Identification of climate change adaptation
Best Practices in the Waste Management Sector

Disaster Waste Management Best practices

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CONTENTS

PART I

PART II

GLOSSARY

Adaptation
Adjustment or preparation of natural or human systems to a new or changing environment which moderates harm or exploits beneficial opportunities.

Biomass fuels or biofuels
A fuel produced from dry organic matter or combustible oils produced by plants.
These fuels are considered renewable as long as the vegetation producing them is maintained or replanted, such as firewood, alcohol fermented from sugar, and combustible oils extracted from soy beans. Their use in place of fossil fuels cuts greenhouse gas emissions because the plants that are the fuel sources capture carbon dioxide from the atmosphere.

Capacity building
In the context of climate change, the process of developing the technical skills and institutional capability in developing countries and economies in transition to enable them to address effectively the causes and results of climate change.

Climate Change
Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer.
Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Droughts
Period of deficiency of moisture in the soil such that there is inadequate water required for plants, animals, and human beings

Earthquake
A sudden break within the upper layers of the earth, sometimes breaking the surface, resulting in the vibration of the ground.

Erosion
Loosing or dissolving and removal of rock or soil as a result of water, ice or wind action.

Floods
Any high flow, overflow, or inundation by water which causes or threatens damage.

Global warming (GW) - usually: the warming trend over the past century
Any period in which the temperature of the Earth's atmosphere increases; also the theory of such changes.

Greenhouse Gas (GHG)
Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride.

Extreme weather event
An extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density function. By definition, the characteristics of what is called extreme

weather may vary from place to place in an absolute sense. Single extreme events cannot be simply and directly attributed to anthropogenic climate change, as there is always a finite chance the event in question might have occurred naturally.

Heat Waves
A prolonged period of excessive heat, often combined with excessive humidity.

Hurricane
A tropical cyclone in the Atlantic, Caribbean Sea, Gulf of Mexico, or eastern Pacific, which the maximum 1-minute sustained surface wind is 64 knots (74 mph) or greater.

Intergovernmental Panel on climate Change (IPCC)
The IPCC was established jointly by the United Nations Environment Programme and the World Meteorological Organization in 1988. The purpose of the IPCC is to assess information in the scientific and technical literature related to all significant components of the issue of climate change.
With its capacity for reporting on climate change, its consequences, and the viability of adaptation and mitigation measures, the IPCC is also looked to as the official advisory body to the world's governments on the state of the science of the climate change issue.

Inundation
The submergence of land by water, particularly in a coastal setting.

Impact
Impact is defined as the actual process of contact between an event and a society or a society's immediate perimeter; an effect or influence, especially when strong
Impact has a broad connotation and refers to both positive and negative influences produced by events on the environment

Landfill
Land waste disposal site in which waste is generally spread in thin layers, compacted, and covered with a fresh layer of soil each day.

Landslides
The sliding downslope of a mass of land on a mountain or hillside

Mitigation
A human intervention to reduce the human impact on the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.

Municipal Solid Waste (MSW)
Residential solid waste and some non-hazardous commercial, institutional, and industrial wastes. This material is generally sent to municipal landfills for disposal.

Natural disaster
Natural cataclysmic event occuring suddenly and causing extreme suffering, even total destruction, such as cyclones, heat waves, earthquakes, floods,tornadoes, etc.

Planning
The process used to develop contingencies in preparation for an event that is likely to occur at some time. Planning includes warning systems, evacuation, relocation of dwellings (e.g., for floods), stores of food and water, temporary shelter, energy, management strategies, disaster drills and exercises, etc.

Preparedness
The aggregate of all measures and policies taken by humans before the event; to be prepared for the event.

Relative Sea Level Rise
The increase in ocean water levels at a specific location, taking into account both global sea level rise and local factors, such as local subsidence and uplift. Relative sea level rise is measured with respect to a specified vertical datum relative to the land, which may also be changing elevation over time.

Recovery
Returning the state of an organisms to the state it had before it was temporarily reduced. For disasters this means bringing all of the societal components back to their pre-event functional status (level of function).

Resilience
A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.

Saffir-Simpson Hurricane Scale (SSHWS) or the **Saffir–Simpson hurricane scale** (**SSHS**) for short
The SSHWS classifies hurricanes – Western Hemisphere tropical cyclones that exceed the intensities of tropical depressions and tropical storms – into five categories distinguished by the intensities of their sustained winds.

Saline Intrusion
Displacement of fresh or ground water by the advance of salt water due to its greater density, usually in coastal and estuarine areas.

SIDS : Small Island Developing States.

Storm Surge
An abnormal rise in sea level accompanying a hurricane or other intense storm, whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone.

Tropical Cyclone
A warm-core, non-frontal synoptic-scale cyclone, originating over tropical or subtropical waters with organized deep convection and a closed surface wind circulation about a well-defined center.

Tsunami
An ocean wave, caused not by wind but by an event within the crust, usually a submarine earthquake or volcanic eruption or major landslide. Out at sea, in deep waters, a tsunami travels as fast as a plane but is almost imperceptible —it is no higher than ordinary ocean swell. But as it approaches the shore, it can reach a height of several tens of metres.

Typhoon
A tropical cyclone in the Western Pacific Ocean in which the maximum 1-minute sustained surface wind is 64 knots (74 mph) or greater.

Vulnerability
The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed; its sensitivity; and its adaptive capacity.

EXECUTIVE SUMMARY

Much attention has been drawn towards the impact of climate change on small pacific island communities, which are among the most vulnerable. In these communities, climate change has become a cross sectoral issue including solid waste management. In this sector, the issue becomes even more acute when considering natural disasters since the quantity and diversity of waste generated during such events greatly exceeds the local technical and financial capacity.

The first part of this document seeks to identify Best Practices in terms of adaptation measures in order to minimize the consequences of natural disasters on solid waste management systems based on a review of existing bibliography.

Findings are applied to the concrete case of Labasa Landfill on Vanua Levu Island (Fiji).

In the literature, most authors cite lack of awareness in waste management techniques, unplanned or illegal landfill sites, lack of capacity to handle large amount of waste, inadequate funding and lack of coodination as being the main issues encountered. Conscious that post disaster situations will always remain a challenge, we try to adopt a positive and pro-active approach to disaster adaptation, contrasting with the rather pessimistic statements of most authors.

The study shows that when dealing with pre-disaster adaptation measures, being prepared is crucial in responding to any natural disaster by helping local communities ensuring that storage or staging locations have been sited in acceptable locations or that available landfill capacity is used appropriately.

The second part focuses on providing guidance in regard to post disaster measures so as to alleviate restoration efforts.
The main findings show that debris segregation is the first ‘line of defense’ when seeking recovery as well as protection of human health and the environment. Since segregating debris is best performed at the original deposited point, community involvement becomes an important success factor.

Segregation has repercussions all the way through the waste management process, ranging from separate vehicles for hauling the segregated products, to new opportunities in developing more complex energy-from-waste schemes utilizing the vast amount of vegetative debris.

In both parts, it is demonstrated that adaptation measures often involve more complex schemes requiring additional financial and organisational resources. Therefore, more cooperation between municipalities and States within the Region, as well as cooperation with local industries and businesses will play an important role in the viability of these measures.
Lastly, not all waste can be recycled, and landfilling will remain a key element of post disaster waste management.

Finally, the proposed measures are compared and ranked in a comprehensive matrix, adressing pre- and post-disaster adaptation measures, providing a useful base for further decisions concerning solid waste management in the Region.

1 INTRODUCTION

The Pacific Region is susceptible to natural disasters including flooding, cyclones, earthquakes and tsunamis. Climate change impacts, such as increased intensity and frequency of rainfall and extreme heat, and more intense tropical cyclones will exacerbate the effects of such natural disasters. The predicted effects of these adverse events include increased damage to waste management facilities, and consequently increased risk of environmental contamination and potentially adverse public health impacts.

In this context, Pacific Island Countries stand among the most vulnerable in the world : they combine high exposure to frequent and damaging natural hazards with low capacity to manage the resulting risks.

For instance, the uptake of renewable energy technology such as the use of photovoltaic cells introduces an additional dimension to the waste management problem. Some photovoltaic cells contain heavy metals and hazardous substances such as cadmium and lead, and rely on lead acid batteries for storing energy. Existing waste management facilities are not prepared to treat or dispose of such products.

Therefore, climate change adaptation in the waste management sector must address these new issues to minimize potential negative health and environmental impacts.

The selected project site will be the Labasa town dump, which is located adjacent to a mangrove, near the Labasa River some 2 kilometres from the Labasa town center on the island of Vanua Levu -Fiji.

This area like most of the coastal hinterlands around Labasa is particularly prone to flooding for the following reasons:

- The configuration of a number of embayments on the north coast of Fiji increases the possibility that stormsurge inundation will combine with river flooding;
- Three rivers (Wailevu, Labasa,and Qawa) have their estuaries in the same area;
- These rivers rise in the highest mountains on the island;
- These river basins face the direction from which most cyclones arise.

This report aims at facilitating the descision-making process when seeking the most cost-effective measures in the context of the Pacific Region and more specifically in the context of the Labasa landfill, at the pre-desaster stage (part I) and at the post disaster stage (part II).

PART 1:
IDENTIFICATION OF CLIMATE CHANGE ADAPTATION BEST PRACTICES IN THE WASTE MANAGEMENT SECTOR

1 IDENTIFICATION OF GEOGRAPHIC AREAS AFFECTED BY DESTRUCTIVE EVENTS LINKED TO CLIMATE CHANGE

1.1 Effects of climat change

1.1.1 Effects of climate change in the Pacific Region

Although climate change has always taken place as a natural phenomenon, the increased rate of change we are experiencing now is, for the most part, due to human activities.

As the atmosphere is getting warmer, the general effects resulting from global climate change are, among others, rise of temperatures, shift in rainfall patterns, melting glaciers, rising sea levels and extreme weather resulting in floods and droughts. Direct consequences of climate change can already be seen worldwide, and such consequences are predicted to intensify in the coming decades.
The effects of climate change are even more destructive on small islands due to their characteristics. The main impacts on small islands and the effects on waste facilities are described in the sub-chapters below :

1.1.1.1 SPECIFIC FEATURES OF SMALL ISLANDS

Small islands have features which make them especially vulnerable to the effects of climate change.
Obvious effects such as sea-level rise is likely to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening the vital infrastructure that supports the socio-economic well-being of island communities.

In the Caribbean and Pacific Islands, more than 50% of the population lives within 1.5 km of the shore. Almost without exception, the air and sea ports, major road arteries, communication networks, utilities and other critical infrastructure in the small islands of the Indian and Pacific Oceans and the Caribbean tend to be restricted to coastal locations, vulnerable to sea-level rise. This threat is likely to be amplified by changes in the frequency and strength of tropical cyclones[1].

The specific and predictible impacts on small Pacific islands are summarized as follows :

Region and system at risk[2]	Changed parameters	Impacts and vulnerability
Pacific small islands: Coastal erosion, water resources and human settlement	Changes in temperature and rainfall, and sea-level rise	▪ Accelerated coastal erosion, saline intrusion into freshwater lenses and increased flooding from the sea cause large effects on human settlements. ▪ Less rainfall coupled with accelerated sea-level rise compound the threat on water resources; a 10% reduction in average rainfall by 2050 is likely to correspond to a 20% reduction in the size of the freshwater lens on Tarawa Atoll
American Samoa; 15 other Pacific islands: Mangroves	Projected rise in sea level	▪ 50% loss of mangrove area in American Samoa; 12% reduction in mangrove area in 15 other Pacific islands.

[1] Intergovernmental Panel on Climate Change: http://www.ipcc.ch/publications_and_data/ar4/wg2/en/tssts-4-2-8-small-islands.html#table-ts-2
[2] Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch16s16-4.html

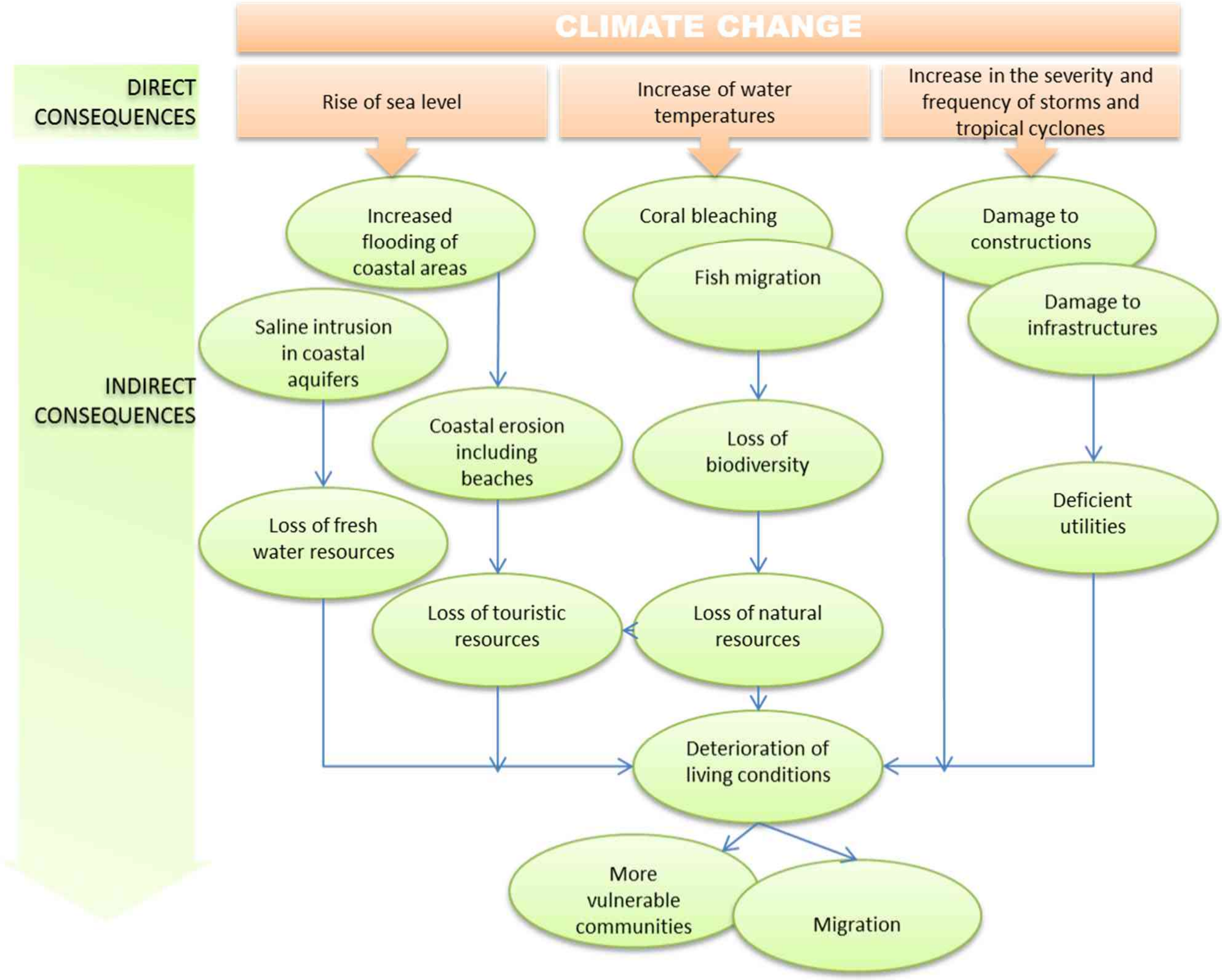


Figure 1 : Direct and indirect consequences of climate change in the Pacific Region (source: Pöyry)

1.1.1.2 DESTRUCTIVE EVENTS LINKED TO CLIMATE CHANGE

Storms and hurricanes are expected to become stronger with climate change and cause more damage to coastal communities, through flooding, erosion, landslides and general damage to infrastructures.

Different waste facilities will be particularly susceptible to different aspects of climate change. However a common set of impacts is likely to be encountered in most waste management facilities :

- Flooding on site and in the surrounding area from surface water, ground water and drainage systems due to increased precipitation;
- Damage or malfunction of weighbridges and gas /leachate production, composition and control system;

- Changes in moisture levels, site hydrology and temperature which could affect waste degradation rates, leachate production and composition;
- Disruption to supporting transport infrastructure hence affecting the delivery of waste due to flooding;
- Increased risk of subsidence and slope instability from drying out of soils followed by rapid wetting due to heavy rainfall;
- Inundation and/or erosion of low lying riverside facilities;
- Increased health risk to workers from increased pathogen and vermin activity of failure of leachate collection system;

1.1.2 Affected geographic areas

Affected areas by the destructive events linked to climate changes are located mainly in the following regions:

1. Atlantic basin including the North Atlantic Ocean, the Gulf of Mexico, and the Caribbean Sea;
2. Eastern Pacific Ocean ;
3. Western North Pacific ;
4. North Indian Ocean ;
5. South-West Indian Ocean;
6. Australian region ;
7. Southern Pacific

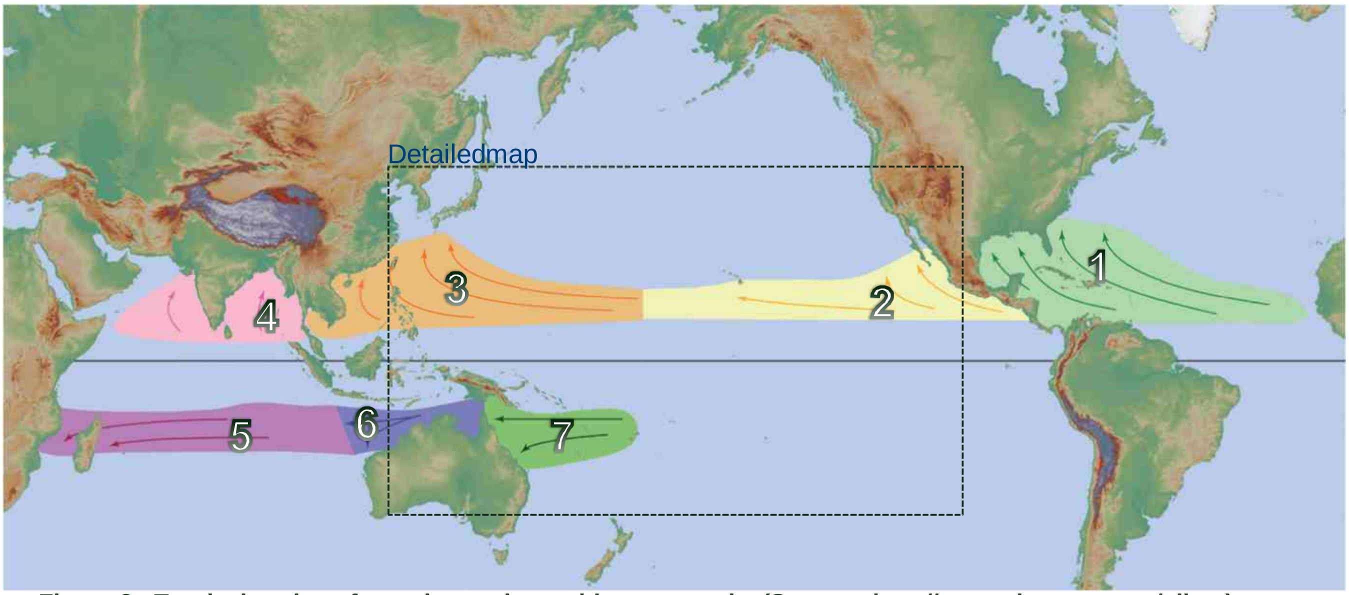


Figure 2 : Tropical cyclone formation regions with mean tracks (Source : http://www.nhc.noaa.gov/climo)

1.1.2.1 HISTORICAL DATA ON PAST EVENTS

Cyclone and typhoon paths in the past ten years and the most affected areas are identified and listed in table 1 below and presented on a map in figure 3.

Only the strongest events i.e. category 5 hurricane on the Saffir-Simpson Hurricane Scale from the last decade in the Pacific Region, are listed. Note that these events may not be the deadliest or the costliest but the strongest according to the Saffir-Simpson Hurricane Scale (SSHS) based on wind speed.

1.1.2.2 AFFECTED COUNTRIES IN THE PACIFIC REGION

The most affected coutries in the Pacific Region are listed below. The list is indicative and shows no order of prevalence. As a result, the statements and conclusions presented in this report are considered most relevant for these countries, although all islands in the Pacific are concerned by high tides and flooding and may eventually be affected by hurricanes.

- Cook Islands
- Tonga
- Vanuatu
- New Caledonia
- Samoa
- Fiji
- Solomon Islands
- Territory of the Pacific Islands
- Marshall Islands

Next page: Table 1 : Cyclone and typhoons paths in the past ten years and most affected areas

Ref.	Event	Region	Category	Damage/ Comments
1	Severe Tropical Cyclone Zoe, December 2002	**Southern Pacific** Areas affected : Solomon Islands, Fiji, Vanuatu, Rotuma	Category 5 (SSHS), Category 5 (Australian scale)	Severe Tropical Cyclone Zoe was the most intense tropical cyclone recorded in the Southern Hemisphere. Fatalities : None recorded
2	Severe Tropical Cyclone Beni, January 2003	**Southern Pacific** Areas affected : Vanuatu, New Caledonia, Queensland	Category 4 (SSHS), Category 5 (Australian scale)	Fatalities : 1 Damage : $7 million (2003 USD)
3	Severe Tropical Cyclone Erica, March 2003	**Southern Pacific** Areas affected : Queensland, Southeast Papua New Guinea, Solomon Islands, New Caledonia	Category 4 (SSHS), Category 5 (Australian scale)	Fatalities : 2 total Damage : $15 million (2003 USD)
4	Severe Tropical Cyclone Heta, December 2003	**Southern Pacific** Areas affected : Samoan Islands, Tonga, Niue	Category 5 (SSHS), Category 5 (Australian scale)	Fatalities : 2 Damage : $113 million (2004 USD)
5	Severe Tropical Cyclone Olaf, February 2005	**Southern Pacific** Areas affected : Samoa, American Samoa, Cook Islands	Category 5 (SSHS), Category 5 (Australian scale)	Fatalities : 0 direct, 2 missing Damage : $10.0 million (2005 USD)
6	Severe Tropical Cyclone Percy, February 2005	**Southern Pacific** Areas affected : American Samoa, Tokelau, Cook Islands	Category 5 (SSHS), Category 5 (Australian scale)	Fatalities : None
7	Severe Tropical Cyclone Ului, March 2010	**Southern Pacific** Areas affected : Vanuatu, Solomon Islands and coastal Queensland	Category 5 (SSHS), Category 5 (Australian scale)	Fatalities : 1 direct Damage : $72 million (2010 USD)
8	Severe Tropical Cyclone Inigo, April 2003	**Australian region** Areas affected : Indonesia, Australia	Category 4 (SSHS), Category 5 (Australian scale)	Fatalities : 58 direct Damage : < $6 million (2003 USD)
9	Severe Tropical Cyclone Ingrid, March 2005	**Australian region** Areas affected : Northern Queensland, Northern Territory, Northern Western Australia	Category 4 (SSHS), Category 5 (Australian scale)	Fatalities : 5+ direct Damage : At least $14.4 million (2005 USD)
10	Severe Tropical Cyclone Larry, March 2006	**Australian region** Areas affected : Far North Queensland	Category 4 (SSHS), Category 5 (Australian scale)	Fatalities : 1 total Damage : $1.1 billion (2006 USD)
11	Severe Tropical Cyclone Glenda , March 2006	**Australian region** Areas affected : Australia	Category 4 (SSHS), Category 5 (Australian scale)	Severe Tropical Cyclone Glenda was among the strongest tropical cyclones to threaten Western Australia Fatalities : None reported Damage : $965,000 (2006 USD)

12	Severe Tropical Cyclone Monica, April 2006	**Australian region** Areas affected : Australia	Category 5 (SSHS), Category 5 (Australian scale)	Severe Tropical Cyclone Monica was the most intense tropical cyclone, in terms of maximum sustained winds, on record to impact Australia Fatalities : None Reported Damage : $5.1 million (2006 USD)
13	Severe Tropical Cyclone Hamish, March 2009	**Australian region** Areas affected : Queensland	Category 4 (SSHS), Category 5 (Australian scale)	Fatalities : 2 direct Damage : $46 million (2009 USD)
14	Severe Tropical Cyclone Laurence, December 2009	**Australian region** Areas affected : Northern Territory, South Australia and Western Australia	Category 4 (SSHS), Category 5 (Australian scale)	Fatalities : None reported Damage : $9 million (2009 USD)
15	Severe Tropical Cyclone Yasi, January 2011	**Australian region** Areas affected : Solomon Islands, Vanuatu, Papua New Guinea, Queensland, South Australia, New South Wales, Northern Territory and Victoria	Category 4 (SSHS), Category 5 (Australian scale)	Fatalities : 1 indirect Damage : $3.6 billion (2011 USD)
16	Typhoon Nida (Dindo),May 2004	**Western North Pacific** Areas affected : Philippines and Japan	Category5(SSHS), Typhoon (JMA)	Fatalities : 31 direct Damage : $1.3 million (2004 USD)
17	Typhoon Dianmu June 2004	**Western North Pacific** Areas affected : Japan and South Korea	Category 5 (SSHS), Typhoon (JMA)	Fatalities : 6 direct Damage : $68.5 million (2004 USD)
18	Typhoon Megi, October 2010	**Western North Pacific** Areas affected : Philippines, Taiwan, China	Category 5 (SSHS), Typhoon (JMA)	Fatalities : 69 dead, 4 missing Damage: $709 million (2010 USD)
19	Typhoon Guchol, June 2012	**Western North Pacific** Areas affected : Philippines, Japan	Category 4 (SSHS)	Fatalities : 3 direct Damage : $100 million (2011 USD)
20	Typhoon Sanba, September 2012	**Western North Pacific** Areas affected : Palau, Japan, South Korea, North Korea, China, Russia	Category 5 (SSHS), Typhoon (JMA)	Fatalities : 6 total Damage : $378.8 million (2012 USD)
21	Typhoon Bopha (Pablo), November 2012	**Western North Pacific** Areas affected : Federated States of Micronesia, Palau, Philippines	Category 5 super typhoon (SSHS)	Typhoon Bopha was the strongest tropical cyclone to ever hit the southern Philippine island of Mindanao. Fatalities : 1,146 total, 834 missing Damage : $1.04 billion (2012 USD)

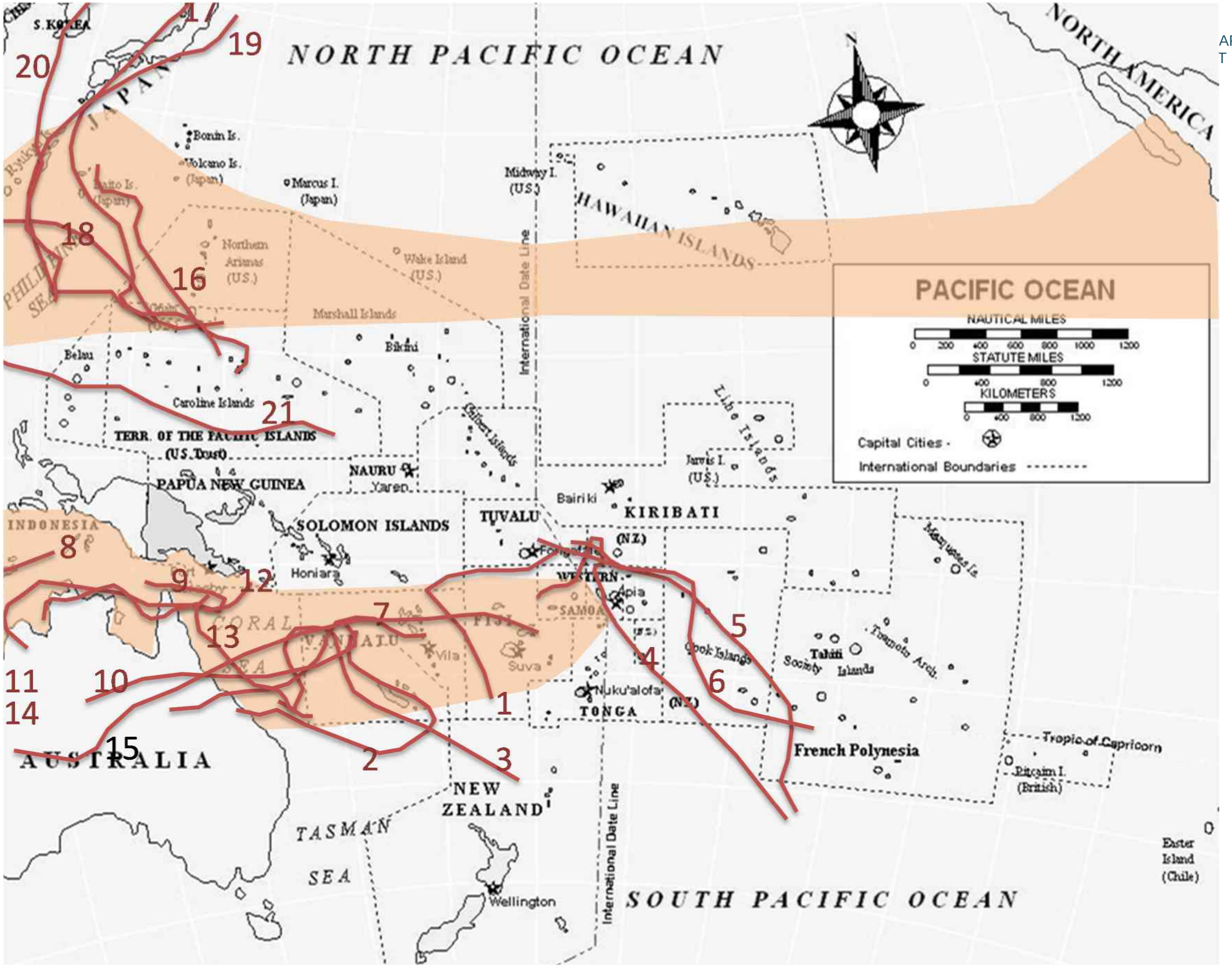


Figure 3 : Category 5 cyclones and typhoons in the Pacific Region since 2002

2 ADAPTATION MEASURES

2.1 Planning

The first step in Waste Management is sensible planning : Experience has shown that having a disaster debris management plan minimizes the amount of waste, speeds up recovery and protects human health and the environment.

The components of the plan should include:

- Disposal capacity: Initial step should seek to understand the type and volume of waste generated depending on the magnitude of the natural disaster and ensure that corresponding facilities exist for storage and disposal;
- Pre-negotiated contracts or list of pre-qualified contractors for managing debris: This aspect will greatly speed up waste and debris removal;
- Institutional reinforcement: The responsibilities for waste management should be clearly defined in order to have a clear response;
- Communication: Proper communication before disaster and after disaster is key to community awareness and participation to the efficient waste management;
- Environmental and social guidelines: In any situation debris management should comply with minimal environmental and social guidelines so as to not aggravate the current situation.

2.1.1 Disaster event analysis and waste characterization study

2.1.1.1 PREPARE EMERGENCY RESPONSE PLAN (ERP) INCLUDING SOLID WASTE MANAGEMENT

- Introduction

In most countries of the Pacific Region, Emergency Response Plans (ERP) exist. Procedures generally include primary and secondary evacuation routes for casualties, backup power systems, fresh water supply but not always address waste systems. This is due to the fact that, from an institutional point of view, SWM is under the responsibility of municipalities, whilst other sectors such as public health and other utilities are under the responsibility of higher (national) entities, at least when dealing with emergency situations.

That is why, ERPs should be reviewed and refined at the municipal level in order to properly encompass Solid Waste Management. The steps leading to an efficient SWM ERP are described below:

- Waste characterization study

The amount and type of debris generated varies depending on the occurrence - see table 2. At the municipal level, a survey should estimate the magnitude and composition of waste as a function of disaster type and strength; allowing the development of specific waste management schemes, as well as subsequent end-uses.
Note that the characterization should seek to identify quantities in terms of tonnage as well as in terms of volume, as much of the hauling and storage will deal with bulk waste only.

Occurrence	Impacts and vulnerability
Tsunami	widespread deposition of wastes on relatively narrow coastal fringe, potentially pan-oceanic (including sub-sea deposition)
Earthquake	localized generation of building material waste (and sediment from landslides) from seismic activity
Flood	generally localized generation of soil, sediment and building material waste
Hurricane	high-velocity winds and storm surge generally impact region of first landfall with high volumes of building material and vegetation waste being generated
Forest Fires	although low volumes of waste are generated, includes building material waste; de-vegetated slopes are more vulnerable to mud-slides/landslides

Table 2 : typology of waste depending on the occurrence

In addition to building material and vegetation waste, the waste management plan should comprise the following wastes :

- Wastes arising from disaster relief operations, especially medical, health-care wastes and any equipment that will eventually be disposed of;
- Debris from industrial plants or transport accidents. Large industrial sites in areas struck by disasters are a serious cause for concern as regular municipal authorities have little experience in handling industrial waste. While the expertise in the industry can assist, there remain legal liability questions, and a dire lack of facilities that can accommodate such specific wastes.
- Regular household waste generated during the emergency period that has to be managed at the same time as the debris.

2.1.1.2 IDENTIFY TEMPORARY STORAGE SITES

- Role of temporary storage sites

Hurricanes or ice storms, for example, can generate much more vegetative debris than a municipality can typically manage. Therefore, pre-identification of potential temporary storage or disposal areas for large volumes of inert solid debris close to where such waste might be generated speeds up the implementation of the SWM ERP. Hauling waste over large distances in an emergency situation becomes utterly counterproductive. These sites can be used to temporarily store debris before transferring it to another facility, and can serve as pre-processing site. Municipalities also can use these sites to distribute reusable or recycled products, such as free mulch or wood, to the public.

- Sizing

According to the Federal Emergency Management Agency (USA), experience has shown that 60,000 square meters of land are needed to process 100,000 cubic meters of debris with a provision for any hazardous materials, as hazardous materials may be delivered to this location by mistake or included with other non-hazardous materials, which is likely to occur as affected citizens may be confused about how to categorize their waste or where they should bring it.

- Site selection

However, finding ample space to stage, store, and process debris is always a challenge. In general, such sites may include existing disposal facilities, local parks, or closed industrial/military facilities, etc.

To protect human health and the environment, selected temporary debris management sites should[3]:

- Be sufficient in size with appropriate topography and soil type (work with state/local environmental agencies to determine appropriate topography and soil type);
- Be located an appropriate distance from potable water wells and rivers, lakes, and streams (work with state/local environmental agencies to determine appropriate setback distances);
- Not be located in a floodplain or wetland;
- Have controls in place to mitigate storm water runoff, erosion, fires and dust;
- Be free from obstructions, such as power lines and pipelines;
- Have limited access with only certain areas open to the public, such as areas to drop off debris;
- Be located close to the impacted area, but far enough away from residences, infrastructure, and businesses that could be affected by site operations, since the sites could produce noise at levels deemed unacceptable by residents or attract rodents that may carry disease;
- Preferably be on public lands because approval for this use is generally easier to obtain, but could also be located on private lands. Private lands may be convenient and logistically necessary for temporary debris storage sites. Consider potential agreements with private land owners in advance to ensure the use of these needed areas.

For hazardous waste bulking sites, the following safeguards should be considered:

[3] EPA - March 2008 – Planning for natural disaster debris guidance

- Area to be used should be covered with two layers of plastic sheeting, tarps, or a concrete pad.
- Fence off area with T-posts and orange barricade fencing;
- Surround fenced off area with absorbent booms (to absorb any potential leaks) or sandbags (to prevent spills from seeping into the ground);
- Use (wooden) pallets to raise collection bins off the ground (to ascertain potential leaks);
- Provide adequate space for walking/carrying items between pallets;
- Segregate containerized gases, liquids, or solids by material type (e.g. corrosive wastes, reactive wastes), place each material type in a separate bin or barrel, and label the bin or barrel appropriately;
- Cover collection bins or barrels with plastic liners/lids or cover the entire hazardous waste collection site with a tent to prevent water collecting in bins;
- Cylinders containing compressed gas should be placed upright with cap on and secured in place;
- Provide sufficient fire extinguishers for the site in case fire breaks out; four fire extinguishers per 10,000 square feet are recommended, placed at the corners or in easily accessible locations.

2.1.1.3 IDENTIFY RECYLING/REUSE OPTIONS

This task consists in identifying how possible separation and recovery of potentially valuable waste components may be carried out to minimize waste to be transported and treated. This point partly overlaps with resource management activities and resilience building since recovered products may provide secondary materials for reconstruction and employment for victims.

Note that ownership, resale or donation conditions of such recovered waste should be pre-determined as part of the planning process to avoid “unpleasant” situations during the crisis.

2.1.1.4 IDENTIFY END USES AND MARKETS

Most of the materials generated by natural disasters are recyclable and can be reused.

Therefore, municipalities should identify the existing market for debris materials. For instance, rosters listing local recyclers of scrap metal, white goods, mixed C&D materials, land clearing debris, concrete, asphalt pavement hazardous waste, HHW and electronics should be established.

Arrangements to contact, contract and mobilize their services should be in place prior to the disaster and clearly appear in the SWM ERP.

In the same perspective , it is recommended that planners identify the sites where recycling will occur, any equipment needed, the best market options for material reprocessing, as well as considerations about hauling distances.

The most common options for C & D waste are listed below :

Material	On site Processing	Market
Concrete	Crushed to 10 cm maximum particle size	Blend and sub-grade preparation; stockpile for future use
Structural steel	Cut with hydraulic shears	Local scrap metal processor
Asphalt	Ground on-site and crushed to 10 cm maximum particle size	Reused as aggregate
Refractory bricks	Hand recovered ; mortar taken off, palletised; shrink-wrapped	Stockpiled for reuse in the new building
Bricks	Crushed to 10 cm maximum particle size	Blend and sub-grade preparation; compact in 30 cm lifts; stockpile remainder for future use
Wood (frames, floors, etc.)	None	Local processing as chips for use as fuel or planned for furniture
Electrical (copper) and plumbing (iron, copper, and brass)	None	Local scrap metal company
Old iron fence	Stockpiled	Future reuse on site
Other, mixed wastes	Collected for disposal	Transport to landfill

Table 3 : Technology Policy options for C & D wastes (UNEP, 2008)

2.1.1.5 IDENTIFY REPROCESSING EQUIPMENT

Specific equipement should be available for reprocessing the large amount or waste. A review of the various types of equipment available on the market for C&D waste reprocessing is presented in the second part of this report.

2.1.2 SWM risk assessment study

Some urban areas are more vulnerable than others, and SWM ERPs should clearly identify these areas as a priority in resource allocation so as not to aggravate the situation.

These areas having generally lower design and construction standards will incur more damage which will generate more debris and waste, finally leading to the accumulation of waste. Such accumulation combined with little means to evacuate it will further increase the population’s vulnerability.

To limit the impact of disaster waste in vulnerable areas, these areas should be clearly identified. Such areas should be marked in the SWM ERP in red so that adequate resources are allocated when needed.
Likewise, older buildings of public of private ownership of which design pre-dates disasterproof construction standards should also be considered as vulnerable.

2.1.2.1 SLUM UPGRADING

Although land-use planning and preparedness measures will provide significant contribution in mitigating the impact of the natural hazards, hazard-resistant construction principles can be even more effective in mitigating the impact of extreme winds and earthquakes.

Modern techniques of design and construction are increasingly complex and sophisticated, and incorporate extensive specialist techniques which reduce the impact of natural hazards upon physical structures. In practice, technical skills are often concentrated on large projects, resulting in poor standards of construction on smaller projects and slums – although expensive buildings of complex construction may be no more resistant to particular hazards than a simple dwelling in a slum.

In terms of slum upgrading, the priority should be to identify features which make the building more or less vunerable to specific hazards, develop model hazard-resistant dwelling types of various size and standards, and promote their widespread adoption.

Three basic principles can help guide in understanding the weaknesses, strenghts and potential improvements which can be made to local construction to resist natural disasters such as typhoons :

- Provide sideways support – the building should be designed so that walls, roof and floors provide mutual support;
- Provide strength in tension;
- Encourage general local good practice – the observance of locally evolved good practice regarding such things as sound foundations, a sensible choice of location, good materials, and regular maintenance will usually go a long way towards achieving safer building.
- Provide training in the basic principles of safe construction is a high priority, and could initially focus on residents of the informal sector.

2.1.2.2 DRAINAGE/SEWER CONSTRUCTION AND MAINTENANCE

Surface water drainage or sewer systems may be disrupted in a number of ways during disasters. For example, pipes, culverts and channels can be blocked by debris or uncollected refuse. As a result, drainage structures can fail by bursting or scouring under excessive surcharge; watercourses can overflow or their training walls and embankments can fail; waste can accumulate and eventually block pumps.

Adaptation measures include :

- Ensure that waste is never disposed of or stored in or nearby sewage channels;
- Ensure regular cleaning and maintenance of the drainage and system, especially before rainy seasons
- Maximize the extent of gravity drainage, minimize the extent of areas requiring pumping stations;
- Ensure that development is controlled to conform with the land-use strategy including procedures to minimize waterpollution following system failure,such as flood routing of sewage;
- Locate waste-water installations in less vulnerable areas.
- Adopt a pro-active policy for on-site pre-treatment of industrial effluent (including re-use of treated waste-water) and hospital sewage;
- Enlarge drainage channels.

2.1.2.3 IMBEDDING DISASTER RESPONSE WITHIN GENERAL SWM PLANNING

Solid Waste Management Master Plans are the cornerstone in terms of long term planning at the sectoral level. Such documents when reviewed or updated should include specific provisions for more efficient emergency response.

The main points are listed below:

- Develop alternative collection routes in vulnerable areas so as to avoid flooded areas and others risk areas;
- Setup SWM ERP brigades for removal, transport and handling of debris and waste that might be called upon - and that would not already be employed in other aspects of humanitarian crisis relief. In effect, these brigades will have a stand-by list of resources able to address immediately the waste management functions, and know the land areas available for storage/disposal;
- Sensible siting of SWM facilities : according to their location, municipal and commercial waste facilities, including landfills and dump sites, are vulnerable to natural disasters. Low-lying ground, shoreline, or steep hillsides are locations to avoid.

2.1.2.4 BUILDING RESILIENCE IN THE SWM SECTOR

By definition, community resilience is the ability to utilize available resources to respond to, withstand, and recover from adverse situations.

Several steps can be taken in order to develop resilience in a community, specifically regarding SWM.

- **Develop cooperation with neighboring cities or districts**
  State and local governments are typically the first source of assistance to a community in the wake of a natural disaster. Many states and communities have prepared or are preparing for disasters and are generally willing to share information and resources.
  State and local governments can enter into mutual aid agreements with neighboring states and local governments prior to any natural disaster. Such an agreement could provide for either binding commitments or nonbinding intentions of support to assist one another in the event of a natural disaster. Through these agreements, communities can loan equipment and personnel with specific expertise or experience.
  In the United States, the Emergency Management Assistance Compact (EMAC) is a good example of a mutual aid agreement between states. Through EMAC, a disaster-impacted state can request and receive assistance from other member states quickly and efficiently, resolving two key issues upfront: liability and reimbursement.

- **Identify in advance the types of equipment and supplies that waste teams will need to implement the plan**
  Quick procurement of these items through mutual aid agreements or standing contracts, or stockpiling such equipment should be considered and planned for. If stockpiling is too expensive for one city alone, perhaps a group of neighbouring cities could stockpile the equipment.
  Types of equipment that a community might need include chain saws, portable generators, cellular phones, flashlights, batteries, vehicle repair equipment (flat tires occur more often because of glass and metal debris in roads), and extra work clothing.

- **Develop cooperation with other municipal services (water and sewage, traffic and transportation, fire departments) or private contractors**

  SWM ERP should not limit their reach to waste management activities,but should seek to maintain close links with disaster management agencies, and ensure that waste management is incorporated into overall emergency plans

  In substantial natural disasters, community resources typically are overwhelmed. Communities likely will need to hire private disaster debris management contractors in these special circumstances. Often, such contractors are experienced in dealing with disaster recovery work, such as establishing staging areas, hauling and segregating debris.

  It would be beneficial for municipal officials to identify what disaster debris management contractors are in their area. Planners could establish relationships with such contractors while drafting their community's disaster debris management plan.

  Other private companies and local businesses may be able to offer specific assistance as well such as allowing large parking lots to be converted into debris staging areas or community drop-off locations. Construction companies might make earth-moving equipment, water pumps, and other necessary equipment available for immediate use in the event of a disaster. Trucking companies might be able to lend trailers, dump trucks, or roll-off dumpsters. These opportunities are just examples of how a community can work with the private sector in the event of a disaster.

- **Budget for emergency response actions and cash- for-work (CFW) operations**

  CFW oeprations are a way of putting the money back in the pockets of members of the community who need it most. Therefore, they directly contribute to community resilience.

  Such operations require fairly large amounts of cash to be available. Unfortunately, such budgetary items are almost never included in most local governments' budgets - It is worth noting that even costs for disaster response itself, including debris diversion, are ofter absent of local budgets.

  In this perspective, specific SWM activities following a disaster should be properly budgeted and include provisions under the form of escrow accounts dedicated to CFW operations with pre-authorised cash withdrawals from local banks.

  Since most of the financial effort will be borne by national or international entities, such operations must follow stringent procedural, recordkeeping, and documentation requirements. Each municipality should train appropriate staff to familiarize with the authorities, work eligibility, cost eligibility, application procedures, damage survey report process, and other details.

- **Develop Community based Solid Waste Management systems**

Slum areas have a very high density of population and are likely to generate a large amount of debris. Therefore, populations in these areas should be encouraged to deliver solid waste to transfer station of temporary storage sites.
Such efforts may be part of a CFW operations to provide incorme generating activities in the most affected areas.
Preliminary capacity reinforcement of non-waste personnel to assume waste management functions during a crisis is necessary.

- **Capacity reinforcement for SWM staff and NGO's**

Annual functional training could take place in order to increase public awareness about disaster debris management issues.

Workshops and training would also enhance the effort toward a coordinated approach to disaster debris diversion. These workshops would include local agency staff, officials, and other parties who are responsible for solid waste and disaster debris planning, as well as demolition contractors or volunteers who could assist the cities and the county in implementing the disaster debris diversion programs.

2.2 Facility design and construction or retrofitting

2.2.1 Vulnerability assessment

Prior to designing a new SWM site, the selected site should undergo a thorough vulnerability assessment. This assessment should lead to new design standards specific to low probability / high impact events.

When the vulnerability assessment has been carried out, it should lead to a set of recommendations aiming specifically at reducing the risk of damage arinsing from natural disasters.

The most common recommendations are presented hereunder.

2.2.2 Erosion control

Any waste management facility must be equipped with run-on and run-off controls. Run-on and run-off controls prevent rain water and other liquids or solids from running onto the unit (and creating leachate) and stop this leachate from running off the unit, thus carrying contaminants into surrounding soils, surface waters, and ground water.

All potentially impacted facilities should be protected by a combination of the following Best Management Practices :

Technique	Description	Picture
Ensure durability of cover layer		
Erosion Control Mats	Erosion Control Mats are geotextiles, mats, plastic covers, or erosion control blankets designed to stabilize disturbed soil areas and protect soils from erosion by wind or water. This technique could be more expensive than other erosion control measures, due to labor and material costs.	
Mulchig /Compost blanket	A compost blanket is a layer of loosely applied compost or composted material that is placed on the soil in disturbed areas to control erosion and retain sediment resulting from sheet-flow runoff. It can be used in place of traditional sediment and erosion control tools such as mulch, netting, or chemical stabilization. When properly applied, the erosion control compost forms a blanket that completely covers the ground surface. This blanket prevents storm water erosion by: (1) presenting a more permeable surface to the oncoming sheet flow, thus facilitating infiltration; (2) filling in small rills and voids to limit channeled flow; and (3) promoting establishment of vegetation on the surface.	

Evacuate rainwater and prevent damage from uncontrolled runoff

Pipe Slope Drains

A temporary rigid or flexible pipe that conveys runoff down unstabilized slopes. The drain is anchored on the upstream end with some form of headwall to limit erosion, secure the pipe, and direct water into the pipe inlets.

Pipe slope drains convey concentrated flows of surface runoff and protect preliminary and final graded slopes. Pipe slope drains are used during the establishment of temporary and permanent ground covers on sites with long, unstabilized, steep slope areas that are subject to erosion from overland flow. They minimize erosion down a slope because all flow is confined to an enclosed pipe.

Diversion Dikes

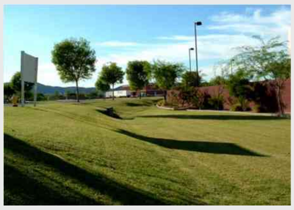
A ridge of compacted soil (recommended with a vegetated lining) that is often located at the top or base of a sloping disturbed area, and redirects runoff to a less sensitive outfall or area.

Depending on the location and topography, diversion dikes can achieve two goals:
- Located on the upslope of a site, they can prevent surface sheet flow runoff from entering a disturbed construction site (ex :recycling sites)
- Located on the downslope of a site, they can divert sediment-laden runoff created onsite to sediment trapping devices, preventing soil loss from the disturbed area (ex : landfill).

Drainage Swales

A drainage way with a lining of grass, stone, asphalt, concrete, or other material. Permanent channels must be designed and constructed in accordance with appropriate local design standards.

Drainage swales are used as perimeter controls or slope protection to convey runoff without causing erosion by intercepting runoff from above unprotected slopes or at the perimeter and directing the runoff to sediment trapping device or stabilized outlet. Depending on the design of the drainage swale, different objectives can be achieved. A meandering or winding swale with vegetation helps to reduce flow velocities and reduce suspended sediments. A straight, lined swale provides the maximum conveyance of drainage flows.



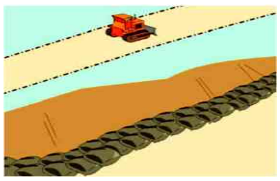
Prevent landslide and destruction

Organic Filter Barrier

A temporary linear sediment barrier consisting of straw bales, sediment wattles or similar material, designed to intercept and slow sediment-laden sheet flow runoff. Organic filter barriers allow sediment to settle from runoff before water leaves the construction site. Organic filter barriers include straw bales, sediment wattles, and other organic filter berms.Organic filter barriers reduce runoff velocity and cause deposition of the transported sediment load. They are well suited to sites with small disturbed drainage areas that are not subjected to concentrated flows and that will ultimately be seeded, sodded, or landscaped.

Sand Bag Barrier

A temporary berm constructed of stacked sandbags, along the perimeter of a site, installed across a channel, or along the right of way in a disturbed area. The sandbags may be filled with pea-sized gravel to enhance filtration. A sandbag barrier is designed to intercept and slow the flow of sediment-laden runoff. Sandbag barriers allow sediment to settle from runoff before water leaves the construction site.



Gravel Filter Berms

A temporary berm constructed of open graded rock or bags of gravel installed at the toe of a slope, or the perimeter of a developing or disturbed area.

Gravel filter berms are designed to intercept and detain sediment-laden water from an unprotected area, detain the sediment, and release the water in sheet flow.

Silt Fence	Silt fences are used as temporary perimeter controls around sites where construction activities will disturb the soil. They can also be used around the interior of the site. A silt fence consists of a length of filter fabric stretched between anchoring posts spaced at regular intervals along the site at low/down slope areas. The filter fabric should be entrenched in the ground between the support posts. When installed correctly and inspected frequently, silt fences can be an effective barrier to sediment leaving the site in storm water runoff.	
Create natural and sustainable protection to the infrastructure		
Revegetation	Revegetation consists of an area of trees, shrubs, vines, and ground covers that create a buffer or a groundcover between a disturbed construction area and neighboring areas, particularly natural water bodies. Revegetation buffers can provide superior, low maintenance, long-term erosion protection, and can often result in a more stable and aesthetically pleasing development. Vegetation stabilizes the soil and help prevent erosion, decrease stormwater runoff, moderate temperature, provide buffers and screens, filter pollutants from the air, supply oxygen, and provide habitat for wildlife.	
Hydro-seeding or mulching	Seeding is used to control runoff and erosion on disturbed areas by establishing perennial vegetative cover from seed. It reduces erosion and sediment loss and provides permanent stabilization. This practice is economical, adaptable to different site conditions, and allows selection of a variety of plant materials.	
Soil Binders / Chemical Stabilization	Chemical stabilizers, also known as soil binders or soil palliatives, provide temporary soil stabilization. Vinyl, asphalt, or rubber is sprayed onto the surface of exposed soils to hold the soil in place and minimize erosion from runoff and wind. These materials are easily applied to the surface of the soil, can stabilize areas where vegetation cannot be established, and provide immediate protection. Chemical stabilizers alone are used in areas where other methods of stabilization are not effective because of environmental constraints. They can also be used in combination with vegetative practices to enhance erosion and sediment control.	

Table 4 : Description of main erosion control measures

2.2.3 Flood and overflow prevention

- Prevent overflow

Any surface impoundment must be designed to prevent the flow of liquids over the top of an impoundment (overtopping). This is accomplished by constructing and maintaining dikes or berms (walls or man-made hills surrounding the unit) and ensuring a minimum distance (called freeboard) between the surface of the waste and the top of the impoundment to prevent overflow because of high winds or heavy rainfall.

- Raise infrastructure above ground level and avoid excavation

Facilities will need a drainage system that can cope with high levels of rainfall and improved attenuation of runoff.

2.2.4 Facility preparedness

- Reserve specific cells for incoming disaster waste
  After disaster, waste management facilities and especially landfills will receive considerable amounts of waste. Such eventuality has to be taken into consideration at the design stage.
  Any new landfill should therefore be equipped with disposal capacity to cope with the inflow of waste to be treated.

- Design platform for disaster waste sorting and recovery
  As seen earlier, post disaster resource management is a way to build community resilience by recovering value from waste and debris. Such activities are to be encourage but may only be possible, if suitable facilities are in place.
  The best way is usually a platform that can be used as sorting and temporary storage space by recyclers.Note that providing suitable storage and tranportation containers such as “big bags” seems necessary for the evacuation of recovered products.

- Build specific storage space for toxic waste
  In all cases any toxic waste, or identified as such, should not be mixed with other types of waste. Therefore, facility design should allow for separate storage of hazardous waste.

- Limit electrical equipment
  When designing new facilities, the need for electrical power should be minimize. In case of natural disasters, power outages would shutdown all activities on site.

- Access roads and platforms
  Design of waste management facilities should ensure all weather access to site. This means that the choice of construction materials for access roads and the design itself should take into account erosion, flooding or any other occurrence that could damage the infrastructures.
  For example the use of water sensitive material or fine material for access roads and platforms is prohibited.
  In this case, sufficient amounts of selected material should be stockpiled at landfill site for rebuild operations.

- Close and reclaim existing landfill and built new landfill in less vulnerable area
  In the case of existing facilities, following the vulnerability assessment, it may become more cost effective to relocate the facility altogether.
  Such drastic measures are common in Europe when existing landfills are located in areas of natural risks of are threatening natural amenities.
  Likewise, Climate change adaptation may call for the resetlement of SWM facilities, when risk become too important to be managed by local communities.

2.3 Operation

2.3.1 Risk factoring

When sites have been designed and constructed and when adaptation measures have been applied, there is a way to further reduce risk associated with natural disasters by applying factoring strategies.

Factoring strategies may take various forms, as shown in the following examples:

- Store collection vehicles in several locations, rather than a central depot in order to avoid loss of all equipment at once;
- Encourage informal communities to arrange collection and delivery to an agreed point on the border of the area for final disposal;
- Encourage manufacturers and suppliers to collect, re-use or dispose their waste products which should greatly minimize the amount of waste to be transported and treated;
- Adopt a long-term proactive policy to gradually reduce the quantities of waste, for example, by reducing packaging;

2.3.2 Resource management

Climate change adaptation and sustainability issues are forcing SWM into resource management techniques. In terms of operating SWM facilities, this aspect requires the installation of waste processing and composting capacity, such as:

- Wood shredder
  The quantity of wood waste following naturals disasters is usually very important. Any further use for this wood requires processing the wood into chips that can be easily stored and transported.
- Windrow composting
  The quantity of organic/fibrous waste may be so large that it may no be suitable for direct landfilling. Therefore, windrow composting areas could be a way to reduce moisture levels and reduce volumes of waste.
  A fraction of the compost could be used for reclaiming some parts of the landfill or as cover layer of recent waste cells.
- Burning pits
  In the case of waste that cannot be composted because of space requirements or weather conditions or general adverse impacts of composting such as odors and pest open air combustible waste burning at land fill site may be organised.

2.3.3 Energy from waste

In some cases, energy from waste schemes could potentially be a valid response to disaster waste treatment. The main issue with disaster waste is the fact that it comes as a (very) discontinuous flow, while Energyfrom waste installations require a fairly regular flow.
Although buffering could be a solution it seems as though the chances of treating disaster waste through such systems may only concern a small proportion of the overall waste generated.

- Methanize waste

  Large amounts or organic waste generated during natural disasters can be processed in order to be introduced in a mathanizer. Such facilities usually require sizeable investments specifically the power block.
  Furthermore, operation of such facilities falls under the competence of utility companies and not

- Pelletized waste

  Producing Refuse Derived Fuel (RDF) from combustible waste and pelletize it is a good alternative for combustible waste such as wood and paper.
  Current studies in New Caledonia are reviewing technologies to use RDF as secondary fuel in a coal fired power plant[4]. The first conclusions show a large capacity for fuel substitution, and waste from other pacific islands could be shipped to New Caledonia.

  In terms of investment and operation, producing pellets and shipping them is a costly process and requires maintaining inventory of inventory of specific collection and transportation equipment such as big bags.

2.4 Success of these measures in effectively mitigating the effects of CC – Case Study

See Part II – Case study is presented jointly for part I and II.

[4] Feasibility study for the co-combustion of RDF in the coal fired plant of Lapita – Pöyry/Naldeo - 2013

3 COMPARISON MATRIX

3.1 General assessment criteria

All development work and activities have impacts, although the vast majority of the proposed measures have no adverse effects on the environment, some measures may be preferable to others in terms of environmental and social outcome or more affordable from a financial point of view.
In this perspective we tried to assess each measure according to a set of criteria:

- Environmental sustainability
- Social sustainability
- Capacity to specifically target effects of climate change
- Specific cost of measure in US$ per ton of waste generated

3.1.1 Environmental Sustainability

Environmental impact of each activity widely depends on the current state of the environment..
Therefore, we tried to use standard criteria with qualitative indicators as shown in the table below.

Concerning the indicators, lack of objective data does not allow a quantitative approach based on fully measurable metrics. As a result, we opted for a semi quantitative rating reflecting the relative effect of each measure within the contexte of the Pacific Region.

Criteria	Indicator
Water resources considering groundwater, rivers, lakes, and sea for drinking and irrigation Consider water availability, quality and pollution	- Quality of water discharged by SWM activities
Land and soil Use of land, soil erosion and contamination. Deforestation and removal of mangroves	- Amount of land lost for biodiversity, and community/recreational areas
Air Pollution from smoke, gas, chemicals or sewage	- Emissions of harmful gases such as greenhouse gases (GHGs), dioxins, furans, heavy metals, etc
Fauna Migration,depletion, proliferation of pests and invasive species	- Number of pests and invasive species
Waste Amount of waste generated	- Amount of waste being disposed of in uncontrolled conditions
Energy Net energy used	- Amount of energy consumed or generated by the activity and as a

	result of the activity

Table 5 : Environmental sustainability criteria and indicators

Each indicator is given a value ranging from -3 to +3 according to the effect, 0 meaning ‘no effect’ or ‘not relevant’.

-3	-2	-1	0	1	2	3
very detrimental	detrimental	slightly detrimental	neutral	slightly beneficial	Beneficial	very beneficial

3.1.2 Social sustainability

Social sustainability is a rather complex notion. The reduction of the criteria to one indicator is a drastic choice. However, for lack of data, it was chosen to use the direct benefits do the community as an indicator.
“Direct benefits” being the value returned to the local community in cash or kind including employment opportunities, as a result of the activity.

As above, indicator may range from -3 to +3.

3.1.3 Focus on Climate Change adaptation

Some of the proposed measures have a much broader focus that just adapting to Climate Change. This indicator seeks to establish how directly focused each measure is in regard to Climate Change adaptation:

0	1	2	3
neutral	not specific	specific	very specific

3.1.4 Cost in US$ per ton of waste

The cost is the all-inclusive investment cost per ton of waste generated, based on recent projects in the Pacific Region, in Australia and Europe for a community of approximately 100,000 inh.
Financial data that could not be found in the litterature was estimated.

3.2 Relevance at Labasa landfill

This part aims at refining the assessment specifically for the Labasa landfill. The facility is located adjacent to a mangrove, and the Labasa River, some 2-3 kilometers from the Labasa Town Center on the island of Vanua Levu; This part of the island being particularly prone to flooding induced by cyclones.

Each measure will be rated from 0 (not applicable) to 3 (very relevant) according to the following criteria:

In order to clearly emphasize the measures that are directly relevant to Labasa landfill, general applicability will be calculated by multiplying the relevance in adapting the landfill by the sum of all other criteria, thus leading to a scale ranging from 0 to 54 for this indicator. Measures which do not have a direct effect or distant effect on the lnadfill are subsequently rated 0 and disregarded.

	Criteria:	**Relevance**
1	Relevant for adapting Labasa landfill to climate change	
2	Available footprint at Labasa	
3	Local availability of construction material/equipment	
4	Local technical capacity	
5	Local financial capacity	
6	Impact on local marine, estuarine and terrestrial environment	
7	Social impact at and around the site	
	General applicability to Labasa Landfill	**= criterion 1 x (criterion 2 +…+ criterion)**

0	1	2	3
not applicable	slightly relevant	relevant	very relevant

4 CONCLUSION

Litterature has decribed the main issues arising from disasters in the SWM sector. Most authors cite lack of awareness in SWM techniques, unplanned or illegal landfill sites, lack of capacity to handle large amount of waste, inadequate funding and lack of coodination as being the main issues encountered.

This report adresses the measures that will help prevent such issues to occur.

Each measure is compared in a matrix. However no ranking of these measures is proposed at this stage: the aplicability of each measure being subjected to local constraints such as local financial capacity.

The application of the above mentioned measures to Labasa landfill is also specifically assessed and rated in order to pinpoint the most suitable ones in terms of climate change adaptation.

At Labasa the most relevant aspects are found to be design, construction and operation of the site. Conversely, although planning activities are important aspects for the Region they will have no noticeable effect at landfill level.

Best practices applied to Labasa landfill, ranked by order of relevance, are listed in table 6 below:

Top ranking adaptation measures for Labasa landfill	**score**
Develop low vegetation on landfills for erosion contol	26
Reserve specific cells for incoming disaster waste	21
Design platform for disaster waste sorting and recovery	20
Use specific cover layer with coarse material	18
Develop cooperation with neighbouring cities or districts	16
build protective dikes, culverts or other structures to divert runoff	16
Use rip rap at the bottom of slopes and in trenches	16
Avoid open ponds (for leachate storage)	16
stockpile amounts of selected material at landfill to rebuilt access roads and platforms and use as cover material	16
budget for emergency response actions and work for cash operations	14

Table 6 : Top ranking measures for Labasa Landfill

4.1 Evaluation Matrix

Adaptation measures and activities	Objective (s)	Environmental sustainability	Social sustainability	Focused on CC adaptation	Cost US$/t of waste	Relevance at Labasa Landfill
Planning						
Disaster event analysis and waste characterization study						
Prepare emergency response plan including SWM	*Define resources to be specifically allocated to SWM In case of disaster*	2	1	3	$0.10	0
Identify temporary storage sites	*Allow quick removal of waste from road network*	2	0	3	$0.10	0
Identify recyling/reuse options	*Minimise waste to be transported and treated / generate revenue*	1	1	1	$0.10	4
Identify end uses and markets	*Ensure that recycled material is effectively reused or recycled*	1	0	1	$0.10	2
Identify reprocessing equipment	*Provide for reprocessing capacity of recovered waste*	1	0	2	$0.05	4
SWM Risk assessment study						
Identify vulnerable areas in regard to SWM	*allocate resources for SWM according the priorities*	2	2	3	$0.10	0
Urban development						
Slum upgrading	*Poor areas are the first to suffer from disaster and produce large amounts of debris*	2	3	1	$10.00	0
Drainage/sewer construction and maintenance	*Prevent waste and debris from blocking the sewer system*	3	3	1	$10.00	0
SWM planning						
Develop specific collection routes in vulnerable areas	*Avoid areas where SWM will be impossible (flooded areas)*	2	2	3	$0.10	0
Specific siting of SWM facilities	*Avoid flooded areas (coastal ou riverine areas)*	2	0	2	$1.00	0
Resilience Building						
Develop Community based Solid Waste Management systems	*Prepare communities to assist in sorting and removing waste from densely populated areas*	2	2	2	$1.00	0
Develop cooperation with neighbouring cities or districts	*Mutualise effort and mitigate risk*	1	0	1	$0.10	16
Develop cooperation with other municipal services (water and sewage, traffic and tranportation, fire departments)	*Foster coodination and resource allocation*	1	0	1	$0.10	0
Capacity reinforcement for SWM staff local commmunities and NGO's	*Raise awareness and train stakeholders to SWM in regard to CC*	0	1	2	$1.00	4
budget for emergency response actions and work for cash operations	*Involve population in SWM and generate revenue for victims*	0	3	3	$1.00	14

Adaptation measures and activities	Objective (s)	Environmental sustainability	Social sustainability	Efficiency	Cost US$/t of waste	Relevance at Labasa Landfill
Design and construction or retrofit of SWM facilities						
Erosion control						
build protective dikes, culverts or other structures to divert runoff	*Evacuate rainwater and prevent damage from uncontrolled runoff*	2	0	2	$5.00	16
Use rip rap at the bottom of slopes and in trenches	*Prevent landslide and destruction*	3	0	2	$5.00	16
Use specific cover layer with coarse material	*Ensure durability of cover layer through disaster*	3	0	2	$1.00	18
Develop low vegetation on landfills for erosion contol	*Create natural and sustainable protection to the infrastructure*	3	0	2	$0.10	26
Flood prevention						
Avoid open ponds (for leachate storage)	*Prevent overflow and spills*	2	0	2	$1.00	16
Raise infrastructure above ground level and avoid	*Prevent flooding and encourage gravity drainage*	2	0	2	$5.00	6
Facility preparedness						
Reserve specific cells for incoming disaster waste	*Ensure sufficient disposal capacity and prevent pollution*	3	0	3	$5.00	21
Design platform for disaster waste sorting and recovery	*Encourage recycling and value recovery*	1	0	3	$2.00	20
Avoid intallation of electrical equipment	*Prevent shutdown due to power outage*	1	0	2	$0.00	12
stockpile amounts of selected material at landfill to rebuilt access roads and platforms and	*Ensure all weather access to disposal site*	2	0	2	$1.00	16
Build specific storage space for toxic waste	*Prevent toxic spills prior to toxic waste elimination*	3	0	2	$5.00	14
Maintain inventory of specific collection and tranportation equipment such as big bags	*Efficient collection , evacuation and temporary storage of large amounts of waste and debris*	0	0	2	$1.00	7
Close and reclaim existing landfill and built new landfill in less vulnerable area		*Depends an baseline*	*Depends an baseline*	2	$10.00	?
Operation of SWM facilities						
Risk factoring						
Encourage communities to organise pre collection to defined skip points	*Speed up waste and debris removal*	3	2	3	$1.00	0
Encourage industrial or commercial establishments to reuse or recycle their waste	*Minimise theamount of waste to be tranported and treated*	2	0	3	$1.00	10
Park equipment in several locations rather than central depot	*Avoid loss of all equipment at once*	1	0	3	$0.10	3
Resource management						
Wood shredder	*Wood recycling capacity*	0	0	2	$1.00	5
Mobile crusher and screen	*Demolition waste recycling capacity*	0	0	2	$1.00	5
Windrow composting	*Organic/fibrous waste composting capacity*	2	0	1	$1.00	14
Burning pits	*Organise open air combustible waste burning at land fill site*	0	0	2	$0.10	6
Energy from waste schemes						
Methanize waste	*Produce biogas from biodegradable waste*	2	0	1	$10.00	2
Pelletized waste	*Produce Refuse Derived Fuel from combustible waste*	1	0	1	$5.00	1

APPENDIX I :

Detailed table for Environmental sustainability criterion

	Water	Land and soil	Air	Fauna	Waste	Energy	Total
	Quality of water discharge	Amount of land available for biodiversity, and community/recreational areas	Emissions of greenhouse gases	Number of pests and invasive species	Amount of waste diposed of in non-sanitary conditions	Energy consumed	
Disaster event analysis and waste characterization study							
Prepare emergency response plan including SWM	0	0	0	0	2	0	2
Identify temporary storage sites	0	0	0	0	2	0	2
Identify recyling/reuse options	0	0	0	0	1	0	1
Identify end uses and markets	0	0	0	0	1	0	1
Identify reprocessing equipment	0	0	0	0	1	0	1
SWM Risk assessment study							
Identify vulnerable areas in regard to SWM	0	0	0	0	2	0	2
Urban development							
Slum upgrading	1	0	0	0	1	0	2
Drainage/sewer construction and maintenance	2	0	0	0	1	0	3
SWM planning							
Develop specific collection routes in vulnerable areas	0	0	0	0	1	1	2
Specific siting of SWM facilities	1	1	0	0	0	0	2
Resilience Building							
Develop Community based Solid Waste Management systems	0	0	0	0	1	1	2
Develop cooperation with neighbouring cities or districts	0	0	0	0	1	0	1
Develop cooperation with other municipal services (water and sewage, traffic and tranportation, fire departments)	0	0	0	0	1	0	1
Capacity reinforcement for SWM staff local commmunities and NGO's	0	0	0	0	0	0	0
budget for emergency response actions and work for cash operations	0	0	0	0	0	0	0

	Water	Land and soil	Air	Fauna	Waste	Energy	Total
	Quality of water discharge	Amount of land available for biodiversity, and community/recreational areas	Emissions of greenhouse gases	Number of pests and invasive species	Amount of waste diposed of in non-sanitary conditions	Energy consumed	
Erosion control							
build protective dikes, culverts or other structures to divert runoff	1	0	0	0	1	0	2
Use rip rap at the bottom of slopes and in trenches	1	1	0	0	1	0	3
Use specific cover layer with coarse material	1	0	0	1	1	0	3
Develop low vegetation on landfills for erosion contol	1	1	1	0	0	0	3
Flood prevention							
Avoid open ponds (for leachate storage)	2	0	0	0	0	0	2
Raise infrastructure above ground level and avoid excavation	1	0	0	0	0	1	2
Facility preparedness							
Reserve specific cells for incoming disaster waste	1	0	0	0	2	0	3
Design platform for disaster waste sorting and recovery	0	0	0	0	1	0	1
Avoid intallation of electrical equipment	0	0	0	0	0	1	1
stockpile amounts of selected material at landfill to rebuilt access roads and platforms and use as cover material	0	0	0	0	2	0	2
Build specific storage space for toxic waste	2	0	0	0	1	0	3
Maintain inventory of specific collection and tranportation equipment such as big bags	0	0	0	0	0	0	0
Close and reclaim existing landfill and built new landfill in less vulnerable area	2	-2	0	0	0	-1	-1
Risk factoring							
Encourage communities to organise pre collection to defined skip points	0	0	0	0	1	2	3
Encourage industrial or commercial establishments to reuse or recycle their waste	0	0	0	0	1	1	2
Park equipment in several locations rather than central depot	0	0	0	0	1	0	1
Resource management							
Wood shredder	0	0	0	0	1	-1	0
Mobile crusher and screen	0	0	0	0	1	-1	0
Windrow composting	0	0	1	0	1	0	2
Burning pits	1	0	-2	0	1	0	0
Energy from waste schemes							
Methanize waste	0	0	1	0	0	1	2
Pelletized waste	0	0	0	0	0	1	1

APPENDIX II :

Detailed table for Relevance at Labasa Landfill

	Relevant to CC adaptation at Labasa landfill	Available footprint at Labasa	Local availability of construction material/equipment	Local technical capacity	Local financial capacity	Impact on local marine, estuarine and terrestrial environment	Social impact at and around the site	General applicability to Labasa Landfill
Disaster event analysis and waste characterization study								
Prepare emergency response plan including SWM	0							0
Identify temporary storage sites	0							0
Identify recyling/reuse options	2	0	0	1	0	0	1	4
Identify end uses and markets	1	0	0	1	0	0	1	2
Identify reprocessing equipment	2	0	0	1	0	0	1	4
SWM Risk assessment study								
Identify vulnerable areas in regard to SWM	0							0
Urban development								
Slum upgrading	0							0
Drainage/sewer construction and maintenance	0							0
SWM planning								
Develop specific collection routes in vulnerable areas	0							0
Specific siting of SWM facilities	0							0
Resilience Building								
Develop Community based Solid Waste Management systems	0							0
Develop cooperation with neighbouring cities or districts	2	0	0	3	3	1	1	16
Develop cooperation with other municipal services (water and sewage, traffic and tranportation, fire departments)	0							0
Capacity reinforcement for SWM staff local commmunities and NGO's	1	0	0	1	1	1	1	4
budget for emergency response actions and work for cash operations	2	1	0	2	1	1	2	14

	Relevant to CC adaptation at Labasa landfill	Available footprint at Labasa	Local availability of construction material/equipment	Local technical capacity	Local financial capacity	Impact on local marine, estuarine and terrestrial environment	Social impact at and around the site	General applicability to Labasa Landfill
Erosion control								
build protective dikes, culverts or other structures to divert runoff	2	1	1	2	1	2	1	16
Use rip rap at the bottom of slopes and in trenches	2	1	1	2	1	2	1	16
Use specific cover layer with coarse material	2	2	1	2	2	1	1	18
Develop low vegetation on landfills for erosion contol	2	3	3	2	3	1	1	26
Flood prevention								
Avoid open ponds (for leachate storage)	2	1	1	1	1	2	2	16
Raise infrastructure above ground level and avoid excavation	1	1	1	1	1	1	1	6
Facility preparedness								0
Reserve specific cells for incoming disaster waste	3	1	1	1	1	2	1	21
Design platform for disaster waste sorting and recovery	2	1	2	2	2	1	2	20
Avoid intallation of electrical equipment	2	1	1	1	1	1	1	12
stockpile amounts of selected material at landfill to rebuilt access roads and platforms and use as cover	2	1	1	2	2	1	1	16
Build specific storage space for toxic waste	2	1	1	1	1	2	1	14
Maintain inventory of specific collection and tranportation equipment such as big bags	1	1	1	1	1	1	2	7
Close and reclaim existing landfill and built new landfill in less vulnerable area	?	?	?	?	?	?	?	?
Risk factoring								
Encourage communities to organise pre collection to defined skip points	0							0
Encourage industrial or commercial establishments to reuse or recycle their waste	2	0	0	2	1	1	1	10
Park equipment in several locations rather than central depot	1	1	0	2	0	0	0	3
Resource management								
Wood shredder	1	2	0	1	0	0	2	5
Mobile crusher and screen	1	2	0	1	0	0	2	5
Windrow composting	2	1	0	2	1	2	1	14
Burning pits	1	1	0	2	3	0	0	6
Energy from waste schemes								
Methanize waste	1	0	0	0	0	1	1	2
Pelletized waste	1	0	0	0	0	0	1	1

PART 2 :
POST DISASTER WASTE MANAGEMENT BEST PRACTICES

1 DESCRIPTION OF WASTE MANAGEMENT ORGANISATION IN THE PACIFIC REGION

1.1 Review of SWM practices

1.1.1 In the Pacific Islands Region

The regional average waste generation rate is 0.66 kg per person per day.

Waste composition in the Pacific islands is mainly composed of biodegradable waste (kitchen and yard waste), as shown on the graph below :

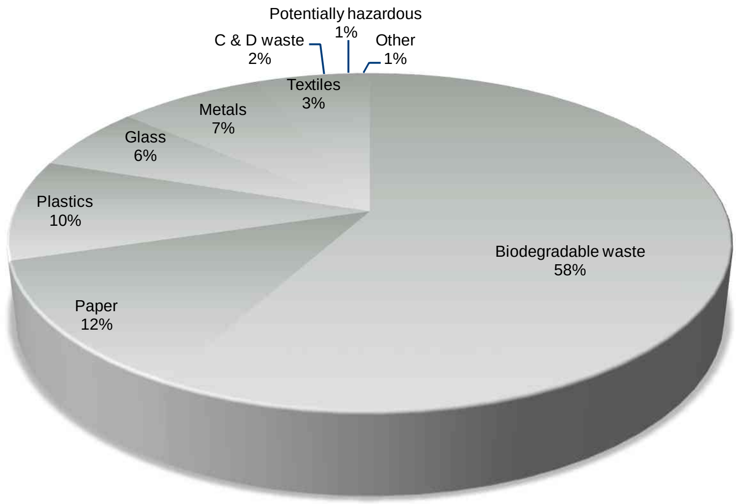


Figure 4 : Regional Waste composition in the Pacific islands Source : *S.C. Raj (2000), Solid waste education and awareness in Pacific Island Countries, Pacific Regional Waste Awareness and Education Programme, SPREP*

Historically, open burning was the main technique for disposal of solid waste in the Pacific island countries. In recent years, this practice has shifted to landfilling, which is cause for concern for small island states because of limited availability of land.

There are various types of landfills that can be developed, however, preferred strategies have emerged in the Pacific Region such as the "Fukuoka method", which is a semi-aerobic method first implemented in Samoa. When managed properly, it is a cost-effective and speedy method of stabilizing the waste, especially given the high organic content.

Type of facility	Country
Open dump	Fiji, Kiribati, Palau, PNG Solomon Islands, Tonga
Controlled dump (rehabilitated dump)	Guam, RMI, Tuvalu
Semi-aerobic landfill ("Fukuoka-type")	FSM (Kosrae State), Palau, Samoa, Vanuatu
Anaerobic landfill	Cook Islands, Guam, Fiji, Tonga (Tongatapu)
Incinerator	MW: Fiji, Palau, RMI, Samoa, Solomon Islands, Tonga PW: PNG

Table 7 : Waste disposal facilities in the Pacific Islands

1.1.2 In Fiji

Estimations for waste generation in Fiji is given in table 8. The table shows that the generation rate for Labasa is between 6 and 20 times higher than the average value for Fiji. Despite the fact that figures for Labasa include industrial and commercial waste, such disparity requires specific attention to be paid to commercial and industrial waste from sugar mill and the sawmills.

Division	Council	2007 Population	Waste collected (tonnes/yr)	Daily Generation Rate (kg/person)
Central	Lami	20,223	1,240	0.33
	Nausori	24,383	3,280	0.37
	Nasinu	87,446	12,965	0.41
	Suva	85,691	12,653	0.40
Western	Nadi	12,000	3,409	0.37
	Lautoka	44,226	6,305	0.43
	Ba	15,000	2,045	0.37
	Tavua	1,402	156	0.30
	Sigatoka	9,262	1,183	0.35
Northern	Savusavu	6,000	756	0.34
	Labasa	7,706 – 27,949	16,848	**1.7 – 6.0***

Includes commercial & industrial

Table 8: Comparison of waste generation rates across Fiji - *: Integration of Climate Change Adaptation into the Waste Management Sector (SPREP-2012)*

Solid waste disposal facilities in Fiji are currently not meeting general recommendations in terms of location and operation. For example, 7 out of the 11 sites are located in mangroves without leachate collection and all of them fail to control pest proliferation or odour generation.
It is to be noted that substantial amounts waste produced by industries (sugar mills, saw mills) end up in municipal dumps without any treatment.

The Naboro landfill, completed in 2012, is the only landfill complying with international standards.

Figure 5 : An aerial view of the Naboro Landfill - Source : The Fiji Times, June 2009

1.1.3 Local description at Labasa

In Labasa town, on Vanua Levu island, data suggest that over 16,000 metric tonnes of waste are delivered to the landfill each year. This volume includes green waste as well as industrial and commercial waste.

Since the catchment area of the landfill is unclear, the specific daily production ratio can only be estimated.
Values range from 1.7 to 6.0 kg per person. As seen earlier, such values sharply contrast with the national average of 0.3 to 0.4.

Although basic, the waste management system of Labasa Town is fairly structured. It features a landfill, household waste collection of urban areas, separate medical waste collection and specific waste management fees.

The Seaqaqa District and Labasa peri-urban areas do not have formal waste collection or disposal arrangements.

The Labasa landfill is particularly vulnerable to climate change impacts, because of its location on Vanua Levu – close to the Labasa River, and in a cyclone-prone area of Fiji.

1.1.3.1 HOUSEHOLD WASTE

Labasa is generally an agricultural town, off the tourist track. The surrounding areas of Labasa are mostly farming areas (sugar cane crop), largely contributing to the local industry.
Household waste rate would normally be 0.3-0.4 kg/day/capita rate in LabasaTown, with a high component of biodegradable waste.

1.1.3.2 MEDICAL WASTE

Labasa hosts the main hospital on the island which is the referral centre for all health centres and hospitals on Vanua Levu and for the islands surrounding it.

Until recently, both Labasa and Seaqaqa hospitals were using basic incinerators for contaminated waste, while used/expired drug vials are buried onsite in pits.

The Labasa hospital is now eaquipped with a new Mediburn incinerator since November 2012 and improvement for disposing of expired pharmaceuticals is under way.

1.1.3.3 INDUSTRIAL WASTE

The Sugar Mill produced considerable amounts of bagasse, mill mud and ash during the cane crushing season.
Some bagasse is used as fuel for boilers at the mill, however stockpiles still develop for lack of proper disposal solution.

Sawmills on the Vanua Levu island produce a large amount of sawdust.

2 BEST PRACTICES

2.1 Post-disaster waste management options

Best Practices vary depending on the type of waste. Obviously, in a emergency situation, options will focus on (i) eliminating immediate risks to health and safety (ii) recovering value from waste and eventually (iii) eliminating the waste.

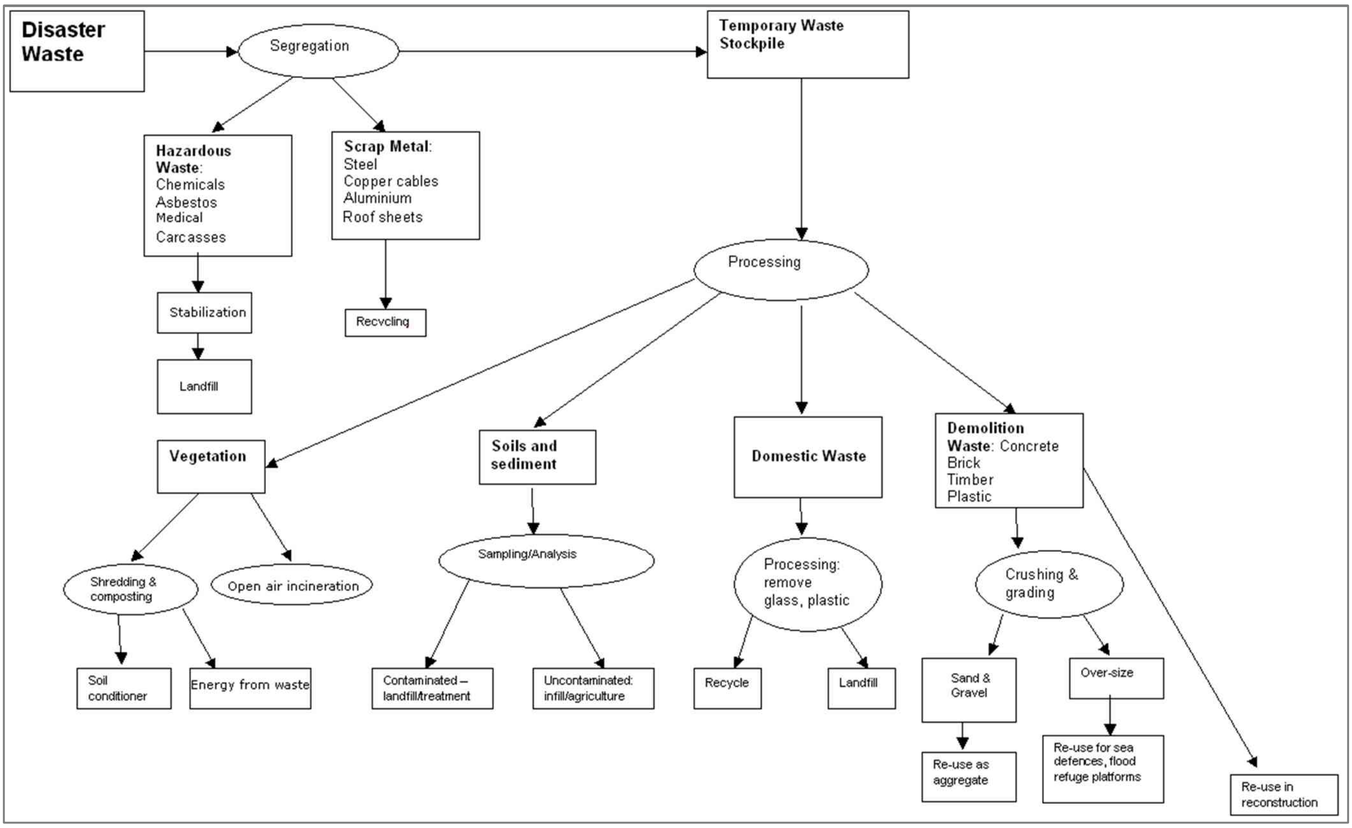


Figure 6 : Options for debris Separation / Segregation – Source : Disaster Waste ManageMent Mechanis - A Practical Guide for Construction and Demolition Wastes in Indonesia –UNEP 2008

2.1.1 Disaster waste mapping

A post-disaster assessment is more focused on the particular disaster and locality. In addition to the issues mentioned under pre-disaster assessment, post-disaster assessments include:

- **Waste Identification**; geographic presence of the wastes to create 'disaster waste maps';
- **Waste Characterisation**; quantification, composition and quality of the identified waste streams collated on 'waste maps';

- **Capacity Assessment**; evaluation of institutional and operational capacity including personnel, machinery, recycling as well as in-country waste management expertise;
- **Risk Assessment**; in accordance an assessment of the risks associated with each waste stream in order to allow for proper handling, processing and disposal;
- **Prioritisation**; each of the identified waste streams is given a ranking (for example, emergency, medium-term, long-term) based on the hazard risk assessment, and taking into account the reconstruction plans as well as general sustainability of the proposed interventions.

2.1.2 Pre-collection and collection

2.1.2.1 CLEAR ACCESS ROADS TO COLLECT WASTE

After disasters, clearance of debris blocking access roads should be the priority.

2.1.2.2 CLARIFY WITH OWNERS BEFORE CLEARING PROPERTIES

After a disaster, taking account of the owner's wish before attempting to dismantle or remove damaged houses or structures is preferable.

In spite of the effort required to identify owners, this approach is percieved as progressive as it makes it easier for real-estate owners to express their will, and for staff to identify plots to be cleared on the spot, thus lowering administrative costs.

For instance, Watari town office in Japan has set a rule that real-estate owners express their will for or against the removal by putting flags.

- Red flags show their will that the damaged houses or buildings be removed together with other debris and rubble on their lands.
- Yellow flags indicate that only debris and rubble within the premises need to be removed and the damaged houses or buildings be left untouched.
- Green flags express that the houses or buildings must be untouched and they do not want anything on their lands to be withdrawn.

2.1.2.3 DEVELOPMENT OF CASH-FOR-WORK OPERATIONS

In most cases, post disaster waste is handled by owners who strip the building and place waste on roads for collection. In such post disater contexte, waste transportation and segregation effort remains very limited for somewhat obvious reasons.

Therefore, when a municipality wants to speed up the clean-up process and promote waste segregation, it can setup a cash-for-work system in which individuals or preferably organised community members and volunteers receive a daily allowance for removing waste and transport it to designated areas and/or carry out segregation activities.

2.1.3 Haulage

Due to material segregation, haulage requires addition effort as different materials require different bins. In all cases, specific containers must be used when transporting : hazardous materials, healthcare waste and carcasses

2.1.4 Treatment and disposal

2.1.4.1 LANDFILLING WITH PRE-TREATMENT

Pre-treating waste prior to landfilling has many advantages:
(i) Reduces waste volume to be landfilled
(ii) Facilitates handling and recovery
(iii) Reduces hazardous nature

- Physical treatment
  Physical treatment prior to landfilling usually aims at reducing the volume of waste. Note that this operation can take place at the landfill or at a temporary debris management site.

  Volume reduction is achieved by grinding the material (or more rarely by burning it). Volume reduction not only preserves landfill capacity, but also reduces waste transportation.

  Prior to grinding waste, products containing asbestos or silica such as solar panels, should be removed to prevent the formation of dust.

- Chemical fixation with lime or cement kiln dust
  When dealing with acids and acid sludges, electrical/electronic waste, inorganic chemical and petrochemical waste, leachates, general debris and inorganic waste containing less than 30% of oil and grease, it is possible to carry out basic stabilization operation using stabilization agents such as lime or cement kiln dust.

  These products will immobilizes the leachable metals by combining with the waste. These chemical bonding agents form a solid structure around the waste that binds the contaminated material into a solid, non-leachable mass safe for landfill disposal. Acid and caustic wastes are neutralized and oxidizers will be reduced.
  The result is a non-hazardous cement-like material.

- Chemical + Mechanical stabilization and desinfection
  In some cases, waste from food industries, carcasses or food relieves requires disinfection as it will quickly decompose entailing bacterial contamination.

  Desinfection through the use of chlorine products (chlorine bleach, etc) is very effective in treating such waste. Chemical disinfection processes are often combined with a mechanical process, such as shredding or maceration, to ensure sufficient exposure of the chemicals to all portions of the waste.

The disinfectant is usually combined with a large amount of water to assist with the disinfection process and to cool the mechanical equipment in the shredding process.

Liquid waste treated with a mechanical/chemical disinfection process can usually be discharged into the sewer system, as long as the waste water treatment plant is able to handle the additional load.

Mechanical/chemical stabilization treatment devices are primarily on-site installations, rather than mobile treatment units, though these devices are available in different sizes based on the amount of waste to be treated.

- Thermal stabilization / autoclave
  Thermal stabilization is mainly used to sterilize waste before landfilling. Thermal stabilization is best advised for:
  - Infectious waste (human or animal tissue, blood, soaked bandages, etc),
  - Hazardous waste (sharps objects, discarded surgical instruments, chemical - medical and industrial - waste, etc)
  - Radioactive waste
  - Contaminated soil or sludge

Since Labasa has the largest medical facility on the island, the main focus will be medical waste treatment. Different techniques of thermal stabilization exist :

- Incineration
- Autoclaves
- Microwave
- Irradiation

After treatment, waste may generally be landfilled like regular municipal waste, or in some cases discharged into the sewer system.

(i) Incineration

Medical/infectious waste incinerators are often referred to as hospital/medical/infection waste incinerators (HMIWIs). The waste passes through the incinerator on a belt, and because most medical waste can be incinerated, the waste does not need to be sorted or separated prior to treatment.

Incineration has the benefit of reducing the volume of the waste (by 90%) , sterilizing the waste, and eliminating the need for pre-processing the waste before treatment. The resulting incinerated waste (ash) can be disposed of in traditional methods, such as brought to a landfill.

The downside of incineration is potential pollution from emissions generated during incineration such as dioxins and furans.

The incineration process can be applied to almost all medical waste types, including pathological waste, and the process reduces the volume of the waste by up to 90%. Modern incinerators can provide a secondary benefit by harnessing the heat created by the incineration process to power boilers in the facility

In some specific cases, hazardous waste containing heavy metals like Pb, Cu, Cr, Zn, etc can be stabilized when incinerated at high temperatures (900 to 950 °C) in the presence of clay and fly ash that can immobilizes their toxic metals to a maximum level.

After treatment, solidified mass can be utilized in construction or disposed off through landfilling without susceptibility of re-mobilization of toxic metals.

(ii) Autoclave

Autoclaves are closed chambers that apply both heat and pressure, and sometimes steam, over a period of time to sterilize medical equipment. Autoclaves are used to destroy all microorganisms that may be present in medical waste before disposal in a traditional landfill.

Medical waste that is subjected to an autoclave is often also subjected to a compaction process, such as shredding, after treatment so that it is no longer recognizable and cannot be re-used for other purposes. The compaction process reduces the volume of the treated waste significantly. After treatment and compaction, the treated waste can be combined with general waste and disposed of in traditional manners.

(iii) Open burning

Open burning has raised significant public concern, but state/local officials may allow it when needed if storage is lacking and debris amounts are large.
In all cases, burning of waste can be a fire hazard as well as a potential environmental hazard in relation to the gases emitted during combustion.

Therefore, it is generally recommended to burn vegetative debris in an open pit, while both vegetative debris and segregated clean building material may be burned in an ACI (Air Curtain Incinerator-see below for description).

Treated wood and wood coated with lead-based paint should be removed from the waste stream before any burning process. Similarly, no materials suspected to contain asbestos should be burned.

There main open burning methods are described below:

- Uncontrolled Open-Air Incineration
- Controlled Open-Air Incineration
- Air Curtain Pit Incineration (ACI): The air curtain burning method incorporates a pit constructed by digging below grade or building above grade (if there is a shallow groundwater table) and a blower
- Portable Air Curtain Incinerators (http://www.leesburgflorida.gov/)

Further illustration regarding open burning is presented in the table below:

Incineration method	Description	Advantages	Inconvenients
Uncontrolled open-air burning		• Very economical • No need for energy	• Only suitable for vegetation • Lacks any type of environmental control • Fire hazard
Controlled Open-Air Incineration		• Cost-effective • No need for energy	• Only for vegetation • No environmental control
Air Curtain Pit Incineration (ACI)		• Used for vegetative debris including tree stumps and combustible C&D waste or debris; • More complete combustion due to high velocity air injection which creates extremely high combustion temperatures • Minimize the dangers of fires associated with open burning due to wind and drought condition • The portability and quick set-up time saves costs on heavy equipment by utilizing multiple burning pits around the site • Low maintenance operation for the Air Curtain Blower	• Requires energy for the fan (electricity or fuel) • Maintenance of pits, which are susceptible to erosion
Portable Air Curtain Incinerator		• Most efficient incineration systems available because the pre-manufactured pit is engineered to precise dimensions to complement the blower system. • Reduce the particulate matter (PM) or smoke, • Stalling the smoke particles in this region just under the air curtain causes them to re-burn, further reducing their size to an acceptable limit. • ideal for areas with high water tables and sandy soils as well as areas where smoke capacity must be kept to a minimum.	• More expensive • Needs energy for the fan (electricity or fuel) • Needs equipement to transport the container

Table 9: Open burning techniques

- Microwave and irradiation

These systems are not suitable for disaster waste.They are mentioned only for the sake of completion

2.1.4.2 TEMPORARY STORAGE PRIOR TO LANDFILLING

In many large scale disasters, waste volumes exceed permanent disposal site capacities. Temporary or sub-standard debris and waste disposal sites can be employed.

Temporary storage areas can also be established to sort material collected during kerbside collections. Some recycling can be carried out, in particular metals segregation, and vegetative waste can be chipped and used as mulch or for landfill cover.

Lined temporary storage and reduction areas should be established for ash, household hazardous waste, fuels, and other materials that may contaminate soils and groundwater.

2.1.4.3 LANDFILL OPERATION

Landfills play an important role in any disaster waste management strategy, providing effective means of managing disaster waste when designed and operated appropriately.

However, design and operation rarely makes provision for disaster waste, and municipalities should consider expanding existing facilities (in terms of size and waste acceptance) or constructing new facilities.

In particular, the introduction of recycling and health and safety management procedures should be considered as mandatory considerations as part of both the emergency response/recovery and solid waste management systems.

Some other measures will foster effective waste management and disposal such as keeping the access road clear and trafficable, compacting and applying a cover layer over fresh waste.

- Keep a clean access road to the landfill
  Very often waste is dumped along the access road preventing access to the landfill itself. Keeping the access road clear and trafficable at all times is a prerequisite to proper landfilling.

- Waste compaction
  Waste compaction is essential, simply due to the saving of landfill space. In addition compacted waste has a range of other benefits such as better mechanical stability, less odour release, reduced risk of landfill fires, etc.

  Good waste compaction can also reduce leachate generation rates (by increased surface runoff) as different research studies indicate.
  Compaction is achieved using dozers or waste compactors. The latter being more effective, but also more expensive and hence often not affordable for landfill operators on small islands under tropical climates.

Therefore, most effective waste compaction can be reached by spreading the waste in 30 to 40 cm thick layers with subsequent compaction by repeated passages of the available waste compaction equipment. The number of compaction passes needs to be optimized in conjunction with fuel consumption of the compactor (operational costs).

- Daily cover application
  Daily cover application is essential and should be standard practice in every landfill. Daily cover application will minimize odours, waste blowing, and vector populations.
  It might also avoid landfill fires, minimize contamination of surface runoff, and improve aesthetics of landfill operation.

  The availability of soil or other inert matter as cover material is crucial, that is why landfill operators often face difficulties regarding the availability of suitable cover material, which frequently leads to landfill operation without daily or weekly coverage of the waste.

  In this perspective, instead of transporting soil or other inert material to landfill over long distances, unutilized compost or demolition waste could be used as alternative daily cover material.

  This can be considered as “best practice” for sites with insufficient soil cover material or lack of financial resources.

2.1.5 Introduction of 3RC (Reduce, Reuse, Recycle and Compost)

Due to the potentially large volumes of material produced in a natural disaster, recycling and reuse will lessen the burden on disposal facilities, cut costs, and provide a valuable material resource.

Reuse and recycling (including mulching/composting), coupled with efficient processing and transportation, not only conserves natural resources but also helps reduce the amount of greenhouse gas emissions and saves scarce landfill space.

Processing disaster debris through grinding, shredding, or any other means without an understanding of the end uses and market specifications may result in the products becoming unusable for their intended purposes, necessitating disposal of the debris.

2.1.5.1 PRE-TREATMENT PRIOR TO RECYCLING, REUSE OR COMPOST

Pre-treatment prior to recycling, reuse or composting consists in sorting, size reduction and storage.

Shredding and size reduction of MSW is most commonly utilized in the materials recovery sector of integrated solid waste management, i.e. recycling.

Historically the major benefits of size reduction are threefold:

(i) Shredding the bulk waste stream breaks the raw MSW into its basic components by tearing and breaking open paper, plastic, and glass containers such that material recovery and separation will be more effective.

(ii) Shredding the MSW reduces the average particle size to a more workable size that can be better handled by any subsequent processing equipment or personnel.

(iii) Most importantly for material recovery facilities (MRF's), shredding produces different size distributions for the different material components of MSW, allowing for automated material separation such as air classifiers, screens and optical sorters.

Depending on the materials that need to be recycled, different equipement are required for sorting and storing prior to recycling, reuse or reexportation.

	EQUIPMENT	MATERIALS HANDLED
Crushing / Comminution Equipment	**Size reduction is the unit operation during which waste materials are mechanically reduced in size. The objective is to obtain a product that is reasonably uniform and considerably reduced in size in comparison with its original bulk form**	
Hydraulic breaker or jackhammer	A pneumatic impact tool is used for breaking oversized material into pieces small enough to be processed by the next crusher/reduction unit in the process.	Concrete pavement, foundations.
Jaw Crusher	Designed to crush large chunks of concrete, asphalt, etc.	Concrete, asphalt, pipes, steel, rebar, manhole lids, etc. Compressible materials such as wood and plastics tend to jam up the jaws and severely reduce throughput.
Hopper	Receives the chunks and feeds them to the cone, or impactor.	
Cone	Crushes concrete and asphalt to aggregate size	
Impactor	Crushes concrete and asphalt to aggregate size	
Hammermill	Also known as wood hog, it can process a variety of wood materials. Reduction occurs as the heavy hammers, attached to a rotating element, impact the material as it enters and eventually force the shredded material through the discharge of the unit.	Wood

Stump Grinder	Large machines, often trailer-mounted and top-loaded by on-board knuckleboom loaders. The machine is more expensive than a wood hog but can handle large bulky materials.	Wood, stumps
Rotary Shear Shredders	Low-speed, high-torque machines that rip and tear material apart.	Ideal for primary reduction of bulky wood material, such as pallets, crates and stumps, up to 3" to 4" in diameter. Large units can also reduce concrete, steel drums, white goods and furniture.
Screw Shredders	Shredding is done by two parallel screws with opposing threads.	bulky wood material, including tree stumps, brush, logs, scrap lumber, clean wood, pallets, trees, yard trimmings.

Screening/ Separating Equipment	**Screening is a unit operation used to separate mixtures of materials of different sizes into two or more size fractions by means of one or more screening surfaces.**	
Grizzly Screen	Vibrating grizzly feeders are ideal for feeding rubble and mixed C&D material to the primary crusher.	rubble and mixed C&D material
Vibrating Screen	Vibrating screens can be designed to vibrate from side to side, vertically, or lengthwise.	
Trommel Screen	An inclined rotating cylindrical screen where material to be separated tumbles and contacts the screen several times as it travels down the length of the screen.	
Disc Screen	Disc screens consist of parallel horizontal shafts equipped with interlocking lobed (or star-shaped) discs that run perpendicular to the flow of infeed material.	Wood
Air Classifiers	A separator which uses an air stream to separate materials based on the weight difference of the material.	Commingled waste (plastic, glass, paper, metal)
Flotation	A unit operation which employs water to separate wood from rubble-based material.	separate wood from rubble-based material

Magnetic & Electric Field Separation	**Uses the electrical and magnetic properties of waste materials to separate them.**	
Magnetic Separation	Designed to remove ferrous metals from a moving bed of material.	ferrous materials
Electrostatic Separation	High-voltage electrostatic fields can be used to separate nonconductors of electricity, such as glass, plastic, and paper, from conductors such as metals.	nonconductors such as glass, plastic, and paper
Eddy Current Separation	Separates non-ferrous metal (usually aluminum cans) from the waste stream by passing a current through the materials. These systems can be expensive.	
Manual Picking Station	**An elevated platform with a conveyor and a catwalk along both sides of the conveyor. Manual sorting is done by removing specified items from the conveyor and dumping`` them in the appropriate chute provided.**	

Table 10 : Selected reprocessing equipment (UNEP, 2008)

For instance, selected equipements that could be useful for reprocessing C & D wastes at Labasa, are further described below :

Solid waste crushing machine	
Basic purpose	• For size reduction of solids.
Description	• This machine is used to reduce the size of solids such as concrete, bricks or asphalt to manageable sizes so that it can be easily transported or reused.
Essential characteristics of equipment	• Mobile - either self-propelled or can be transported on a flat-bed truck. • Jaw crusher that can handle a variety of C&D wastes • Can include a sorter that separates the solids into different aggregate sizes
Type of waste processed	• Concrete (including blocks), stone (marble, granite, rock, etc.) brick, etc.
Capacity of machine	• Size of materials produced: about 0.2 in. to 3 in. • Capacity: 15-20 tons per hour. • Mobility: mobile - self-propelled or truck mounted.
Power needs	• Diesel operated.

Waste sorting machine	
Basic purpose	• Separation of solids to different sizes
Description	• This machine is used to sort C&D and municipal waste into different types and/or sizes so that it can be reused /recycled.
Essential characteristics of equipment	• The machine uses a manual sorting process to separate C&D wastes according to their size and weight. • Then machine can also be used for MSW waste, when not in use for debris or C&D wastes.
Type of waste processed	• Mixed C&D waste, MSW wastes.
Elements required	• Belt conveyor: 50-75 cm wide, 7-10 m long. • Hopper (loading ramp).
Capacity of machine	• 5-8 tons per hour.
Power needs	• Electrical or diesel power.

Waste Shredding machine	
Basic purpose	• For shredding of plant and vegetative matter. • For shredding plastic waste.
Description	• This machine is used to shred plant and vegetative matter into smaller manageable pieces so that the resulting organic waste can be used more effectively as a fuel or as mulch for composting. • This machine is used to shred plastic waste into smaller manageable pieces so that the resulting plastic waste can be used more effectively as recycling materials.
Essential characteristics of equipment	• Essentially handles organic waste and plastic waste (excludes solid C&D wastes such as concrete, brick or stone). • The machine can also be used for MSW waste, when in use for debris or C&D wastes.
Type of waste processed	• Plants and other vegetative matter. • Plastic waste.
Capacity of machine	• 3000 to 5000 kgs per hour. Max. size of plant trunks: 15-20 cm for vegetative matter. • 500 to 1000 kgs per hour for plastic waste.
Power needs	• Diesel powered.

Composting facility	
Basic purpose	• For treating and processing organic waste.
Description	• This facility is used to process organic waste through open windrow process to produce compost.
Essential characteristics of equipment	• Essentially handles organic wastes, and composts them using a windrow turner.
Type of waste processed	• Plants and other vegetative matter (organic waste).
Capacity of facility	• 5-10 tons of organic waste per day.
Elements required	• Processing area of 500 m^2 (20 x 25 m^2). • Building and its facilities (including office, drainage system pumping station, mechanical electrical, water supply leachate collection). • Machine for turning over compost pile - 50-80 horsepower tow-behind windrow turners/aeraters; 500-1000 m^3 per hour throughput. • Thermometer (multi). • Nutrition test kit (compost quality test). Test kits (and procedure manuals) to measure pH, soluble salts/phosphorus and potassium), moisture content, percentage of organic matter particle size and bulk density.
Power needs	• Electrical or diesel power.

Table 11 : Selected reprocessing equipment (UNEP, 2008)

2.1.5.2 RECYCLING

Recycling waste following disasters has numerous benefits:

- reduced cost of disposal and burden on disposal facilities;
- employment opportunities for affected communities;
- recycled material can be fed back into the rehabilitation and reconstruction process.

Many components of disaster waste can be recycled. Materials can be used in a number of post-disaster applications including soil for landfill cover, aggregate for concrete, and plant material for compost (fertilisation and slope stabilisation).

In general contractors are keen on bidding for recyclable products, if it is well sorted. Contracts and monitoring should be developed to ensure that the recycling procedures comply with local, tribal, State, and Federal environmental regulations.

Common recyclable materials include:

- Metals - Hurricanes and tornadoes can cause extensive damage to mobile homes, sun porches, and green houses. Most of the nonferrous and ferrous metal debris is suitable for recycling. Metal maulers and shredders can be used to shred trailer frames, trailer parts, appliances, and other metal items. Ferrous and nonferrous metals are separated using an electromagnet and then sold to metal recycling firms.

- Soil - Debris removal operations may include transporting large amounts of soil to a debris management site. It may be combined with other organic materials that will decompose over time. This procedure can produce significant amounts of soil that can be sold, recycled back into the agricultural community, or stored onsite to be used as cover.
  In agricultural areas where chemical fertilizers are used heavily, recovered soil may be too contaminated for use on residential or existing agricultural land. It may be necessary to monitor and test the soil to ensure that it is not contaminated with chemicals. If the soil is not suitable for any agricultural or residential use, it may ultimately have to be landfilled.

- Concrete, asphalt, and masonry debris - Concrete, asphalt, and masonry products can be crushed and used as base material for certain road construction products or as a trench backfill. Debris targeted for base materials needs to meet certain size specifications as determined by the end user.

2.1.5.3 REUSE

Opportunities should be explored with the beneficiaries for reusing items, which may otherwise be thrown out as waste. Many materials can be reused and opportunities for reuse will dependant on culture, location and facilities available. For example, wood from packaging can be used as firewood or for shelter items, boxes and containers reused for storage etc.

2.1.5.4 COMPOSTING

In many small islands, where there is limited or no space for landfilling, and where the soils are sandy, and poor in structure, the production of compost from organic waste would have a two-fold benefit. Firstly, it reduces the volume of waste to be land filled, and secondly, it provides a nutrient, and structural boost to the soils where it is applied.

Composting is the controlled biological decomposition of organic material in the presence of air to form a humus-like material. Controlled methods of composting include mechanical mixing and aerating, ventilating the materials by dropping them through a vertical series of aerated chambers, or placing the compost in piles out in the open air and mixing it or turning it periodically. Instead, composting, as a treatment option, is used to decompose large quantities of waste either on-site (e.g., on a farm in association with animal disease control activities) or off-site (e.g., composting facilities). Off-site composting will involve transportation considerations.

Windrowing is a common method of composting, based on storing the organic waste in long rows. Windrows can be open,or covered depending on the cliate and the moisture content of waste. Over time, the windrows of composting waste are aerated, turned and mixed as necessary to maintain the ideal composting conditions. Aeration can either be done manual or mechanical turning, or by static aeration introducing air via a network of perforated pipes within the compost piles. Windrowing using mechanical turning likely to be more suitable.

2.1.5.5 ADVANTAGES AND INCONVENIENTS OF 3RC METHODS

Method	Advantages	Inconvenients
Recycling	• Reduction of landfill space used. • Reduction in the quantity of raw material demand (for purposes where recyclable materials are suitable). • Possible reduction in waste management costs. • Reduction in transportation for raw materials and debris. • Job creation (for developing countries, in particular).	• Time to collect and process the materials; • Unavailability of specialised processing equipment • Inability to physically separate the materials • Lack of desire to offset raw material use in rebuild; • Unavailability of disposal sites; • Cost relative to other disposal methods • Unavailability of markets to absorb large quantities of material
Reuse	• Arguably the simplest method to minimize waste	• Reused material generally need cleaning and is of lower quality
Composting /Windowing	• Environmentally friendly	• Land use

Table 12 : Comparative aspects of 3RC methods

2.1.6 Energy from waste

Waste-to-energy treatment options is the best technique for combustible waste, such as waste wood. Note that the quantity of industrial waste from sugar plants and sawmills at Labasa and the power requirements (thermal and electrical) from these industries could be an opportunity to develop industrial scale waste-to-energy schemes that could absorb green waste and wood waste as boiler fuel.

For example, Green Energy Resources, a company that provides renewable energy, purchased 2 million tons of vegetative debris from Louisiana and Mississipi in September 2005, after hurricane Katrina to produce wood chips.The same approach took place in Texas following Huricane Rita, with millions of tons of vegetative debris shredded into biomass fuel and shipped to various European countries to be used for power generation.
Likewise, in Florida, nearly half of the vegetative debris generated by Hurricanes Charley, Frances, and Jeanne in Polk County was used to generate electricity by Progress Energy. The company's Ridge Generating Station received about 800,000 cubic yards of debris. County officials stated that this was not only the most environmentally preferable option, but also the most cost effective.

2.1.6.1 CHIPS OR PELLETS FOR REFUSE DERIVED FUEL (RDF) PRODUCTION

Refuse derived fuel is a fuel produced by shredding, sorting and dehydrating any combustible product in order to generate a higher heating value fuel. RDF can be used in cement plants, waste to energy plants or co-combusted in a coal fired power plant.

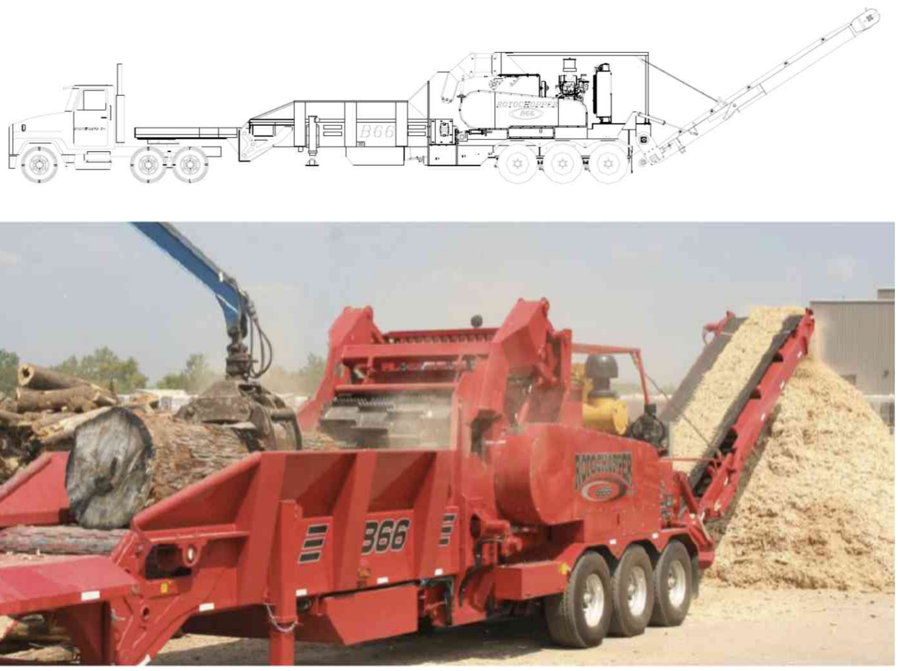


Figure 7 : Example of one-pass diesel horizontal wood grinder – Source: Rotochopper USA

Studies are under way in New Caledonia to use between 5 and 10% of secondary fuel in the Lapita coal fired power plant, amounting to nearly 50,000 tons of RDF per year.

2.1.6.2 ANAEROBIC TREATMENT WITH BIOGAS RECOVERY

Natural disaster debris may be sent to a waste-to-energy facility, depending on the types and amounts of debris present. Typical non-hazardous waste-to-energy facilities can handle many types of debris, including vegetative debris, C&D materials, furniture and other home contents, and putrescible wastes. Additional storage capacity may be necessary for this material as natural disasters often produce more material than a typical combustor can handle. Since these facilities often are equipped with air pollution controls, contamination that can pose a problem to recycling and composting operations (such as treated wood) may not be a problem here.
Some waste-to-energy facilities require that the debris be ground prior to receiving it. This could be addressed in any pre-negotiated contracts.

Natural disasters can create large amounts of vegetative debris (the primary biomass produced from many natural disasters) that could be used as a fuel or energy source. Using biomass to create energy instead of disposing it via open burning or in landfills has both environmental and economic benefits. Environmental benefits include saving landfill capacity and reducing air emissions.

Power plants that accept biomass may not be located near communities affected by disasters, so delivering the materials to power generators instead of landfills may require little extra effort or cost. One obstacle that may exist is that the volume of debris may be much more than the facility can handle. Several different methods of materials management might be needed to effectively deal with very large quantities of material in a timely manner.

2.2 Global review of past experiences

CASE 1 : Louisiana - Hurricanes Katrina and Rita - August 29, 2005

Hurricane Katrina struck southeastern Louisiana, causing widespread damage along the coastline and in New Orleans. The Louisiana Department of Environmental Quality (LDEQ) issued it first emergency declaration on August 30.
This declaration, in part, addressed debris management issues. Thereafter, LDEQ developed a debris management plan.

Preparedness / Planning

Communication

The LDEQ (Louisiana Department of Environmental Quality), together with EPA and the U.S. Coast Guard, formed a unified command.This facilitated debris management and recycling discussions between LDEQ and EPA. Daily communication was established with the US Army Corps of Engineers (USACE) and FEMA.
Outreach to citizens was facilitated through flyers, websites, TV and radio announcements, and news releases.

Collection and Recycling

The State of Louisiana identified recycling as a priority.

- Vegetative debris : Vegetative debris was generally chipped or ground and used as cover at landfills. Household hazardous waste (HHW) : Over 24 million pounds of HHW was collected. Much of the HHW was recycled. Recycled materials included batteries, propane cylinders, gasoline, and oil.
- Electronic wastes : over 12,500 tons of discarded electronic wastes have been collected and properly recycled. The electronics were being properly recycled, in a cost effective manner, through the use of EPA's Recycling Electronics and Asset Disposition (READ) Services.
- White goods : EPA was involved in the collection, refrigerant extraction, and recycling of the steel from nearly 400,000 white goods.
- Vehicles and vessels : The LDEQ was requested by the Governor's Office to remove the hurricane damaged vehicles and vessels destroyed after the two hurricanes. Approximately 12,000 vehicles and vessels from the public rights-of-way and from private property were collected.

Lessons Learned

- Large scale recycling
- Damage vehicle collection

Source

"Planning for Natural Disaster Debris Guidance" published by the U.S. Environmental Protection Agency (EPA), March 2008 (document EPA530-K-08-001)

CASE 2 : Mississippi - Hurricane Katrina - August 29, 2005

Hurricane Katrina slammed into the Mississippi and Louisiana Gulf Coast and moved up the eastern side of Mississippi.
One of the biggest environmental challenges the Mississippi Department of Environmental Quality (MDEQ) faced was managing the enormous amount of debris caused by Hurricane Katrina.
According to FEMA, approximately 46 million cubic yards of debris was created in the State of Mississippi alone. Of this amount, over 24 million cubic yards was generated in the three Gulf Coast counties of Hancock, Harrison, and Jackson. Approximately 70% (or over 17 million cubic yards) of the debris in these three coastal counties consisted of building and structural type wastes and the other 30% (or just over seven million cubic yards) consisted of trees, limbs, and other vegetative debris.

Preparedness / Planning

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Communication

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Collection and Recycling

Immediately after the storm, MDEQ conducted an evaluation of the recycling capabilities and of the existing landfill capacity on the Gulf Coast. This evaluation indicated that recycling of much of the disaster debris would be difficult given that the materials were mixed together and in some instances contaminated or damaged beyond recovery.
Consequently landfill disposal would likely be the most practical solution to the largest volume of the debris.

New emergency landfill sites for the debris as well as other management options needed to be considered because of a significant shortfall in landfill disposal capacity. MDEQ also was concerned that the communities should preserve some available landfill capacity for the future needs of the counties as large volumes of wastes would also be generated in rebuilding our Gulf Coast.
Overall, some 340 temporary sites were approved for handling the wastes generated by Katrina. Of the 340 sites, more than 250 were chip or burn sites for vegetative wastes only, approximately 30 sites were approved for staging wastes, and approximately 80 sites were approved as burial sites.

On the coast, the 13 temporary emergency landfill sites and the six permitted disposal sites received the bulk of the 17 million cubic yards of building and structural debris (along with six permitted disposal sites). The other disposal sites were used primarily for the disposal of vegetative debris which could not be recycled.

Household Hazardous Waste : HHW and similar items from commercial businesses were segregated from the debris at the point of initial collection, in some instances at a specific staging or segregation site, and then finally again at the actual disposal sites.

Larger household items (such as large appliances, lawn mowers, computers, and televisions) : they were segregated and removed because these items contain chemicals, refrigerant, heavy metals, and petroleum products. In addition, these bulky items would make proper compaction at the landfills difficult to achieve.

Perhaps the greatest recycling success was with white goods and other similar metals. Mississippi had less success in recycling electronics products due to the damage and salt water inundation to many of the units that were collected. However, there were some sponsored events on the coast to recover damaged electronic materials.

Lessons Learned

MDEQ conducted **environmental siting reviews** on the existing landfills and on the 13 sites used for the temporary emergency landfills.

Debris sites **were required to receive proper compaction, a periodic earthen cover and a final earthen cover upon closure**. Proper compaction was important at landfills because it helps to prevent the infiltration of rainwater into the landfill, thereby reducing leachate generation and the combustion potential within the landfill.
MDEQ has worked with FEMA to **ensure proper closure of disposal sites, mulch sites, burn sites and staging sites**. With FEMA's assistance, MDEQ installed groundwater monitoring systems at each of the 13 emergency disposal sites and at the six permitted existing disposal sites that took the Katrina debris.

MDEQ is also working on an evaluation and revision of the Emergency Debris Management policies implemented after Katrina. The revised policies will be compiled into a Debris Management Plan that will assist the different members in being prepared for the next disaster event that could occur in Mississippi.

Working with Private Companies Dell Computer and Best Buy partnered with EPA, the states, and local governments to increase collection and safe recycling of computers and related electronic equipment, including monitors, printers, scanners, keyboards, mice, laptops, TVs, VCRs, DVD players, radios, and disks destroyed by the effects of Hurricane Katrina. This effort resulted in recycling of more than 220,000 pounds of electronics debris.

Source

"Planning for Natural Disaster Debris Guidance" published by the U.S. Environmental Protection Agency (EPA), March 2008 (document EPA530-K-08-001)

CASE 3 : Palm Beach County, Florida - Hurricanes Frances and Jeanne - September 3, 2004

Palm Beach County, Florida was hit by Hurricane Frances. The county's Solid Waste Authority (SWA) immediately established nine temporary debris management sites throughout the county. Three weeks later, the county was hit by Hurricane Jeanne. With winds exceeding 115 miles per hour, these two powerful storms caused a large amount of damage to the county.

Preparedness / Planning

Palm Beach County had a debris management plan in place prior to the 2004 storm season. Solid Waste Authority (SWA) drafted a plan to restore public infrastructure following a disaster, locate and secure temporary debris storage sites, put policies in place to assist local municipalities in clearing roads for emergency personnel, and facilitate federal reimbursement. The plan included pre-existing contracts that provide trained and qualified debris management contractor services in the event of a disaster. Five contractors and numerous subcontractors and vendors were employed in the debris collection and management processes, all of which were approved by FEMA.

Communication

In the hours before Hurricane Frances made landfall, SWA began **communicating with the public through the Palm Beach County Emergency Operations Center.** SWA instructed residents to keep garbage separated from storm debris and announced that its customer service information hotline would be open within hours immediately following the storm. The customer service information staff received and processed more than 100,000 phone calls in two months. The **public information campaign conducted just before hurricane season** educated the public to place vegetative debris and mixed debris in different piles. The campaign proved to be very effective in shaping the public response during the recovery efforts.

Collection and Recycling

Local haulers and contractors, coordinating with SWA, cleared roadways and neighborhoods of more than two million cubic yards of debris during four weeks after the hurricane. Temporary debris collection sites were established at nine locations two days after Hurricane Frances passed. The temporary debris sites stayed open for three months and approximately four million cubic yards of debris were collected and processed. Approximately 80% of the debris was vegetative debris and 20% was mixed debris. More than three million cubic yards of vegetative debris was ground up and consolidated into chipped mulch. SWA innovatively diverted most of the mulch from the landfill and conserved more than 25 acres of landfill space. SWA reused approximately 872,000 cubic yards of mulch through land application to large tracts of agricultural land located in the western parts of Palm Beach County.

Lessons Learned

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Source

"Planning for Natural Disaster Debris Guidance" published by the U.S. Environmental Protection Agency (EPA), March 2008 (document EPA530-K-08-001)

CASE 4 : Escambia County,Florida - Hurricane Ivan - September 15, 2004

Escambia County, Florida, Hurricane Ivan made landfall with winds exceeding 130 miles per hour. The 661 square mile county, including the Pensacola metropolitan area, was impacted by the storm's eastern eyewall that produced the strongest wind gusts and heaviest rain bands. The storm generated more than ten million cubic yards of debris in a 12-hour period.
Escambia County successfully diverted more than half of the debris from disposal in landfills and recovered more than 90% of the displaced beach sand

Preparedness / Planning

Escambia County Solid Waste Management Department officials had a hurricane debris management plan in place prior to Hurricane Ivan. In developing the plan, private contractors submitted information to be placed on a list of potential debris management service providers. County officials planned to select contractors from this list in the event of a disaster.
The **existing management plan also identified temporary debris storage and processing sites.** Many of the county-owned parks were used to stage debris for processing and disposal. These sites easily could be returned to recreational facilities after the debris was removed. Meanwhile, without the Navy-owned recreation area which was not in the plan, the temporary sites that had been included in the County's plan could not have accommodated such a large volume of debris.

Communication

As soon as the area was placed under a hurricane warning, Escambia County officials b**egan communicating with the public through radio and TV public service announcements.** Residents were urged to segregate debris generated by the hurricane from other household or municipal wastes. These messages continued throughout the event and were the primary means of communication with the public until newspapers resumed operations. A **debris hotline** was also established after Hurricane Ivan and was still in operation a year later, making valuable contributions to the clean up efforts of both Hurricanes Dennis and Katrina in 2005.

Collection and Recycling

Clearing the roadways by cutting and staging downed trees was the first priority of the state and county road crews while County officials initiated the **contractor selection process.** Once contracts were in place, it was ultimately the debris contractors' responsibility to identify the means of debris management. The County managed more than 6.5 million cubic yards of vegetative debris in various ways: 6**0% exported to Italy and sold as biomass for energy generation; 15% sold to paper mills; 15% used as landfill cover; and 10% incinerated on site in air curtain incinerators.** The storm eroded the existing beaches and dune system and deposited the sand onto roadways and beachfront properties and into Escambia Bay. The **sand was filtered through a screen to sort out contaminants.** Approximately 95% of the sand was recovered through the screening process and reused to establish a five-year protective berm.
In the aftermath of the 2004 hurricane season, Seminole County, Florida, processed more vegetative debris than the total amount processed over the entire previous decade.
Most of the vegetative debris was wood waste, which the County ground into mulch. The County used 360 tons of the ground mulch to establish temporary debris storage and processing site. The mulch was used as a good road base for heavy machinery and vehicles because the ground was saturated.

Lessons Learned

County officials included a list of contractors in the county's debris management plan. **The contractors were not pre-qualified, which slowed the initial evaluation process after the storm hit.** County officials have since revised their current debris management plan and it now contains pre-qualified debris contractors in the case of another disaster event. These contractors can be mobilized and engaged prior to the landfall of a hurricane.

Escambia County officials also learned **that communication with the public should be ongoing through a public awareness campaign.** One of the biggest problems that the county faced was public outcry for debris to be picked up sooner rather than later. Making the public aware of the county's debris management procedures and policies would help the public plan and react in a better and more efficient way.

Source

"Planning for Natural Disaster Debris Guidance" published by the U.S. Environmental Protection Agency (EPA), March 2008 (document EPA530-K-08-001)

CASE 5 : Alstead , New Hampshire - 2005 Flooding

During the first week of October 2005, the western part of the State of New Hampshire was subjected to intense flooding and damage.

Preparedness / Planning

The area received approximately 12-inches of rainfall in a 30-hour period. The inability of existing drainage networks to handle the intense rainfall caused a road embankment to fail resulting in a 30-40 foot high wall of water and debris being discharged into the valley. The resulting flood resulted in loss of life, damage to private property, destruction of homes and businesses, severe damage to infrastructure, extensive erosion, contamination of drinking water and loss of agricultural productivity.

Communication

Soon after the flooding subsided, the Town of Alstead relied on local television, cell phones, and word of mouth (the small nature of the town made this possible) to inform residents of the magnitude of the flooding and what plans were being put in place to collect debris.

Collection and Recycling

The local community field in the town became a temporary storage area for flood debris. Materials were **sorted into separate piles of tires, wood, cars, metal, and trees.** Trees were shredded into wood chips and topsoil was recovered by screening some of the woody debris.

Lessons Learned

Emergency Permits for temporary facilities were helpful in collecting, processing, and disposing /reuse (CPD) of disaster debris.

Pre-identifying proximate emergency CPDs is extremely helpful so that their site capacity and handling rates can be estimated and it allows to account for any archeological, historic or environmental issues. Modification of existing facility permits, on a temporary basis, was important to handle incoming disaster debris.

Pre-planning in the following areas also can save time and money and/or increase the effectiveness of the operations:

1) estimate volumes and types of debris to be encountered,

2) establish debris segregation protocol prior to the event and communicate with others, e.g. FEMA, ACE, EPA, USCG and Other States,

3) pre-identify processing/disposal facilities and capacities (e.g., wood burning power plants for tree/brush/clean wood), and

4) open burning is almost inevitable for some debris; especially trees and brush (pre-identify State Air Agency/EPA requirements for the burns, including air monitoring).

Implementation of clean-up efforts was another area where valuable lessons were learned, including:

1) trying to have 2-3 weeks of supplies for response staff to be self-sufficient on-site,

2) reviewing debris clean-up projects for any Supplemental Environmental Projects (SEPs) being considered by the enforcement agencies to see if they can be included and/or modified for disaster debris clean-up,

3) reviewing debris types and characteristics and deciding if any special processing tools are relevant (e.g. shaking screens to remove dirt/sediment from building debris prior to landfill disposal, need for tugs to remove sunk vessels, etc), and

4) making sure that homeowner debris is separate from state/local agency clean-up efforts to simplify FEMA reimbursement.

Source

"*Planning for Natural Disaster Debris Guidance" published by the U.S. Environmental Protection Agency (EPA), March 2008 (document EPA530-K-08-001*

CASE 6 : The Tokage typhoon, Japan - October 2004

The Tokage typhoon (Typhoon No. 23 of 2004) hit the Japanese islands from 19 to 21 October 2004, leaving a trail of damage and destruction. It was the worst typhoon for 2004. While the impacts was heavy – 93 dead with more than 490 injured as of 29 November 2004 – extensive damage was avoided due to the various levels of preparedness and mitigation measures that were in place at the national, prefectural and local levels. The typhoon produced 45,000 tons of waste, which was equal to the total waste normally produced in 1.5 years by the city. The waste was composed of domestic materials (including electrical appliances), woods and logs, significant amount of weeds, and silt.

Preparedness / Planning

It has to be noted, however, that waste management (collection, treatment, processing, disposal and incineration) is well organized in Japan, via strong laws and regulations, and good implementation of programmes by local governments. It particularly, also includes hazardous wastes. This may have contributed to a significantly lower impact of the typhoon.

Typhoon Tokage and Waste Management Issues:

Two ministries are primarily responsible for the waste management. Ministry of Environment deals with waste produced by the disaster event, and the Ministry of Health, Labour and Welfare handles debris and rubble, resulting from collapsed buildings and infrastructure. Since Tokage produced an unusual amount of waste, it was the primary responsibility of the Ministry of Environment to work with local governments, and provide resources (both technical and financial).

Communication

The city found itself unable to handle the waste, and had to seek help and cooperation from surrounding cities and prefectures. This waste also caused several other problems in terms of clearing the waste in a timely manner to avoid health hazards, treatment and incineration of wastes (location, man-power, cost), and recycling of waste materials, where possible.

Collection and Recycling

High percentage of electrical waste: A related problem of wastes and debris was the handling of a high percentage of household electrical appliances, which were discarded due to water logging and flooding of houses. Few residents realized that most of these appliances could be recycled and used again, highlighting the need for sharing appropriate information and awareness on techniques to carry out such restoration.

High volume of waste plant debris and logs: Significant part of the waste was composed of plant debris and logs, which was transported by rivers and flood waters from mountains and forests to Toyo-oka city. These debris and logs created a barrier in the rivers, resulting in overflows and flooding. This was caused by improper management of planted forests, culling of trees, and clearing of ground cover – an example of an upstream issue having significant downstream impacts.

Lessons Learned

Lessons learned from the Tokage typhoon in Toyo-oka can be classified into 3 parts:

1) infrastructure management : Dyke Management, Urban and land-use management, Forest Management and River Basin Management

• **Forest Management:** To enhance growth of stronger trees, some of the slow-growing trees are culled, but not cleared since these do not have any market value. During a typhoon, these wood debris are washed downstream, clogging the rivers. Proper forest management is a key to reducing the impacts of flooding during disasters.

2) policy, strategy, and planning,

3) community activities.

Source

ENVIRONMENTAL MANAGEMENT AND DISASTER PREPAREDNESS - Lessons Learnt from the Tokage Typhoon (Typhoon 23 of 2004) in Japan Copyright © 2005 UNEP

2.3 Review Matrix

In the following matrix, we seek to identify Best Practices for each type of waste encountered in a post-disaster situation.
Although not specific, the review is most adapted to the context of Labasa.

Activity		Type of waste	Household waste		Debris									Others		
			Household waste and waste from relief operations	Waste water sludge	Vegetative debris	Concrete / bricks	Household furnishings (carpeting, insulation)	Plastics	Paper and cardboard	Timber	Electrical equipment	Soils and Sediments	Bulky items: vehicles, containers...	Hazardous materials and substances*	Healthcare waste and carcasses	Commercial and industrial waste
Pre-collection and collection			Manual collection possible			Manual sorting possible		Manual collection and sorting possible	Manual collection possible	Manual sorting possible	Manual collection and sorting possible			Separate collection by trained operatives and personnal protection equipment		To be organised by owner
Haulage				Specific vehicle												
Treatment and disposal	Direct landfilling	direct lanfilling	Landfilling with chemical fixation with lime									Use as cover layer (if clean)				Impose pre-treatment to owner
	Landfilling with pre-treatment	Chemical stabilization										I f contaminated		Landfilling with chemical fixation	Chemical fixation or disinfection	To be arranged by owner
		Thermal stabilization														
		Open pit burning			If composting not available				If composting not available	If reuse not available					Only in emergency situation	Only in emergency situation
	Size Reduction Technology	Crushing / shredding prior to landfilling			If composting not available					If reuse not available						To be arrnaged by owner
Pre-treatment prior to Recycling, reuse or compost	Sorting and Size Reduction Technology	Crushing / shredding prior to storage in bins/bags for reuse / recycling														
Recycling	Local reprocessing	storage prior to recycling			In Energy- from-Waste schemes								if available			Storage at industrial site
	Reexportation	Conteneurization prior to reexportation														
Reuse						Extract steel and bricks				Extract wood for cooking and construction						Reuse by owner
Composting	Windrow composting															
Energy from waste	production of chips or pellets for Refuse Derives Fuel production				In industrial boiler					In industrial boiler						In industrial boiler
	Anaerobic treatment with biogas recovery															

*Hazardous materials and substances
Heavy metal contaminated materials
Hydrocarbons such as oil and fuel
Paint, varnishes and solvents
Pesticides and fertilizers
Household cleaning products

LEGEND

- Best practice
- Alternate Best Practice
- Practice with caveat
- To proscribe
- Not applicable

3 CONCLUSION

As seen in the first part of this report, being prepared is crucial in responding to any natural disaster by helping local communities ensuring that storage or staging locations have been sited in acceptable locations or that available landfill capacity is used appropriately.

However, despite the effort in preparing for the situation, post disaster situations will always remain a challenge and the objective of the second part of this report was to identify, between all waste management techniques, the most relevant approach for Labasa in a post disaster situation.

The matrix presented is the result of a literature review, and may not serve as a decision-making tool as such. However, it may serve as a base for further reflection on how to structure the SWM system locally.

This matrix demonstrates that debris segregation is the first 'line of defense' when seeking recovery as well as protection of human health and the environment.

Since segregating debris is best performed at the original deposited point, such as curbside or field separation, community involvement become an important success factor.

Segregation has repercussions all the way through the waste management process, ranging from separate vehicles for hauling the segregated products, to new opportunities in developing more complex energy-from-waste schemes.

Deploying such schemes requires considerable financial and organisational resources, therefore more cooperation between municipalities and states within the region will become necessary.

Another important aspect is to instruct industrial and businesses to segregate their own waste and debris and manage it directly so that it does not end up in the municipal system without prior treatment. At Labasa, industries generate large quatities of vegetative/biodegradable waste. Therefore, persuading local industries to develop energy-from-waste schemes could be beneficial on a daily basis, but would also create valuable opportunities for post disaster municipal waste such as green wood, timber, etc.

Finally, not all waste can be recycled, and landfilling will remain a key element of post disaster waste management. .

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International Solid Waste Association, Available at : http://www.iswa.org/web/guest/home

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