022. *Report of the 2022 NSW Flood Inquiry.* **https://www.nsw.gov.au/sites/default/files/noindex/2022-08/NSW_Government_Reponse.pdf** [accessed 8/11/2022]

OFFICE OF GREEN INDUSTRIES SA. 2015. *Disaster Waste Management Scoping Study Final Report.* Retrieved from **https://www.greenindustries.sa.gov.au/__media_downloads/165438/Disaster%20Waste%20Management%20Scoping%20Study_final%20-Sept%20without%20map%20(1).pdf** [18/05/2023]

OFFICE OF THE INSPECTOR-GENERAL EMERGENCY MANAGEMENT. 2017. *The Cyclone Debbie Review. Lessons for delivering value and confidence through trust and empowerment. Report 1: 2017-18.* Retrieved from **https://www.igem.qld.gov.au/sites/default/files/2019-02/Cyclone%20Debbie%20Review%20Rpt1-17-18_PUBLIC_WEB.pdf** [6/10/22]

ONAN, K., ÜLENGIN, F. & SENNAROĞLU, B. 2015. An evolutionary multi-objective optimization approach to disaster waste management: A case study of Istanbul, Turkey. *Expert Systems with Applications,* 42, 8850-8857.

PHAM, T. T. H., APPARICIO, P., GOMEZ, C., WEBER, C. & MATHON, D. 2014. Towards a rapid automatic detection of building damage using remote sensing for disaster management: The 2010 Haiti earthquake. *Disaster Prevention and Management: An International Journal,* 23, 53-66.

PHONPHOTON, N. & PHARINO, C. 2019. A system dynamics modeling to evaluate flooding impacts on municipal solid waste management services. *Waste Management,* 87, 525-536.

PORTUGAL-PEREIRA, J. & LEE, L. 2016. Economic and environmental benefits of waste-to-energy technologies for debris recovery in disaster-hit Northeast Japan. *Journal of Cleaner Production,* 112, 4419-4429.

POUDEL, R., HIRAI, Y., ASARI, M. & SAKAI, S.-I. 2018. Establishment of unit generation rates of building debris in Kathmandu Valley, Nepal, after the Gorkha earthquake. *Journal of Material Cycles and Waste Management,* 20, 1663-1675.

PRAMUDITA, A. & TANIGUCHI, E. 2014. Model of debris collection operation after disasters and its application in urban area. *International Journal of Urban Sciences,* 18, 218-243.

PRASETYA, G., BLACK, K., DE LANGE, W., BORRERO, J. & HEALY, T. 2012. Debris dispersal modeling for the great Sumatra Tsunamis on Banda Aceh and surrounding waters. *Natural Hazards,* 60, 1167-1188.

RAILA, E. M. & ANDERSON, D. O. 2017. Healthcare waste management during disasters and its effects on climate change: Lessons from 2010 earthquake and cholera tragedies in Haiti. *Waste Management and Research,* 35, 236-245.

RAWSTHORNE, M., HOWARD, A., JOSEPH, P., SAMPSON, D. & KATRAK HARRIS, M. 2023. Understanding community-led disaster preparedness. *Australian Journal of Emergency Management,* 38(2), 49-54. **www.doi.org/10.47389.38.2.48**

SAAT, N., MALIA, W. N., IKRAM, A. M., AISHAH, H. S., ZAWAHA, I., ASHIKIN, M. N. & NORASMARINA, M. S. 2016. Perception of flood waste management among stakeholders in Kelantan. *Journal of Environmental Science and Technology,* 9, 317.

SAFFARZADEH, A., SHIMAOKA, T., NAKAYAMA, H., HANASHIMA, T., YAMAGUCHI, K. & MANABE, K. 2017. Tasks and problems involved in the handling of disaster waste upon April 2016 Kumamoto Earthquake, Japan. *Natural Hazards,* 89, 1273-1290.

SAHIN, H., KARA, B. Y. & KARASAN, O. E. 2016. Debris removal during disaster response: A case for Turkey. *Socio-Economic Planning Sciences,* 53, 49-59.

SAKAI, S., POUDEL, R., ASARI, M. & KIRIKAWA, T. 2018. Disaster waste management after the 2016 Kumamoto Earthquake: A mini-review of earthquake waste management and the Kumamoto experience. *Waste Management & Research,* 37, 247-260.

SANGHA, K. K., SITHOLE, B., HUNTER-XENIE, H., DANIELS, C., YIBARBUK, D., JAMES, G., MICHAEL, C., GOULD, J., EDWARDS, A., & RUSSELL-SMITH, J. 2017. Empowering remote Indigenous communities in natural disaster prone northern Australia. *International Journal of Mass Emergencies and Disasters,* 35(3), 137-153.

SANGHA, K.K.; EDWARDS, A.; RUSSELL-SMITH, J. 2019. Long-term solutions to improve emergency management services in remote communities in Northern Australia. *Australian Journal of Emergency Management,* 34(2), 23–31.

SASAO, T. 2016. Cost and efficiency of disaster waste disposal: A case study of the Great East Japan Earthquake. *Waste management,* 58, 3-13.

SHIBATA, T., SOLO-GABRIELE, H. & HATA, T. 2012. Disaster Waste Characteristics and Radiation Distribution as a Result of the Great East Japan Earthquake. *Environmental Science & Technology,* 46, 3618-3624.

SITHOLE, B.; CAMPION, O.B.; HUNTER-XENIE, H. 2019. Hazard-smart remote communities in northern Australia: Community-led preparedness. *Australian Journal of Emergency Management,* 34(1), 28–34.

STATE OF NEW SOUTH WALES, 2022a. *2022 Flood Inquiry Volume 2: Full Report.* Retrieved from **https://www.nsw.gov.au/sites/default/files/noindex/2022-08/VOLUME_TWO_Full%20report.pdf** [accessed 18/10/2022]

STATE OF NEW SOUTH WALES, 2022b. *2022 Flood Inquiry Volume 1: Summary Report.* Retrieved from **https://www.nsw.gov.au/sites/default/files/noindex/2022-08/VOLUME_ONE_Summary.pdf** [accessed 8/11/2022]

SURJAN, A., MATHUR, D., LASSA, J.L. & MATHEW, S. 2018. 'Lessons Not Learnt: Darwin's paying the price after Cyclone Marcus'. *The Conversation,* March 27, 2018. Available at **https://theconversation.com/lessons-not-learned-darwins-paying-the-price-after-cyclone-marcus-93862** [accessed 24/1/2024]

SZANTOI, Z., MALONE, S., ESCOBEDO, F., MISAS, O., SMITH, S. & DEWITT, B. 2012. A tool for rapid post-hurricane urban tree debris estimates using high resolution aerial imagery. *International Journal of Applied Earth Observation and Geoinformation,* 18, 548-556.

TABATA, T., MORITA, H. & ONISHI, A. 2018. What is the quantity of consumer goods stocked in a Japanese household? Estimating potential disaster waste generation during floods. *Resources, Conservation and Recycling,* 133, 86-98.

TABATA, T., WAKABAYASHI, Y., TSAI, P. & SAEKI, T. 2017. Environmental and economic evaluation of pre-disaster plans for disaster waste management: Case study of Minami-Ise, Japan. *Waste Management,* 61, 386-396.

TABATA, T., ZHANG, O., YAMANAKA, Y. & TSAI, P. 2016. Estimating potential disaster waste generation for pre-disaster waste management. *Clean Technologies and Environmental Policy,* 18, 1735-1744.

TASMANIAN GOVERNMENT, 2017. *Tasmanian Flood Recovery: from floods into recovery.* Retrieved from **https://knowledge.aidr.org.au/media/3997/flood-recovery-action-plan.pdf** on 28/11/2022

THOMPSON, B. K., ESCOBEDO, F. J., STAUDHAMMER, C. L., MATYAS, C. J. & QIU, Y. 2011. Modeling hurricane-caused urban forest debris in Houston, Texas. *Landscape and Urban Planning,* 101, 286-297.

VAHANVATI, M. & KULIGOWSKI, E. 2022. August 22, 2022. 'Tinnie army' leads to NSW flood inquiry call to train community members as first responders. How will that work? The Conversation. Retrieved from https://theconversation.com/tinnie-army-leads-to-nsw-flood-inquiry-call-to-train-community-members-as-first-responders-how-will-that-work-188900

VAHANVATI, M., MCEVOY, D., KUH, D. & IYER-RANIGA, U. (2022). *Inclusive and Disaster Resilient Shelter Guide Urban Informal Settlements, Honiara, Solomon Islands*. RMIT University. **https://cur.org.au/cms/wp-content/uploads/2022/02/sisg_published-3.pdf**

VELAND, S., HOWITT, R. & DOMINEY-HOWES, D. 2010. Invisible institutions in emergencies: Evacuating the remote Indigenous community of Warruwi, Northern Territory Australia, from Cyclone Monica. *Environmental Hazards: Human and Policy Dimensions,* 9, pp. 197-214.

VICTORIAN GOVERNMENT 2022. *Victorian Government Bushfire Clean Up.* **https://www.vic.gov.au/bushfire-clean-up-program)**

WAKABAYASHI, Y., PEII, T., TABATA, T. & SAEKI, T. 2017. Life cycle assessment and life cycle costs for pre-disaster

waste management systems. *Waste Management,* 68, 688-700.

WALGA. n.d. Local Waste Management Arrangements for Emergency Events. Major Milestone 1: Research Report. Retrieved from **https://www.wastenet.net.au/Profiles/wastenet/Assets/ClientData/Major_Milestone_1_Research_Report_29_09_17.pdf [7/12/2022]**

XIAO, J., XIE, H. & ZHANG, C. 2012. Investigation on building waste and reclaim in Wenchuan earthquake disaster area. Resources, *Conservation and Recycling,* 61, 109-117.

YOO, H. T., LEE, H., CHI, S., HWANG, B.-G. & KIM, J. 2017. A preliminary study on disaster waste detection and volume estimation based on 3D spatial information. *doi,* 10, 428-435.

ZHANG, F., CAO, C., LI, C., YANG, L. & HUISINGH, D. 2019. A systematic review of recent developments in disaster waste management. *Journal of Cleaner Production* 822-840.

ZHANG, H., DUAN, H., ZUO, J., SONG, M., ZHANG, Y., YANG, B. & NIU, Y. 2017. Characterization of post-disaster environmental management for Hazardous Materials Incidents: Lessons learnt from the Tianjin warehouse explosion, China. *Journal of environmental management,* 199, 21-30.

Section 3: Data collection and analysis

ASHTON, K. 2021. Hundreds of asbestos pieces found across remote NT community but health risk is low, study finds. ABC News. Retrieved from: **https://www.abc.net.au/news/2021-03-12/asbestos-found-in-nt-remote-community-galiwinku/13237462**

EAST ARNHEM REGIONAL COUNCIL 2021. Agenda Galiwinku Local Authority Meeting Thursday 28 January 2021. Retrieved from: **https://irp.cdn-website.com/79fa6d12/files/uploaded/2021-01-28%20Galiwin-ku%20LA%20Agenda.pdf**

GIBSON, J. 2019. Milingimbi water concerns stall future developments in Arnhem Land. ABC News, Sunday 10th November 2019. Retrieved from **https://www.abc.net.au/news/2019-11-10/milingimbi-water-shortage-concerns-in-arnhem-land/11686470**

HATFIELD-DODDS, Z. 2016. Integrating Understandings of a Yolngu Seasonal Calendar: A cross-disciplinary exploration of Scientific and Indigenous Seasonal Knowledge in North East Arnhem Land, Australia. Honours Thesis, Fenner School of Environment and Society, Australian National University. Available at **https://openresearch-repository.anu.edu.au/bitstream/1885/287563/1/HATFIELD_DODDS%20Zac-%20ENVS4000_Honours%20Thesis.pdf.pdf** [accessed 24/1/2024]

HOPE, Z. 2015. Galiwinku residents displaced after Cyclone Lam have largely rejected the tent city. *NT News,* 4 April 2015.

NORTHERN TERRITORY EMERGENCY SERVICE. 2021. Territory Emergency Plan. Retrieved from: **https://pfes.nt.gov.au/sites/default/files/uploads/files/2022/NT%20Emergency%20Service_Territory_Emergency_Plan_122022.pdf**

NORTHERN TERRITORY EMERGENCY SERVICE. (2023). Ramingining Local Emergency Plan v9.0. **https://pfes.nt.gov.au/sites/default/files/uploads/files/2023/Ramingining%20Local%20Emergency%20Plan.pdf**

VANOVAC, N. 2015. *Territory locals agree that Cyclone Lam was the biggest storm they've seen.* Northern Territory News. Australian Associated Press. [accessed 23/2/2015] Retrieved from **https://www.theguardian.com/australia-news/2015/feb/20/nt-faces-weekend-of-repairs-as-cyclone-lam-downgraded**

Section 4: Discussion

BAEK, S.-C., KIM, Y.-C., CHOI, J.-H. & HONG, W.-H. 2016. Determination of the essential activity elements of an asbestos management system in the event of a disaster and their prioritization. *Journal of Cleaner Production,* 137, 414-426.

FEDERAL EMERGENCY MANAGEMENT AGENCY 2003. Hazus-MH 2.1 – Earthquake Model Technical Manuel. *In:* FEMA (ed.). Washington, DC.

JIANG, S. & FRIEDLAND, C. J. 2016. Automatic urban debris zone extraction from post-hurricane very high-resolution

satellite and aerial imagery. *Geomatics, Natural Hazards and Risk,* 7, 933-952.

KOYAMA, C. N., GOKON, H., JIMBO, M., KOSHIMURA, S. & SATO, M. 2016. Disaster debris estimation using high-resolution polarimetric stereo-SAR. *ISPRS Journal of Photogrammetry and Remote Sensing,* 120, 84-98.

MARCHESINI, G., BERAUD, H. & BARROCA, B. 2021. Quantification of disaster waste: Review of the available methods. *International Journal of Disaster Risk Reduction,* 53, 101996.

NORTHERN TERRITORY EMERGENCY SERVICE. 2021. Territory Emergency Plan. Retrieved from: https://pfes.nt.gov.au/sites/default/files/uploads/files/2022/NT%20Emergency%20Service_Territory_Emergency_Plan_122022.pdf

POUDEL, R., HIRAI, Y., ASARI, M. & SAKAI, S.-I. 2018. Establishment of unit generation rates of building debris in Kathmandu Valley, Nepal, after the Gorkha earthquake. *Journal of Material Cycles and Waste Management,* 20, 1663-1675.

SAFFARZADEH, A., SHIMAOKA, T., NAKAYAMA, H., HANASHIMA, T., YAMAGUCHI, K. & MANABE, K. 2017. Tasks and problems involved in the handling of disaster waste upon April 2016 Kumamoto Earthquake, Japan. *Natural Hazards,* 89, 1273-1290.

STATE OF NEW SOUTH WALES, 2022a. *2022 Flood Inquiry Volume 2: Full Report.* Retrieved from **https://www.nsw.gov.au/sites/default/files/noindex/2022-08/VOLUME_TWO_Full%20report.pdf** [accessed 18/10/2022]

STATE OF NEW SOUTH WALES, 2022b. *2022 Flood Inquiry Volume 1: Summary Report.* Retrieved from **https://www.nsw.gov.au/sites/default/files/noindex/2022-08/VOLUME_ONE_Summary.pdf** [accessed 8/11/2022]

SUTTON, S. A., PATON, D., BUERGELT, P., SAGALA, S. & MEILIANDA, E. 2022. 'Village'as verb: Sustaining a transformation in disaster risk reduction from the bottom up. *Environmental Science & Policy,* 137, 40-52.

SZANTOI, Z., MALONE, S., ESCOBEDO, F., MISAS, O., SMITH, S. & DEWITT, B. 2012. A tool for rapid post-hurricane urban tree debris estimates using high resolution aerial imagery. *International Journal of Applied Earth Observation and Geoinformation,* 18, 548-556.

TABATA, T., MORITA, H. & ONISHI, A. 2018. What is the quantity of consumer goods stocked in a Japanese household? Estimating potential disaster waste generation during floods. *Resources, Conservation and Recycling,* 133, 86-98.

TABATA, T., WAKABAYASHI, Y., TSAI, P. & SAEKI, T. 2017. Environmental and economic evaluation of pre-disaster plans for disaster waste management: Case study of Minami-Ise, Japan. *Waste Management,* 61, 386-396.

TABATA, T., ZHANG, O., YAMANAKA, Y. & TSAI, P. 2016. Estimating potential disaster waste generation for pre-disaster waste management. *Clean Technologies and Environmental Policy,* 18, 1735-1744.

TASMANIAN GOVERNMENT, 2017. Tasmanian Flood Recovery: from floods into recovery. Retrieved from **https://knowledge.aidr.org.au/media/3997/flood-recovery-action-plan.pdf** on 28/11/2022

YOO, H. T., LEE, H., CHI, S., HWANG, B.-G. & KIM, J. 2017. A preliminary study on disaster waste detection and volume estimation based on 3D spatial information. doi, 10, 428-435.

XIAO, J., XIE, H. & ZHANG, C. 2012. Investigation on building waste and reclaim in Wenchuan earthquake disaster area. Resources, *Conservation and Recycling,* 61, 109-117.

ZHANG, H., DUAN, H., ZUO, J., SONG, M., ZHANG, Y., YANG, B. & NIU, Y. 2017. Characterization of post-disaster environmental management for Hazardous Materials Incidents: Lessons learnt from the Tianjin warehouse explosion, China. *Journal of environmental management,* 199, 21-30.

Appendix A: Risk Profiles

Note these profiles are specifically developed in relation to disaster waste management

Table A.1 at the end of this Appendix summaries the types of waste expected from different natural disasters in these three communities.

Figure A.1 Aerial view of Maningrida

A.1. Maningrida

Except where otherwise noted, information in this profile has been drawn from the Bushtel entry for Maningrida, the Local Emergency Plan for Maningrida, and interviews with study participants.

Context and environment

Located in Arnhem Land, within the boundaries of the West Arnhem Regional Council, Maningrida is about 400kms east of Darwin. Road access is on unsealed roads, either from Jabiru on the Oenpelli-Maningrida road or via Katherine and Beswick on the Central Arnhem Highway-Ramingining Road and Ramingining-Maningrida Road. These roads become impassable for extended periods of time owing to flooding and boggy conditions in the wet season. The region's main airstrip (sealed) is at Maningrida, with dirt strips at Mumeka and Jimarda. The vast majority of supplies for the region are brought by barge from Darwin and offloaded at the Maningrida barge landing.

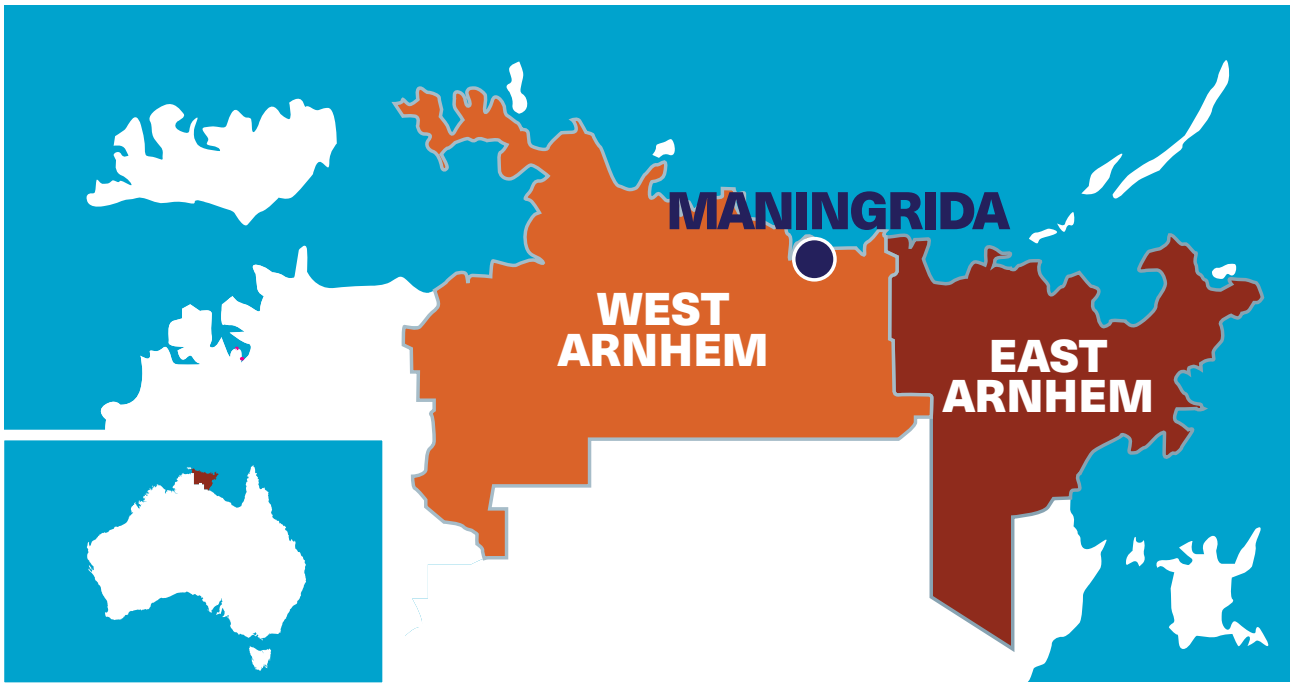


Figure A.1.2 Location of Maningrida (Source https://ecant.org.au/the-facts)

The physical environment of the Maningrida district ranges from the sandy beaches, coastal flats and mangrove lined shores, to floodplains extending out from rivers and creeks, to the savannah woodland and sandstone 'stone country' of the Western Arnhem Plateau. The highest point is about 400m above mean sea level (MSL) in the southwest part of the district. The Bureau of Meteorology weather station at Maningrida is 11m above MSL, whilst the airport is 28.1m above MSL[1].

The region experiences a wet-dry tropics environment. Non-Indigenous people recognize two or three seasons: wet season (November-May), dry season (June-October) and the humid "buildup" (October-November). In contrast, Bininj people, who comprise over 80% of the regional population, recognize six seasons and distinguish between monsoon and storm seasons[2]. Average annual rainfall is 1060mm.

Situated on the coast at the mouth of the Liverpool River, Maningrida is the major community in the district, servicing around 30-32 smaller communities, homelands and outstations. Services and facilities in Maningrida include Police, Health, School, West Arnhem Regional Council, commercial accommodation, community stores, post office, aerodrome, barge services, mobile and internet communications, Bawinanga Rangers, construction companies, Babbarra Women's Centre, Maningrida Arts & Culture Centre, and others. All fuel must be brought into the community, including that required to run the generators at the power station, which is operated by WARC on behalf of PAWA. Additionally, a small 800kW solar farm comprising 2,500 solar panels provides power for about 130 households[3].

According to the 2021 Census, the population of Maningrida (SA1 Level) is 2,956. However, during the Dry Season many people prefer to reside on their homelands, thus the population of town at this time is around 2,500. In contrast, during the wet season the population of Maningrida swells to around 4,000 people as they come into town in order to be able to access goods and services during this period.

As noted above, the vast majority of residents in and around Maningrida are Indigenous. Key languages spoken are Burarra, Ndjebbana, Kunwinjku, Yolngu Matha, and English, with the latter often the 3rd or 4th language for many people. However, Maningrida is one of the most linguistically diverse communities globally, with 15 different languages used or signed on a daily basis[4]. This has implications in terms of communication regarding disaster waste and emergency management more broadly; such communications need to be in English and languages.

[1]Retrieved from: **http://www.bom.gov.au/catalogue/observations/nt-coastal-stations.shtml**
[2]Retrieved from: **https://www.mirarr.net/pages/kakadu**
[3]Retrieved from: **https://www.powerwater.com.au/customers/safety-and-emergencies/updates/news-and-media/media-releases/2017/solar-powers-up-for-strong-community-engagement**
[4]See Vaughan, J. & Singer, R. 2018. Indigenous multilingualisms past and present. Language & Communication, 62, 83-90.

Risk identification

Risks previously identified in the Local Emergency Plan for the Maningrida district included cyclones, bushfires, marine oil spills and transport (road, air, marine) disasters/emergencies. In 2006 Cyclone Monica made landfall 35km to the west of Maningrida as a Category 5 cyclone. Some 75% of housing was damaged, a storm surge of 5-6m was recorded, along with extensive defoliation and major flooding in some catchments[5]. Housing in Maningrida is mostly either concrete block or steel framed, in line with DIPL and NT government procurement requirements[6].

In the course of fieldwork two other risks were identified that have the capacity to generate substantial waste. One interviewee noted there was some potential for earth tremors to crack aging asbestos cement water pipes, which would impact water distribution and sewerage in the community. However, a more significant and likely risk, is that of prolonged power failure, such as might occur owing to machinery/plant breakdowns. Interviewees highlighted the sometimes precarious nature of the power supply and were well aware that a sustained outage would generate large amounts of putrescibles (food) waste both from residents as well as the community stores. Such an event would also impact on the distribution of water and sewerage in the communities. Residents and organisations with back-up generators would be unable to run these unless they had already secured a supply of fuel prior to the event, as power is also required for the fuel pumps.

Processes in place

Details regarding emergency procedures, roles and responsibilities in relation to cyclones, bushfires, marine oil spills and transport (road, air, sea) are provided in the Local Emergency Management Plan for Maningrida.

Pre-cyclone clean-ups are undertaken by the Council. Although no site has been identified for temporary storage, there is sufficient space at the existing landfill to create a temporary sorting locale.

Challenges for managing waste from disasters

- Challenges include but are not necessarily limited to:
- Lack of a dedicated disaster waste management plan.
- The multilingualism of Maningrida is a challenge as Vaughan (2018) reports there is no common lingua franca between all the language groups.
- Staff recruitment and retention is an ongoing challenge both in terms of having the actual available staff to do the work in BAU times, let alone disasters, as well as maintenance of corporate knowledge regarding previous disasters, processes, and procedures.
- Staff turnover may also present a risk where there are existing good working relationships between different organisations in relation to waste, and disaster waste clean-up, that rely on/are dependent upon the relationships between individuals, rather than the strength of the relationship between the organisations.
- Lack of appropriate equipment to remove and process green waste.
- Access and ability to remove/transport waste out of the community. During the wet season, barge is the only form of transport able to remove large amounts of waste from the community. During the Dry season road access is possible but requires 4WD. We saw single trucks on the Oenpelli-Maningrida road between Gunbalunya and Ramingining, but this road is not suitable for road trains. Smaller trucks may be a potential option for removing non-urgent waste that cannot be put into landfill and that does not need to urgently removed, but weight restrictions and physical road conditions will remain challenging.
- No dedicated evacuation centre exists in Maningrida, however the Maningrida school, BAC Offices, MPA Offices, MPA Hotel Rooms (but not the common room), function as emergency shelters when necessary, and have a combined capacity for around 500 people.

[5]See Hanson-Easy and Hansen.2016. *Maningrida and cyclone Monica.* Retrieved from **SS32_Maningrida_and_cyclone_Monica.pdf (coastadapt.com.au)**
[6]Retrieved from: **https://ourfuture.nt.gov.au/__data/assets/pdf_file/0007/821581/capital-works-design-guidelines.pdf**

Figure A.2 Aerial view of Milingimbi

A.2. Milingimbi

Except where otherwise noted, information in this profile has been drawn from the Bushtel entry for Milingimbi, the *Local Emergency Plan for Ramingining v9.0* (which includes Milingimbi), and interviews with study participants.

Context and environment:

Located in the Arafura Sea, within the boundaries of the East Arnhem Regional Council (EARC) LGA, Milingimbi is part of the Crocodile Island group, about 440kms east of Darwin and 200km west of Nhulunbuy. The island lies about 0.5km offshore. Access is via air or sea (barge, or boat from the Ramingining barge landing - the latter is accessed via unsealed an road from Ramingining which may flood or become boggy in the wet season. The island's airstrip is sealed. All supplies for Milingimbi are brought by barge from Darwin and offloaded at the barge landing immediately adjacent to the community. A minimum tide of 2.2m above sea level is required in order to be able to access the landing.

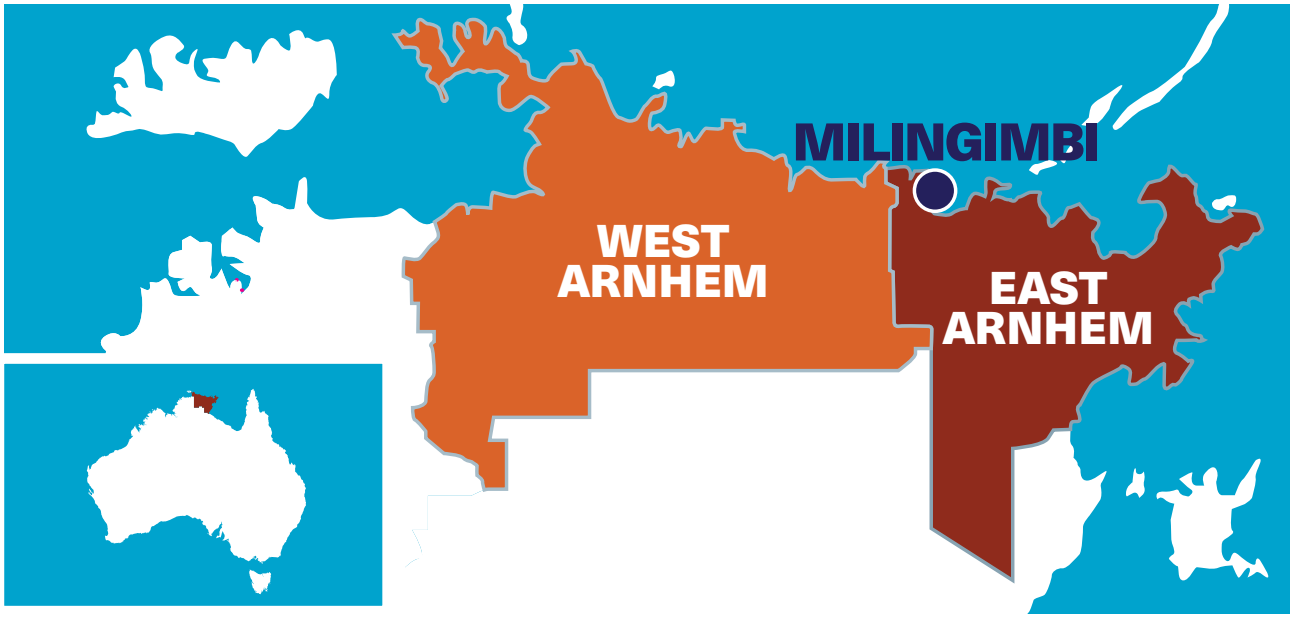


Figure A.2.2 Location of Milimgimbi (Source: Figure A.1. Location of Maningrida (Source https://ecant.org.au/the-facts)

Milingimbi is a low-lying island, 7km long and 4km wide, consisting of sandy beaches, coastal flats and mangrove lined shores, with extensive salt flats extending out from the tidal creeks. These salt flats flood during the wet season, king tides and during storm surges. There is some savannah woodland in the centre of the island, surrounding the airstrip. The Bureau of Meteorology weather station at Milingimbi is 4m above MSL, whilst the highest point is the airport at 15m MSL[8]. Milingimbi is reliant on ground water sourced from a shallow aquifer beneath the airport. These limited water supplies have restricted the extent of housing and other development that has occurred on the island to date[9].

The region experiences a wet-dry tropics environment. Non-Indigenous people recognize two or three seasons: the wet season (November-May), dry season (June-October) and the humid "buildup" (October-November). In contrast, Yolgnu seasonal definitions are complex and highly localized; in the Crocodile Islands region, people recognize three types of seasons. Monsoon seasons (defined by the direction of the prevailing winds), six 'meteorological' seasons (defined by wind, rain, temperature), and three 'ecological seasons'. These seasons may occur multiple times a year, and in any order[10]. Average annual rainfall on Milingimbi is 1187mm[11].

Services and facilities in Milingimbi include Police, Health, School, East Arnhem Regional Council, commercial accommodation (Rulku Lodge), community store, Milingimbi & Outstations Progress Resources Aboriginal Corporation (includes Crocodile Rangers), Credit Union, Post Office, and the Milingimbi Art and Cultural Centre. All fuel must be brought into the community, including that required to run the generators at the power station. Additionally, there is a small 435kW solar farm[12]. Roads on the island are mostly sealed and accessible year round.

According to the 2021 Census, the population of Milingimbi (SA1 level) is 1288, of whom 96% are Indigenous. However, the population is highly mobile, with people often travelling to neighbouring islands including Galiwinku to access other services and/or to fulfil traditional cultural obligations.

As noted above, the vast majority of residents in and around Milingimbi are Indigenous. Traditional ownership is complex, as many people have moved from ancestral estates into the town area. The island has four ancestral estates, but over 21 clan groups inhabiting the island[13]. The main language is Yolngu Matha; although Gapupuyngu and English are also spoken the latter is often the 2nd or 3rd language for many people. This has implications in terms of communication regarding disaster waste and emergency management more broadly; such communications need to be in English and language.

Risk identification:

Hazards previously identified in the Local Emergency Plan for the Ramingining district (which includes Milingimbi) include cyclones, flooding, fire, air and road crashes, with the former two most likely. Tropical Cyclone Lam (2015) impacted Milingimbi through power outages and tree damage to buildings, however apart from power outages, Milingimbi was largely unaffected by Tropical Cyclone Nathan (2015)[14].

In the course of fieldwork other risks were identified by interviewees. The first is that during king tides the salt pan adjacent to the community floods and water comes up over the road, sometimes reaching the level of vehicle hub caps. This type of flooding has only started occurring in the last 12-18 months. The water stays on the road for a day or so, but does not yet restrict vehicle access to the adjacent houses. These houses are on the slope of the ridge that runs along the beachfront so they are not yet being flooded, but if a king tide coincided with a storm surge/cyclonic event, then it is likely that some infrastructure, including housing, would be inundated.

The precarious nature of the power supply (i.e. grid currently running right at capacity) was also raised during discussions. A sustained outage would generate large amounts of putrescibles (food) waste both from residents as well as the community store.

The research team was also advised that while newer construction on the island is compliant with the building code and thus provides appropriate shelter during cyclones, there are still some older raised houses around which contain asbestos. This presents a potential hazard during clean-up.

Interviewees also referred to a previous incident in which a fire broke out in a shed. Toxic fumes from the blaze meant that one of the Camps had to be evacuated.

Marine oil spills were not identified by interviewees as a

[8]Retrieved from: **http://www.bom.gov.au/climate/averages/tables/cw_014404.shtml**
[9]See Gibson, J. (2019, 10 Novermber 2019). Milingimbi water concerns stall future developments in Arnhem Land. ABC News. **https://www.abc.net.au/news/2019-11-10/milingimbi-water-shortage-concerns-in-arnhem-land/11686470**
[10]See Hatfield-Dodds, Z. (2016). Integrating Understanding of a Yolngu Seasonal Calendar: A cross-disciplinary exploration of Scientific and Indigenous Seasonal Knowledge in North East Arnhem Land, Australia (pp.15-23).
[11]Retrieved from: **http://www.bom.gov.au/climate/averages/tables/cw_014404.shtml**
[12]Retrieved from: **https://pv-map.apvi.org.au/power-stations**
[13]See Commonwealth of Australia (2010). *Local Implementation Plan Milingimbi.* Retrieved from **milingimbi_sept2011.pdf** (dss.gov.au)
[14]See Northern Territory Emergency Services. 2023. *Ramingining Local Emergency Plan v9.0*

potential risk, nor are they identified in the existing Local Emergency Management plan, however this potential hazard is included in the LEMP for Maningrida, so it should also be included in the Ramingining LEMP.

Processes in place

The capacity of the Milingimbi community to respond to disasters has been enhanced recently with the establishment of a permanent police presence on the island. Prior to this, it was Local Government staff who bore the first responder responsibility for incidents on the island.

Further details regarding emergency procedures, roles and responsibilities in relation to cyclones, are provided in the Local Emergency Management Plan (LEMP) for Ramingining. Regarding waste related issues, responsibility for clearing roads, coordinating inspections of damage to public buildings, and waste management are the responsibility of EARC. EARC and CDP share responsibility for community clean-up according to the LEMP. PAWA are responsible for restoring power and water, with ALPA ensuring there is drinking water available for the community in the interim.

Appendix D of the old 2020/2021 LEMP for Ramingining included a list of the communications, firefighting, medical, transport, plant, fuel, accommodation and food resources available from various organisations on the island.

This included equipment necessary to deal with disaster waste such as trucks, backhoe, frontend loader, and so on[15]. This resource list/register appears to be absent from the latest version of the *Local Emergency Plan for Ramingining* but should be reinstated in the next version.

The Local Emergency Plan for Ramingining identifies three emergency shelters on Milingimbi: a 300 person capacity cyclone shelter at the airport, the education centre which has capacity for 200 people, and Sport and Recreation Hall (staging area) with capacity for 100 people. EARC also has a list of strong homes in Milingimbi.

Regarding the capacity/capability to address disaster waste, it should be noted that there is no mulcher on Milingimbi; fallen trees are burnt.

EARC provides a hard rubbish collection service provided prior to the beginning of the wet season and at the end of the Wet season, in addition to the BAU household waste collection service, Cash-for-cans, and Mobile Muster.

Crocodile Rangers have capacity and capability, having played a role in patching roofs and clearing fallen trees in the aftermath of Cyclone Lam.

Challenges for managing waste from disasters

Challenges include but are not necessarily limited to:

- Lack of a dedicated disaster waste management plan.
- Lack of accommodation, which affects staff retention and recruitment. This also affects ability of external organisations to come and provide services and assistance both in BAU times, as well as in the aftermath of a disaster.
- Lack of staff, staff recruitment and retention, is an ongoing challenge both in terms of having the actual available staff to do the work in BAU times, let alone disasters, as well as maintenance of corporate knowledge regarding previous disasters, processes, and procedures. This was an issue across multiple organisations to the point where it is nearly impossible to hold stakeholder (inter-organisation) meetings because the lack of staff means that each organisation has to close their doors for the duration of these meetings.
- Lack of local decision-making authority and structural organizational issues which have unintentionally impeded collaboration, and instead created a silo approach regarding service delivery within organisations.
- Systematic structural issues negatively impacting upon relationships between organisations and hindering a more collaborative approach.
- Limited local (residents) capacity and willingness to work, combined with a lack of strong local leadership, which has stemmed from people feeling disempowered for a long period of time.
- Current local community attitudes towards rubbish/ waste in general.
- Access to the island is only by air or sea. Realistically, barge is the only form of transport able to remove large amounts of waste from the community.
- Anecdotally, one resident indicated that they thought that the emergency shelter at the airport is too far from town for people to get to if they don't have a car.

[15]See Ramingining Local Emergency Plan 2020/21.

Figure A.3 Aerial view of Ramingining

A.3. Ramingining

Except where otherwise noted, information in this profile has been drawn from the Bushtel entry for Ramingining, the *Local Emergency Plan for Ramingining v9.0,* and interviews with study participants.

Context and environment:

Located in Central Arnhem land, Ramingining is about 30km inland, 580kms east of Darwin via the Arnhem Highway and Maningrida Access Road, and 435km west of Nhulunbuy by road. Alternative road access is via Katherine and Beswick on the Central Arnhem Highway-Ramingining Road. These roads are unsealed and become impassable for extended periods of time owing to flooding and boggy conditions in the wet season.

The Ramingining airstrip is sealed and located about 3.7km from the community via sealed roads. The vast majority of supplies for Ramingining (including groceries) are brought by barge from Darwin and offloaded at the barge landing, located about 29km from the community, via an unsealed road, which can also become boggy and flooded during the wet season. A minimum tide of 2.2m above sea level is required in order to be able to access the barge landing.

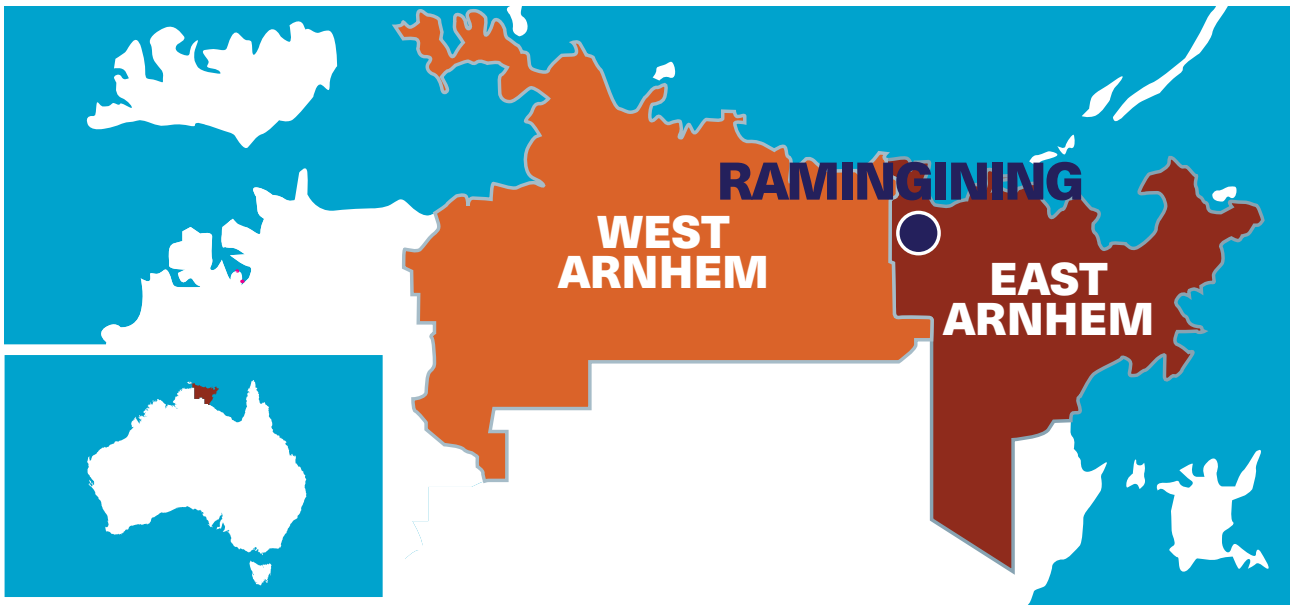


Figure A.3.2 Location of Ramingining (Source: https://ecant.org.au/the-facts)

The area encompassed by the *Local Emergency Plan for Ramingining v9.0* ranges from the sandy beaches, coastal flats and mangrove lined shores, to floodplains extending out from rivers and creeks, to the savannah woodland and northern edge of the Arnhem land escarpment. Just to the east of Ramingining lies Arafura Swamp, an extensive inland freshwater swamp. The Ramingining airstrip is 66m asl[16], while the community is around 30m asl[17].

The region experiences a wet-dry tropics environment. Non-Indigenous people recognize two or three seasons: wet season (November-May), dry season (June-October) and the humid "buildup" (October-November). In contrast, Yolgnu seasonal definitions are complex and highly localized; in the Crocodile Islands region just to the north of Ramingining, people recognize three types of seasons. Monsoon seasons (defined by the direction of the prevailing winds), six 'meteorological' seasons (defined by wind, rain, temperature), and three 'ecological seasons'. These seasons may occur multiple times a year, and in any order[18]. Mean annual rainfall for Ramingining is around 1185mm[19].

Services and facilities in Ramingining include Police, Health, School, East Arnhem Regional Council, commercial accommodation, community store, Arafura Swamp Rangers Aboriginal Corporation, Bula Bula Art Centre, Credit Union, Post Office, and Ramingining Mechanic, among others. All fuel must be brought into the community, including that required to run the generators at the hybrid solar PV-diesel generation power station[20], located about 6km along the road to the barge landing. Roads within the community are sealed and accessible year round but the road to the local tip and barge landing is an unsealed gravel road that can be subject to flooding in the wet season.

According to the 2021 Census, the population of Ramingining (SA1 level) is 956, of whom 93% are Indigenous. Additionally, there are 11 outstations that 'belong' to Ramingining. However, these populations are highly mobile, depending on the season. Occupancy of the outstations ranges from six to 100 people[21].

As noted above, the vast majority of residents in and around Ramingining are Indigenous. The main language is Yolgnu Matha (Djambarrpuyngu) with another two main languages spoken, Dhuwala and Dhay'yi. In total there are 14 languages spoken across thirteen clan groups including English[22]. However English is often the 2nd or 3rd or 4th language for many people. This has implications in terms of communication regarding disaster waste and emergency management more broadly; such communications need to be in English and language.

Risk identification:

Hazards previously identified in the Local Emergency Plan for the Ramingining district include cyclones, flooding, fire, air and road crashes, with the former two most likely. Tropical Cyclone Lam (2015) impacted Ramingining through power outages and tree damage to buildings[23]. The old 2020/21 *Ramingining Local Emergency Plan* noted that falling trees are no longer considered a significant issue for the community as there are few remaining after this Cyclone.

In addition to cyclones, storms, floods and fires, risks identified by interviewees in the course of fieldwork included the community's reliance on the barge; if the barge can't land (or if the road access to the barge landing is cut off) it directly impacts food security for the community. One interviewee expressed the view that the barge access road needs to be raised to mitigate against flooding (the road travels across a floodplain) because if it was cut off, the community would be dependent upon airdrops for food.

One interviewee made the observation that although the risk from Covid-19 was well managed in the community, it could very easily have been a catastrophe if the number of deaths had been in the order of 20 or more a day. Currently there is one refrigerated container for body storage in Ramingining (which wasn't working at the time of our visit), with the next nearest location the four-bed morgue on Galiwinku.

Marine oil spills were not identified by interviewees as a potential risk, nor are they identified in the existing Local Emergency Management plan, however this potential hazard is included in the LEMP for Maningrida, so it should probably also be included in the Ramingining LEMP.

Processes in place

Details regarding emergency procedures, roles, and responsibilities in relation to cyclones, flooding, fire, air and road crashes are provided in the *Local Emergency Management Plan for Ramingining v9.0.* At least 17 different agencies/organisations are identified as having responsibility for various emergency response and recovery functions (Annex B of the LEMP for Ramingining). In practice, one interviewee told us that the community response is essentially limited to the Police, EARC, Health (the Clinic) and PAWA. Another

[16]Retrieved from: https://www.airservicesaustralia.com/aip/current/ersa/FAC_YRNG_30NOV2023.pdf
[17]Retrieved from: https://en-gb.topographic-map.com/map-fsl7kl/Ramingining/?center=-12.32868%2C134.93554&zoom=15&popup=-12.32868%2C134.92981
[18]See Hatfield-Dodds, Z. (2016). Integrating Understanding of a Yolngu Seasonal Calendar: A cross-disciplinary exploration of Scientific and Indigenous Seasonal Knowledge in North East Arnhem Land, Australia (pp.15-23).
[19]Retrieved from: https://www.eldersweather.com.au/climate-history/nt/ramingining
[20]Retrieved from: https://arena.gov.au/assets/2018/12/nt-setup-a-first-look-at-the-integration-of-pv-diesel-power-stations-remote-communities.pdf
[21]Retrieved from: https://east-arnhem.squarespace.com/ramingining-detailed
[22]Retrieved from: https://east-arnhem.squarespace.com/ramingining-detailed
[23]See Ramingining Local Emergency Plan 2020/21 available at https://pfes.nt.gov.au/sites/default/files/uploads/files/2020/Ramingining%20Local%20Emergency%20Plan%20with%20changes_Redacted.pdf

interviewee told us that responders to a recent fire were EARC, Police and the Rangers.

Regarding waste related issues, responsibility for clearing roads, and waste management are the responsibility of EARC. EARC and Delta Reef share responsibility for coordinating inspections of damage to public buildings, while EARC and CDP share responsibility for community clean-up according to the LEMP. PAWA are responsible for restoring power and water, with ALPA ensuring there is drinking water available for the community in the interim. One interviewee said that EARC were essentially the first responders.

Appendix D of the old 2020/2021 LEMP for Ramingining included a list of the communications, firefighting, medical, transport, plant, fuel, accommodation and food resources available from various organisations in the community. This included equipment necessary to deal with disaster waste such as chainsaws, trucks, Bobcat, frontend loader, and so on[24]. This resource list/register appears to be absent from the latest version of the *Local Emergency Plan for Ramingining v9.0* and should be reinstated in the next version.

Regarding firefighting capabilities, one group of interviewees told us that there is no volunteer firefighting organisation in Ramingining and that appliances are limited to EARC's little fire tank on a trailer and a similar one owned by the Police.

The current Local Emergency Plan for Ramingining identifies one emergency shelter in the community, which has a 570-person capacity.

Regarding the capacity and capability to address disaster waste, interviews in the community suggest that it is largely restricted to EARC, and the Ramingining Rangers, although the extent of collaboration between the two organisations was said to vary from time to time.

EARC provides a hard rubbish collection service provided prior to the beginning of the wet season and at the end of the Wet season, in addition to the BAU household waste collection service, Cash-for-cans, Cash-for-containers, and Mobile Muster. Health waste goes out by barge. One interviewee said that there was more waste produced in the Dry season when road access for trucks was possible, bringing in more goods, compared to the Wet season.

Challenges for managing waste from disasters

Challenges include but are not necessarily limited to:

- Lack of a dedicated disaster waste management plan.
- Virtually no capacity for temporary storage at the existing landfill and no temporary sites have been identified.
- Lack of staff, staff recruitment and retention, is an ongoing challenge both in terms of having the actual available staff to do the work in BAU times, let alone disasters, as well as maintenance of corporate knowledge regarding previous disasters, processes and procedures. At the time we undertook fieldwork (September 2023) EARC staff were dealing with a backlog of waste-related issues as they had not had a full complement of staff in Ramingining for several months.
- Old cars were identified as a challenge, in relation to the paperwork that is required before they can be removed. Buried cars were also identified as a challenge.
- Unknown if there is asbestos in the existing landfill or elsewhere in the community and surrounds.
- Priorities before the next cyclone include securing the loose steel at the tip and improving public awareness.
- Restricted access to the community. Access during the wet season is limited to air and sea. Realistically, barge is the only form of transport able to remove large amounts of waste from the community. During the Dry season road access is possible but requires 4WD. We saw single trucks on the Oenpelli-Maningrida road between Gunbalunya and Ramingining, but this road is not suitable for road trains. Smaller trucks may be a potential option for removing non-urgent waste that cannot be put into landfill and that does not need to urgently removed, but weight restrictions and physical road conditions will remain challenging.
- One interviewee expressed the view that in the event that Ramingining had to be evacuated, it would require the Army to assist, as there are simply not enough vehicles and no public transport available to transport people out of town.

[24]See See Ramingining Local Emergency Plan 2020/21 available at https://pfes.nt.gov.au/sites/default/files/uploads/files/2020/Ramingining%20Local%20Emergency%20Plan%20with%20changes_Redacted.pdf

Summary of types of waste to be expected from natural disasters in the three remote communities of Maningrida, Milingimbi and Raminging

Table A.1 Types of waste generated according to hazard type (Adapted from Brown, 2011)

Hazard Type	Types of Waste generated (modified after Brown et al 2011)	
	Hazardous	**Non-hazardous**
Cyclone	Asbestos, electronic & white goods;	Fallen trees, branches.
	Household waste (e.g. refrigerants, oils, pesticides, paints etc)	Roof and structural damage (e.g. roof sheeting, masonry, concrete & cement, bars, wood & timber, steel, clay, reinforced concrete brick, structural components),
	Industrial & toxic chemicals (including fuels)	Foundation materials/debris from road damage
	Putrescible wastes (eg rotting food)	Pre-disaster waste from landfill
	Healthcare wastes	Recyclables (plastics & metals)
	Human & animal corpses;	Household waste (other than electronic, white goods, food waste)
	Cars/vehicles, Vessels	Emergency food & water packaging
	Pre-disaster waste from landfill & other sites	
Flooding/storm surge of salt pan		
To floor level	Pre-disaster waste from landfill & other sites	Flooring materials
Above floor level	Electronic & whitegoods	household waste (other than electronic, white goods, food waste)
	Putrescible wastes (eg rotting food)	
Fire		
Bushfire	Industrial & toxic chemicals (including fuels)	Fallen trees, branches
	Human & animal corpses	Construction and demolition waste
Structural fire	Asbestos, electronic & white goods	
	Household waste (e.g. refrigerants, oils, pesticides, paints etc)	
	Cars/vehicles	
Sustained power outage	Putrescible wastes (eg rotting food)	

Appendix B: List of organizations invited for interviews

National
National Emergency Management, Resilience and Recovery Agency (NEMRRA)

Northern Territory Government
Dept of Environment, Parks and Water Security
Department of the Chief Minister and Cabinet
Fire and Rescue Service
Emergency Services
Department of Health
Department of Education
Department of Territory Families, Housing and Communities
Department of Infrastructure, Planning and Logistics
Department of Industry, Tourism and Trade

Local Governments
East Arnhem Regional Council
West Arnhem Regional Council
Roper Gulf Regional Council
Coomalie Regional Council
Vic Daly Regional Council
Local Government Australia NT

Non-Government organizations
ALPA
NorthLine
Indigenous construction company
Ranger groups
Red Cross

Appendix C: Interview questions for Australian and Northern Territory government

Part A. About your organisation

1. What is the name of your organisation?
2. What is your position or job title in your organisation and how long have you been in this role?
3. What service do you provide in the community? (brief description of main activities/services provided)
4. Where is the head office of your organisation located and are there branches in other communities?

Part B. Disaster planning/preparedness: organisation and community (current situation)

5a. What sort of disasters do you have in East Arnhem region/community?

- Floods
- Cyclones
- Storms
- Earthquakes
- Tsunamis

5b. What sort of impact do you think those disasters will have on generating waste?

6. Does your organisation have a disaster/risk management plan for this time, and does it include dealing with waste?
   - Yes
   - No
   - Don't know
7. Are existing plans updated? Who is responsible for this and who is responsible for making sure everyone knows about it and what their role is?
8. What steps does your organisation take to prepare for disasters? (e.g. regular clean-ups, controlled burns)
9. Are there any pre-arrangements in place to facilitate regular mitigative clean-ups? (eg at start of cyclone season, start of bushfire season) (if yes, please describe)
   - Yes
   - No
   - Don't know

   Any details:
10. Are there any pre-arrangements in place to come and help clean-up after a disaster? (e.g. with contractors to come and collect the waste)
    - Yes
    - No
    - Don't know

    Any details:
11. Do you know what to do with/what happens to your organisation's waste/rubbish after a disaster? *(i.e. someone comes and collects it; has to be put in bags out on the verge; is it different for different types of rubbish?)*

12a. Is there a disaster/emergency management plan in place for your community? Does it include waste, or is there a separate disaster waste management plan?

- Yes
- No
- Don't know

13b. If there is no disaster waste management plan, why do you think this might be? (e.g. not got around to it, not thought about it before, not a high priority)

14. Is there information in your organization on about what to do in a disaster/emergency? Where is the information about what to do with the waste before and after a disaster? Is it in English or language? *(i.e. how accessible is it eg online only, pinned up in council offices, etc)*
15. Is your organisation included in the disaster management plan/s and/or disaster waste management plan for the community?
16. If you answered 'yes' to qu. 21 above, what roles/responsibilities does your organisation have in that plan? Does it involve dealing with waste? *(if yes, ask if we can have a copy of that doc)*

Part C. Lessons learnt: what happened in previous disasters?

Thinking about previous disasters in your region/community:

17. What previous disasters have there been in the community? When?
18. Did your organisation help in previous clean-ups? If so, why? *(eg no one else around to do it, had a role specified in a disaster/risk management plan)* If not, why not? *(E.g worried about lack of protective gear, hazardous material, was told not to help by other people, organisational policy?)*
19. What role did your organisation do play? *(eg, provided people to help out, provided equipment/machinery, transport etc)*
20. What sort of waste/rubbish was there? (e.g. household rubbish, roofing materials, timber, trees/vegetation etc)

21. After the disaster(s) what happened to the rubbish? i.e where did it go? Was anything salvaged, kept/ re-used?

22. How long did it take to clean-up? How did this impact the community and getting back to normal?

23. To the best of your knowledge/estimation, what did it cost to clean-up (cost to your organisation, cost for community as a whole)?

24. To what extent did previous clean-ups follow a plan? To what extent did they deviate from a plan, and if so why? If a more ad hoc approach adopted was this perceived to be more or less successful than following an existing plan.

25. Who from outside the organisation/community came to help after the last disaster, how long before they arrived, what did they do when they got here and what did your organisation/ community do in the meantime? Who took charge?

26. Did your organisation provide any physical assistance/support for the community in previous disasters and how long did your organisation provide this support for? (e.g. school was used as an evacuation centre for 2 days, or provided temporary accommodation for residents for 3 months)

27. If you answered yes to the question above, what sort of waste/rubbish was created in the evacuation centres? How much, and what happened to it? How was it disposed of initially, and where did it end up eventually? (e.g. lots of plastic water bottles, disposed of in boxes and later taken to the tip.)

28. Did your organisation/the community change how you thought about rubbish/waste and what your organisation would do before the next cyclone/ bushfire/big storm?

29. From an organisational perspective, how do you think previous disasters have been managed generally?

30. Do you think that your organisation's resources, people and their skills/expertise were properly utilised during the last disaster? *(e.g. offered to provide shelter but offer not taken up; had staff with relevant qualifications e.g. use of chain saws, but not asked/allowed to help)*

Part D. Thinking and planning for the future

31. What facilities or areas are available to store waste in the aftermath of a disaster, and did you have access to them?

32. What alternatives are there for storing the different types of waste? *(for example hazardous vs potentially re-useable?)*

33. Are there particular areas/places around the community that should not be used for temporary waste storage/management after a disaster? *(note these areas should be identified on the bushtel plans of these communities, so perhaps just take a copy of these plans and ask if the areas accurately reflect no-go zones/"cultural exclusion zones"?)*

34. What kinds of spaces or objects that might need special consideration during disasters? *(For example sacred spaces)*

35b. Are there any places that will generate dangerous waste? (for example fuel station, health clinic?)

36. During the clean-up, would you like to see stuff being recycled/re-used if it can be done safely, or do you think it should all be taken away?

37. What do you think is important in your community, in terms of emergency management?

38. What role do you think the local community should be play in terms of disaster/emergency management? Are there some kinds of disasters where it would be better if the local community had more say or took the lead on?

39. Again, from an organisational perspective, do you think that your organisation could play a greater and/or additional and/or different role in managing disasters and waste? (i.e. how could the organisation help in the planning, during and/ or in the clean-up afterwards? For example, utilise ranger groups to remove trees from across roads).

40. Can you think of any organisations, or other particular groups or people that could be helpful in managing the rubbish/waste, either helping to clean up beforehand, helping out afterwards, sorting non-hazardous rubbish afterwards etc? If so, why/how do you think they'd be helpful?

41. Which organisations/s do you think are best placed to lead/manage disasters and disaster waste clean-ups? (and why?)

42. Which organisations do you think should help during and after disasters to manage the waste, and why?

43. What changes would you make to improve things in terms of disaster and waste management? (e.g. better communications, procedures in place etc)

44. Do you have anything else you'd like to say regarding getting ready for disasters and/or managing the rubbish/waste?

Thank you, that is the end of the survey. Would you like to be kept up to date and hear about the results of the project? If so, what's the best way to update/contact you?

Appendix D: Interview questions for Local Government

Part A. About your organisation

1. What is the name of your organisation?
2. What is your position or job title in your organisation and how long have you been in this role?
3. What does your organisation do? *(brief description of main activities/services provided)*
4. Where is the head office of your organisation located and are there branches in other communities?

Part B. Waste/rubbish generated by your organisation and the work/services that it does in the community

5. What types of waste (rubbish) is generated in the community (e.g. food waste, medical waste, construction waste, office waste, hazardous waste)?
   - Medical waste
   - Oil
   - Paints
   - Paper & cardboard
   - Construction related
   - Metal
   - Office supplies: printer, cartridges
   - E- waste
   - Tyres
   - Cars

6 . How many times is the rubbish bin collected in a week?

7. Does the volume vary with season? For example, is it more during cyclone season? *(If 'maybe' or 'yes' response, elicit further details i.e. what types of waste, amounts and why)*

Part C. Organization's current Waste Management

8. Is the community satisfied with waste pickup by the council?
9. What types of waste does the community drop off at the landfill? (if yes, what types of waste would you drop off?)

9b. Is there a drop off bay at the landfill?

What is sorted and stockpiled at the landfill?

10. What is the biggest waste issue for your organisation and why?
11. What is the biggest waste issue for the community and why?

Part D. Disaster planning/preparedness: organisation and community (current situation)

12a. What sort of disasters do you have in this region/ community?
   - Floods
   - Cyclones
   - Storms
   - Earthquakes
   - Tsunamis

12b. What sort of impact do you think these disasters will have on generating waste?

13. Does your organisation have a disaster/risk management plan, and does it include dealing with waste?
   - Yes
   - No
   - Don't know

14. Are existing plans updated? Who is responsible for this and who is responsible for making sure everyone knows about it and what their role is?
15. What steps does your organisation take to prepare for disasters? (e.g. regular clean-ups, controlled burns)
16. Are there any pre-arrangements in place to facilitate regular mitigative clean-ups? (eg at start of cyclone season, start of bushfire season) (if yes, please describe)
   - Yes
   - No
   - Don't know

17. Are there any pre-arrangements in place to come and help clean-up after a disaster? (e.g. with contractors to come and collect the waste)
   - Yes
   - No
   - Don't know

18. Do you know what to do with/what happens to the waste/rubbish in the landfill after a disaster?

19a. Is there a disaster/emergency management plan in place for the community? Does it include waste, or is there a separate disaster waste management plan?
   - Yes
   - No
   - Don't know

19b. If there is no disaster waste management plan, why do you think this might be? (e.g. not got around to it, not thought about it before, not a high priority)

20. Where in the community is information about what to do in a disaster/emergency? Where is the information about what to do with the waste before and after a disaster? Is it in English or language? *(i.e. how accessible is it eg online only, pinned up in council offices, etc)*

21. Is your organisation included in the disaster management plan/s and/or disaster waste management plan for the community?

    [skip logic question: if No/DK-U, proceed to question 23]

22. If you answered 'yes' to qu. 21 above, what roles/ responsibilities does your organisation have in that plan? Does it involve dealing with waste? (if yes, ask if we can have a copy of that doc)

Part E. Lessons learnt: what happened in previous disasters?

Thinking about previous disasters in your region/ community:

23. What previous disasters have there been in the community? When? Were you here at the time?

24. What sort of waste/rubbish was generated? (e.g. household rubbish, roofing materials, timber, trees/vegetation etc)

25. After the disaster(s) what happened to the rubbish? i.e where did it go? Was anything salvaged, kept/ re-used?

26. How long did it take to clean-up? How did this impact the community and getting back to normal?

27. To the best of your knowledge/estimation, what did it cost to clean-up (cost to your organisation, cost for community as a whole)?

28. Did your organisation help in previous clean-ups? If so, why? *(eg no one else around to do it, had a role specified in a disaster/risk management plan)* If not, why not? *(E.g worried about lack of protective gear, hazardous material, was told not to help by other people, organisational policy?)*

29. What role did your organisation do play? *(eg, provided people to help out, provided equipment/machinery, transport etc)*

30. To what extent did previous clean-ups follow a plan? To what extent did they deviate from a plan, and if so why? If a more ad hoc approach adopted was this perceived to be more or less successful than following an existing plan.

31. Who from outside the organisation/community came to help after the last disaster, how long before they arrived, what did they do when they got here and what did your organisation/ community do in the meantime? Who took charge?

32. Did your organisation provide any physical assistance/support for the community in previous disasters and how long did your organisation provide this support for? (e.g. school was used as an evacuation centre for 2 days, or provided temporary accommodation for residents for 3 months)

33. If you answered yes to the question above, what sort of waste/rubbish was created in the evacuation centres? How much, and what happened to it? How was it disposed of initially, and where did it end up eventually? (e.g. lots of plastic water bottles, disposed of in boxes and later taken to the tip.)

34. Did your organisation/the community change how you thought about rubbish/waste and what your organisation would do before the next cyclone/ bushfire/big storm?

35. From an organisational perspective, how do you think previous disasters have been managed generally?

36. Do you think that your organisation's resources, people and their skills/expertise were properly utilised during the last disaster? *(e.g. offered to provide shelter but offer not taken up; had staff with relevant qualifications e.g. use of chain saws, but not asked/allowed to help)*

Part F. Thinking and planning for the future

37. What facilities or areas are available to store waste in the aftermath of a disaster, and did you have access to them?

38. What alternatives are there for storing the different types of waste? *(for example hazardous vs potentially re-useable?)*

39. Are there particular areas/places around the community that should not be used for temporary waste storage/management after a disaster? *(note these areas should be identified on the bushtel plans of these communities, so perhaps just take a copy of these plans and ask if the areas accurately reflect no-go zones/"cultural exclusion zones"?)*

40. What kinds of spaces or objects that might need special consideration during disasters? (For example sacred spaces)

40b. Are there any places that will generate dangerous waste? (for example fuel station, health clinic?)

41. During the clean-up, would you like to see stuff being recycled/re-used if it can be done safely, or do you think it should all be taken away?

42. What do you think is important in your community, in terms of emergency management?

43. What role do you think the local community should be play in terms of disaster/emergency management? Are there some kinds of disasters where it would be better if the local community had more say or took the lead on?

44. Again, from an organisational perspective, do you think that your organisation could play a greater and/or additional and/or different role in managing disasters and waste? (i.e. how could the organisation help in the planning, during and/or in the clean-up afterwards? For example, utilise ranger groups to remove trees from across roads).

45. Can you think of any organisations, or other particular groups or people that could be helpful in managing the rubbish/waste, either helping to clean up beforehand, helping out afterwards, sorting non-hazardous rubbish afterwards etc? If so, why/how do you think they'd be helpful?

46. Which organisations/s do you think are best placed to lead/manage disasters and disaster waste clean-ups? (and why?)

47. Which organisations do you think should help during and after disasters to manage the waste, and why?

48. What changes would you make to improve things in terms of disaster and waste management? (e.g. better communications, procedures in place etc)

And finally,

49. Do you have anything else you'd like to say regarding getting ready for disasters and/or managing the rubbish/waste?

Appendix E: List of Interview questions posed to focus groups held in the 3 remote communities

These formed the basis for group discussion and information gathering.

- What would be an appropriate word to use- waste/ debris/ rubbish?
- What happens when a cyclone comes?
- How much rubbish is there before and after a cyclone?
- Process of cleaning up
- Things that can help with managing waste from cyclones

Appendix F: Survey questions for residents from selected communities

- Which community do you live in?
- What is your age group?
- What is your gender?
- How should we deal with waste after a disaster like a big cyclone?
- Who do you think should deal with waste when there is a big disaster like a cyclone?
- Are you satisfied with the cleanup after the cyclone if No, please explain why you are not satisfied so we can do better.
- Is there any hope for sorting or recycling some of the waste in the community?
- How do you think we can get the community more involved in cleanup after disasters?

Appendix G: Sample Community Disaster waste checklist

Community Disaster Waste Checklist

Disaster waste management plan

Is there a DWM plan?	
Summary of key DWM contents	

Participant organization	List of responsibilities	Name	Contact	Additional info

Personnel	Organization	Name of person responsible for	Contact	Available for this event
Landfill management	e.g. Local Council			
Landfill equipment				
Weekly bin collection				
Evacuation Centre				
Volunteers				

Equipment	Organization responsible	Location	Fuelled and ready	Available for this event
Trucks				
Loader				
Grader				
Chainsaws				
Tree mulcher				
Compacter				
Radio				
Generators				
Fuel				
Pumps				
Fire Tenders (slip ons)				
Gloves, boots, masks				
PPE				
Rubbish bags, gloves, cleaning supplies				

Pre-disaster cleanup	Completed Y/N	Additional info		
Public Spaces				
Roads				
Private yards				
Outside the Shop				
School yards				
Cyclone Shelter				
Outside the Clinic				
Outside the Art centre				

Waste management Facility	Temporary Space allocation for waste streams Y/N	Possible waste estimates forecasted based on previous events (tonnes/cu. M/number)		
Putrescibles				
Hazardous (asbestos, batteries, tyres, paints, waste oils)				
Whitegoods				
Green waste				
White goods				
Metal				
E-Waste				
Construction and demolition waste				
Paper, cardboard				
Mixed hard waste				

NORTHERN INSTITUTE
People. Policy. Place.

CHARLES DARWIN UNIVERSITY AUSTRALIA

Regional Development Australia

Proudly sponsored by NORTHERN TERRITORY GOVERNMENT