Disposal of debris following urban earthquakes: Guiding the development of comprehensive pre-event plans

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GNS Science Report 2009/33
August 2009

BIBLIOGRAPHIC REFERENCE

Johnston, D.; Dolan, L.; Saunders, W.; van Schalkwyk, R.; Killeen, C.; Cousins, J.; Glavovic, B., Brown, C.; McIntyre, I. 2009. Disposal of debris following urban earthquakes: Guiding the development of comprehensive pre-event plans, *GNS Science Report* 2009/33 30 p.

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ISSN 1177-2425
ISBN 978-0-478-19692-4

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ABSTRACT

An inefficient or poorly planned response can impose additional social, economic and environmental burden on an already impacted community. Debris disposal following a disaster needs to be considered in two timeframes. The immediate concern is for the safety and wellbeing of the affected population, and debris may be required to be removed during rescue operations. However, once the immediate threats to people have passed, or are being managed, it is necessary to remove debris as quickly as possible to allow communities to rebuild. Disaster events can generate large quantities of debris and the management of this debris can present a major challenge. Drawing on the information in this report and other reviews a list of ten key steps for the effective consideration of debris disposal is proposed.

1. Develop debris disposal plans at a regional and local level, or make appropriate provisions in existing solid waste management plans. Plans should include a detailed strategy for debris collection, temporary storage and staging areas, recycling, disposal, hazardous waste identification and handling, administration, and communication with the public.
2. Identify potential locations or sites for the temporary and/or permanent disposal of debris. Outline a process for final site selection/confirmation in response to post-event requirements in both regional and local plans.
3. Prepare a communication strategy ahead of time. You will need to tell your community when, where, and how normal rubbish collection will resume, and give special instructions for reporting and sorting disaster debris.
4. Prepare for increased demands on council staff in terms of public information, operation and enforcement of debris management systems. This may require additional staff resources to manage the increased workload.
5. Make arrangements for additional equipment and supplies to deal with disposal ahead of time. Identify the types of equipment and supplies that staff and contractors will need to carry out operations.
6. Develop mutual aid agreements with neighbouring councils (and/or CDEM groups) for plant, equipment and expertise.
7. Establish pre-event debris management contracts with private contractors.
8. Establish possible organisational structures, roles and responsibilities and authority between various stakeholders, regulatory authorities and decision-makers including Ministry for the Environment, Department of Labour, Ministry of Health and within local authorities.
9. Determine financing strategies at local, regional and national level for differing size and type of disaster events.
10. Assess and develop an approach to potential impact of disaster debris management on normal environmental processes and standards. For example, undertake a Strategic Environmental Assessment identifying practical strategies to minimise environmental and social impacts.

KEYWORDS

Debris disposal, earthquake, Wellington

1.0 INTRODUCTION

Disaster events can generate large quantities of debris and the management of this debris can present a major challenge. Debris disposal following a disaster needs to be considered within two timeframes. The immediate concern is for the safety and wellbeing of the affected population, and debris may be required to be removed during rescue operations. However, once the immediate threats to people have passed, or are being managed, it is necessary to remove debris as quickly as possible to allow communities to rebuild.

Recent overseas earthquakes have highlighted a range of debris management issues within a post-earthquake recovery context (Lauritzen 1996, UNDP 2000). This includes the importance of waste management after disasters being neglected or underestimated.

In 1995 the United States Environmental Protection Agency (EPA 1995) published a discussion document "Planning for Disaster Debris". The report highlighted a range of issues and illustrates these within case studies from recent events (Hurricane Andrew 1992, Northridge earthquake 1994; Hurricane Iniki 1992 and Hurricane Hugo 1989). The report concludes that:

> "…*any community likely to be faced with significant debris from a natural disaster should develop a debris management plan… The development of a disaster debris management plan usually requires input from neighbouring communities, state officials, local contractors and a variety of local agencies*".

An update of this document was published in 2008 (EPA 2008).

Figure 1 Rubble from collapsed buildings being stockpiled on a soccer field, Kobe 1995 (photo Jim Cousins).

Figure 2 Remains of collapsed motorway, Kobe 1995 (photo Jim Cousins).

New Zealand's last large scale urban earthquake was in the Hawke's Bay in 1931. A huge amount of debris was generated in Napier by the collapse of brick and concrete buildings, this was exacerbated by the fire that followed and which destroyed most of the commercial centre of the town. During the early part of the recovery phase rubble was trucked about 1.5 km west and dumped in a lagoon (Figure 3). After a few weeks one of the reconstruction Commissioners, a Mr Barton, directed that the rubble be instead dumped on the beach adjacent to the town, where it was later covered with clay spoil from nearby landslides, topped with 100–300 mm of soil and now forms a 40–50 m wide domain that runs the length of the commercial part of Napier (Conly 1980, Fussell 1988).

Figure 3 During the first weeks after the 1931 Hawke's Bay earthquake rubble from collapsed buildings was dumped into a lagoon just west of the Napier CBD (photo source: Alexander Turnbull Library).

The approach to debris disposal following that event was different to the way society would respond today. The environment was only first identified as a focus for policy in 1953, with the enactment of the Town and Country Planning Act, 12 years after the 1931 earthquake. With no planning regulations, earthquake debris was used to reclaim land around the coast. There was no consideration of contaminated material, environmental effects of disposal on the surrounding environment, Maori concerns, or implications for coastal processes. Today with the Resource Management Act 1991, such disposal could not be so easily achieved, particularly within or adjacent to the coastal marine area or major waterway.

Many New Zealand councils have had recent experience with flooding events and have developed experience managing debris removal. For example, the 2004 Manawatu flood event highlighted issues around pre-planning for debris disposal and the dilemma of speedy recovery versus longer but more sustainable recovery process (Glavovic & McIntyre (in prep)). A summary of the key findings from the 2004 floods are outlined in Appendix 1. The 2009 bushfires in Victoria, Australia have also presented local councils with a number of debris disposal issues (Figure 4 and 5).

In New Zealand pre-event disposal planning projects, including site selection criteria, disposal site design and preliminary site selection scenarios have been undertaken in respect of:

- Disposal of volcanic ash falling on Auckland following a distal eruption, by the Auckland Regional Council (Johnston et al. in prep); and
- Disposal of carcasses following a foot and mouth disease outbreak, by Biosecurity New Zealand (URS, 2005).

This report outlines considerations for debris disposal in case of a large earthquake and addresses: (1) the types and volume of earthquake debris; (2) strategies for debris collection; (3) temporary storage and staging areas, (4) recycling and disposal optimisation; (5) identification of and/or issues for development of suitable disposal sites; (6) hazardous waste identification and handling; (7) mutual aid arrangements; (8) coordination and dissemination of public information; and (9) land-use planning issues and instruments in Regional and District Plans. These issues are explored within the context of a Wellington earthquake scenario.

Figure 4 A typical house-lot mid-demolition following the devastating Victorian Bushfires (Australia) February 2009. The intense heat and destructive capacity of the fires led to over 3000 homes requiring demolition and debris disposal. Due to the scale of the event, the Australian government elected to let a single contract for all demolition and debris disposal at existing landfills and some incidental recycling (photo Charlotte Brown).

Figure 5 A pile of burnt metal ready for collection and recycling as part of the debris management programme following the Victoria Bushfires. The government appointed contractor elected to recycle metals and some vegetative and masonry items as part of their debris removal programme (photo Charlotte Brown).

2.0 WELLINGTON SCENARIO

A number of earthquakes scenarios have been developed to help assess the impacts of a future earthquake on the Wellington Region. This report considers a shallow earthquake (10 kilometres) measuring magnitude 7.5 on the Richter scale and centred near central Wellington (Cousins *et al.* 2009).

This scenario gives the highest predicted earthquake loss for the city and is commonly employed in the insurance industry for reinsurance assessments. The return period of the event is approximately 700 years. Vertical movements generating tsunami are expected both inside Wellington Harbour and in Cook Strait. Co-seismic subsidence of some parts of Lower Hutt may increase tsunami susceptibility. The following effects could be expected in Wellington City (WRCDEMG 2009):

- Eleven buildings of between 12 and 29 floors collapsed or severely damaged;
- 18,000 houses and 5,000 apartment units extensively or completely damaged;
- More than 50,000 people displaced from their homes;
- Major slips and closures on SH1, between Bulls and Wellington;
- Major slips and closures on SH2, between Woodville and Wellington;
- Wellington Port and airport inoperable;
- Wellington Regional water and wastewater distribution networks largely destroyed;
- Electrical generation and distribution networks inoperable or degraded;
- Telecommunications networks either inoperable, overloaded or degraded;
- Rail lines closed between Wellington and Levin, Wellington and Masterton;
- Telecommunications networks either inoperable, overloaded or degraded, between Kaikoura and Palmerston North;
- Fast moving consumer goods distribution system into the Wellington Region inoperable;
- Fuel distribution system into the Wellington Region inoperable; and
- Rail lines closed between Wellington and Levin, Wellington and Masterton.

Figure 6 Wellington CBD with the Wellington Fault trace marked (Photo: GNS Science).

3.0 KEY DEBRIS DISPOSAL ISSUES

3.1 The type and volume of earthquake debris

The destruction of buildings and structures during an earthquake, coupled with movement of land and land instability creates a range of debris types and materials, depending on earthquake location, strength and structures and activities in the affected area(s). The type of debris created by earthquakes can broadly be defined to include the following (OES 2005):

- Construction & demolition materials;
- Human remains;
- Personal property;
- Animal carcasses;
- Household hazardous waste;
- Metals;
- White metals (appliances);
- Landslide debris; and
- Electronic debris;

Potential industrial waste streams and vehicular and/or vessel debris (including associated oils and fuels) could also be added as separate categories to this list. Demolition waste (and earthquake debris) from buildings and structures can be further classified into the following fractions (Baycan 2004):

- Recyclable materials;
  - Concrete (plain, reinforced, blocks, foundations and coverings);
  - Masonry (bricks, blocks and roofing tiles);
  - Wood (roof rafters, flooring, beams and internal materials);
  - Metal (reinforcing bars, internal installations (heating systems) and bearing structures);
  - Soil and excavation material;
- Non-recyclable materials;
  - Household inventory (all internal furniture and fittings);
  - Organic materials (household waste);
  - Other inert materials;
- Hazardous waste;
  - Asbestos (from insulation, roofing sheets, etc.);
  - Chemicals (materials polluted with chemicals, paints, etc).

The typical composition of rubble generated by the 1999 Marmara Earthquake in Turkey was as follows (Baycan 2004):

- Recyclable;
  - Concrete 60%;
  - Masonry 25%;
  - Soil and excavation materials 5%;
  - Metals (including iron bars) 5%;
- Non-recyclable (wood, plastics, paper, organics) 4%;
- Hazardous <1%;

The Wellington Regional Civil Defence Emergency Management Group (WRCDEMG), Group Debris Disposal Guideline states that Wellington CBD expects to lose 20 percent of its buildings during a major earthquake. The quantity of debris created is expected to be in excess of 2.2 million cubic metres (WRCDEMG, 2008). In addition to earthquake debris, following a major earthquake in Wellington, there will still be a requirement to manage refuse produced by the 'normal' and post earthquake activities by the community.

Likely problems associated with earthquake debris and existing solid waste sources include the following:

- Food spoilage due to interruption of electricity supplies;
- Uncontrolled dumping of waste. This is likely to occur where wastes or debris have already accumulated as people deposit their refuse on existing piles;
- Human waste disposed of with household waste and debris.
- Nuisances (odour, flies, vermin) from accumulation of uncollected organic waste and/or human waste;
- Standing water in debris strewn areas providing a vector (flies, mosquitoes, vermin) breeding ground, leading to spread of disease.
- Healthcare wastes from hospitals, medical centres and/or emergency treatment facilities;
- Risk of disease from decomposing waste;
- Disposal of putrescible solid waste and human waste in areas that drain to streams or waterways can lead to contamination of water, which people may be using for drinking and/or washing, leading to spread of disease;
- Large numbers of bottles and containers (plastic and polystyrene) from delivery of food and water for affected persons and additional emergency workers;
- Unwanted 'in-kind' donations including clothing, toys, household goods.
- Likely lack of water for cleaning would reduce potential for storage of some materials for recycling;
- Inability to use existing collection vehicles where access is blocked or restricted. May be able to set up skips or temporary transfer stations in some areas for people to take their solid waste to.
- Social impacts arising from the presence of temporary debris staging areas, causing noise pollution, visual impacts (including lighting), and traffic congestion.

Suggested actions – Earthquake debris

Action	Identify and estimate debris types and quantities.
Include	Debris from commercial/industrial and residential areas and activities
	Debris or waste types that may be specific to buildings or activities in the areas
	Hazardous wastes that may be specific to activities or industries in the area (and in transit)
	Recyclable and non-recyclable materials
	Existing normal refuse collection/disposal requirements

3.2 Strategies for debris collection

Activities immediately following an earthquake will focus on search and rescue and initial debris clearance from roads to avoid impeding the movement of emergency traffic. Following the 1995 Hanshin-Awaji earthquake in Kobe, Japan, the following observations were made in respect of the collection of debris (Lauritzen, 1998):

- The removal of rubble and other wastes that had accumulated on roads due to collapse of nearby buildings and other structures was the most important issue;
- Temporary storage areas were secured for provisional disposal;
- It took about one month to clear debris from major roads and about three months for smaller roads;

In the normal course of building, demolition wastes are separated on-site and disposed of for re-use, further treatment or disposal. However, during the earthquake cleanup most wastes are mixed, especially during the initial stages of the emergency rescue operations.

Petersen describes the following key issues arising from the management of solid wastes following disasters (Peterson 2004).

- Collapse of municipal solid waste utilities, including probable lack of collection service and uncontrolled tipping of wastes. Waste piles rapidly build up in streets and outside urban areas leading to vermin growth and spread of disease.
- Uncontrolled tipping of healthcare wastes from hospitals and clinics, resulting in serious hygiene risks to local population and secondary infection to patients.
- Building rubble, from damaged buildings piled in urban areas, impeding access and constraining rehabilitation/reconstruction activities. Piles of rubble also attract further waste tipping since the site is considered a "waste dump".
- Hazardous wastes from damaged and/or redundant industrial plants causing serious health risks through compromised or inadequate containment and handling.
- Proliferation of scattered waste piles and dump sites leading to health risks (vermin and personal contact with waste) and risk of contaminating groundwater.

The initial phases of response activity following an earthquake in Wellington, resulting in partial or complete destruction of a large number of multi-storey buildings, will be search and rescue. Transport routes within and to/from the affected area for emergency vehicles will have to be cleared as soon as possible. Transport routes will also need to be identified, prioritised and cleared for provision of food, water and fuel. This would be followed by making safe, or demolishing, buildings and structures that have been damaged.

The materials from initial transport route clearance should be deposited as close as possible to the source(s) to reduce transport times and maximize the capacity of available plant for clearance operations. This may require temporary deposition of debris in available open space for later recycling (and potential re-use in rebuild) and/or collection and disposal.

Processes for debris clearance on private and public properties in the recovery phase need to be considered before determining a collection strategy. In Australia following the 2009 Victorian Bushfires, the government let a single contract for demolition, debris removal and disposal on all affected properties. The US Federal Emergency Management Agency (FEMA) funding, however, under most circumstances requires private property owners to clear their own properties (using insurance or independent funding) and to deposit wastes on the kerb for an organised municipal collection (FEMA) Also refer Section 0 – funding / financing mechanisms.

Suggested actions – Debris collection

Action	Identify transport routes (to prioritise debris clearance)
Action	Identify debris removal plant and equipment
Include	Rescue and emergency services
	Vehicles, plant and equipment for rescue, demolition and debris removal
	Provision of fuel for vehicles, plant and equipment
	Provision of food and water
	Debris transport, temporary deposition strategy and disposal
Action	Identify a debris collection strategy for recovery stage
Include	Public and private sector roles
	Communication plan

3.3 Temporary storage and staging area

Access to existing disposal sites may not be available (or suitable) immediately following an earthquake and/or existing disposal sites may be remote from the affected areas or not have adequate capacity for debris quantities. It is likely that temporary debris management sites will be required, at least in the short term, to efficient removal and management of debris.

Following the 1995 Hanshin-Awaji earthquake in Kobe, Japan, the following observations were made in respect of the temporary storage of debris (Lauritzen, 1998):

- Some waste treatment facilities were damaged. However, no treatment facilities suffered total, or even partial, destruction. Operations were hindered by the lack of electricity, water and other supplies, and the temporarily crippled collection and transport services;
- During waste treatment and disposal, much effort was spent on sorting organic and hazardous material from the rubble waste. Special precautions were made to control and reduce the risk of asbestos emission from the demolition and sorting sites.

Waste from the reconstruction work, repair of damaged buildings and structures, and construction of new buildings and structures also presented a big problem.

The Federal Emergency Management Agency (FEMA, 2007) provides the following sample site layout for a debris management site (see Figure 7).

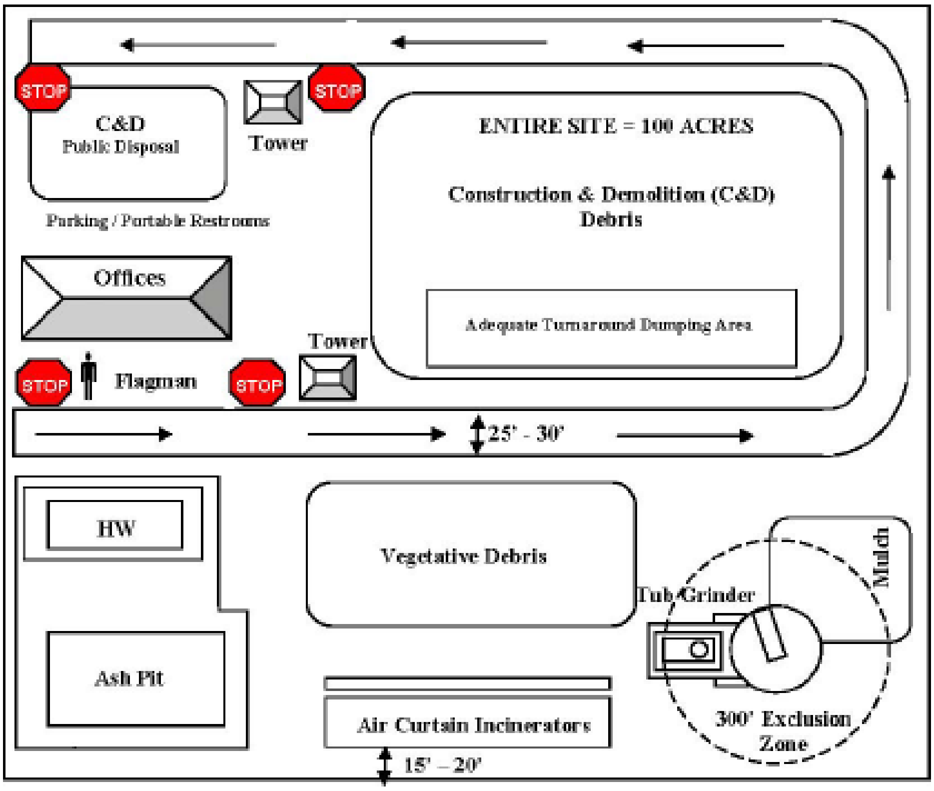

Figure 7 Sample debris management site layout.

WRCDEMG has identified 14 areas close to the Wellington CBD, with a total estimated capacity of approximately 800,000 cubic metres, as shown in

Table 1 (WRCDEMG 2008).

Table 1 Estimated debris storage capacity close to the Wellington CBD

Location	Capacity in Cubic Metres (m^3)
Interisland Ferry marshalling area	82,602
Wellington train yards (starting just North of the train station and ending just short of the SH1 overpass).	485,407
Bluebridge Ferry terminal car park and wharf	52,260
Train station drop off zone and surrounding area	6,600
Car park adjacent to the train station drop off zone	6,636
Land surrounding the law school building	16,356
Michael Fowler car park	13,338
Post Office Square	4,900
Frank Kitts park and wharf	20,385
Grass area near the boat sheds (Frank Kitts Park)	9,234
Wharfs in front of Te Papa and the Boat shed	20,340
Waitangi Park, car park	27,456
Waitangi Park and Overseas Terminal car park	44,274
Chaffers New World car park	8,928
Total temporary accumulation	798,716

The use of temporary debris management sites can increase the cost of debris removal, as materials are handled twice (WRCDEMG 2008). However, it can provide the opportunity to separate materials for recycling (and potential use in rebuild) or treatment by alternative methods, such as incineration (however incineration has a number of associated environmental issues that may need to be considered).

There is a distinct shortfall between the estimated storage capacity and projected debris volume. However, temporary storage areas are likely to be used during the early stages of clean-up operations, including clearance of roads and emergency transport routes. After this time it is expected that more permanent disposal sites will be identified and developed to take debris directly from its original location.

The identification of temporary debris management sites must be done with consideration of the Resource Management Act 1991 (refer section 3.12), and should not preclude their ongoing existing use or any intended future development in accordance with the underlying zoning. For this reason parks and other public open space areas are commonly identified areas in pre-planning processes. Lists and maps of identified areas should be updated periodically as land use/development changes over time. Temporary debris management sites need to consider the full range of social impacts.

Figure 8 Identification of temporary debris management sites for Wellington

Suggested actions – Temporary debris management sites

Action	Pre-select debris management sites, or general locations, and rank these areas in terms of size and/or activities that could be undertaken.
Include	Earthquake hazard assessment of potential sites
	Access
	Land-use regulations
Action	Perform initial environmental assessment
Include	Temporary storage and processing facilities (eg local yards, parks and open space)
	Potential disposal sites (eg existing parks or open space; depressions and gullies)
Action	Determine appropriate waste types and activities for sites (eg C&D sorting/recycling, hazardous waste treatment, disposal)
Action	Evaluate equipment and operational requirements
Include	Processing plant and equipment
	Transport vehicles
	Fuel and water supplies and storage
	Contractors
	Staffing needs and staff facilities

3.4 Recycling and disposal optimisation

Depending on the location, affected areas, local environment and available plant and equipment, there may be a range of debris management, treatment and disposal options including:

- recycling;
- incineration;
- land disposal; and
- land reclamation.

Concrete and rubble waste from the 1995 Hanshin-Awaji earthquake was disposed of as follows (Lauritzen, 1998):

- as filling material for land reclamation;
- at existing permanent disposal sites in each municipal administrative area; or
- at regional permanent disposal sites in the Osaka Bay, for major land reclamation projects.

At the time of the earthquake, the inland landfill and seaside municipal disposal sites in Kobe City had a remaining capacity of 15 million m^3, enough for the disposal of solid waste over the next 10 years. However, because they received massive quantities of solid waste generated by the earthquake, their capacity was filled within just one year. Following the earthquake, 5000 waste-filled vehicles arrived at the disposal sites each day. Consequently, site staff were unable to guide each individual vehicle to the correct location for dumping. As a result disposal operations on site were not performed properly. To prolong the lifetime of the disposal sites, some wastes had to be removed again for volume reduction by crushing and incineration at some future date. In February 1995, the Kobe Harbour construction plan was revised, and permission was given to dispose of 6.6 million m^3 of debris for land reclamation in the harbour area.

Baycan and Petersen (2002) state that the first step in designing a strategy for the management of construction and demolition (C&D) waste following a disaster is to establish the quantities, sources and types of waste, as well as the capacities in place to deal with this waste stream.

Their key considerations include:

- The procedure for managing the C&D waste stream before the event, including sites for disposal and possible recycling and types of materials included in the waste stream;
- The quantity of C&D waste generated by the disaster, including composition and source. The composition will be the basis upon which disposal and/or recycling option is feasible and the source of waste will indicate likelihood of hazardous materials being contained in the waste;
- The capacity of the local area to cope with the waste generated by the disaster, including number and type of trucks, condition of the disposal site and opportunities to recycle.
- An indication of the scope of reconstruction works expected in order to identify opportunities for the utilization of the recycled C&D wastes;
- An understanding of the governmental and local authority structure in order to place the responsibility for C&D waste management at the right office (refer Section 3.12)

The use of existing landfills may be possible, but should not be relied upon due to:

- The possibility that the access routes are disrupted;
- Distance from debris source;
- Damage to site infrastructure;
- Lack of capacity for debris quantities.

Pre-planning should identify options in addition to existing refuse and C&D disposal facilities. The recycling of debris following a major earthquake in Wellington will be largely dependent on the availability of plant and machinery to crush concrete for re-use as aggregate.

Recycling of other materials may be undertaken in a similar manner to that already carried out by a number of demolition operators within New Zealand. Recyclable materials are removed or processed (on-site or at a transfer station) prior to the remaining, generally inert, material being disposed to cleanfill. There are markets for some C&D waste materials, as outlined below (SKM 2004).

Management of concrete and rubble (including reinforced concrete structures, asphalts and pavements, bricks and tiles) generally consists of:

- Disposal to cleanfills;
- Crushing and screening for on-selling.

Figure 9 Current landfill in south Wellington

Concrete blocks and bricks can be re-used, for example, in the landscaping industry. Concrete can be crushed and used as a base material for roads and pavements and as a base material for the construction industry for filling foundations and for underground pipework. Reinforcing bars can be separated and sold for recycling.

Timber can be re-used, often for lower quality temporary work such as boxing for concreting or survey pegs. There is a well established market for native hardwood, with recovered floorboards, architectural features and beams sold for renovations and furniture construction. While the demand is lower than for native hardwood, pine timber (both treated and untreated) is used for construction, renovations, landscaping, furniture and craft work.

In addition, non treated timber can be chipped for use in landscaping or use as hog fuel. Ferrous and non-ferrous metals from demolition have established markets for recycling. There is currently no New Zealand market for plasterboard from demolition. The decision on whether to maximize recycling or rely predominantly on removal and disposal of debris will depend on a number of factors, including:

- Availability of plant and equipment to process debris for recycling;
- Available land, or sites, to undertake recycling activities;
- Availability of, and distance to disposal sites;
- Desired speed of site clearance.

It would be advantageous, in terms of both time and money, to avoid double handling of debris. It may be possible to undertake some recycling activities on site.

Recycling activities can include:

- Crushing of concrete for re-use in future construction activities;
- Separation of bricks, blocks and tiles for re-use;
- Removal of metals (including reinforcing, structural elements, fittings and appliances);
- Composting of vegetation;
- Chipping or grinding of wood for use as fuel or composting bulking agent.

The potential to recycle materials may be determined based on:

- Available sites for collection and sorting of material;
- Existing recycling facilities;
- Availability of mobile plant;
- Availability and capacity of disposal sites;
- Markets for materials (want to avoid long term storage and double handling).

The recycling of some materials may require large areas for long term stockpiling/storage prior to markets becoming available and/or absorbing the stockpiled materials.

Suggested actions – Recycling and disposal

Action	Develop and inventory of existing debris management facilities.
Include	Landfills
	C&D landfills and managed fills
	Cleanfills
	Refuse transfer, sorting, processing and recycling facilities
	Mobile and non-mobile processing plant and equipment
	Composting facilities
	Hazardous waste treatment facilities
Action	Develop and inventory of existing service providers.
Include	Refuse collection companies
	Demolition contractors
	Transport firms
Action	Evaluate existing capacity
Action	Cost / benefit analysis of recycling and disposal options
Include	Time to clear / process
	Availability of temporary and permanent storage and disposal sites
	Availability of recycling personnel and facilities
	Potential recycling reuse markets
	Labour costs
	Economic and environmental impacts of recycling
Action	Identify recycling markets
Include	General markets
	Markets for debris materials in disaster recovery / rebuild

3.5 Identification of suitable disposal sites

In identifying potential sites for temporary storage, sorting/recycling and/or disposal of earthquake debris, the following issues should be kept in mind.

- Prompt removal and disposal of debris following an earthquake will be required to ensure the community recovers as quickly as possible;
- The most appropriate temporary storage and/or disposal site(s) will need to be determined at the time, taking into account:
  - location of debris;
  - transport access;
  - changes in land use over time;
  - an assessment of the likely impact of debris disposal on the preferred disposal site(s);
  - a comparison of the preferred site with other potential sites;
  - the urgency required for cleanup of debris.

In the Wellington Region existing sanitary landfills are not a significant distance from debris source(s). However, given the local topography and often difficult access roads, there is the potential for access to be temporarily blocked by slips after an earthquake. Existing cleanfills and C&D waste disposal sites, that could be used for debris disposal, should be identified within a wide radius of the Wellington CBD.

It would be advantageous to identify potential disposal sites, or general areas for disposal, as part of the pre-planning process. (Processes have been developed to do this for volcanic eruption debris and foot and mouth disease carcasses.) Pre-planning, including preliminary indication of suitable sites or areas, coupled with good documentation and record keeping during emergency disposal operations will assist in limiting the potential for future adverse effects on the environment from disposal sites.

It may be possible to use small capacity existing sites in the short term while developing dedicated disposal sites for longer term disposal.

Potential problems and environmental effects in respect of disposal sites include:

- Leachate (although not as high in BoD, heavy metals and volatile organic compounds as landfill leachate);
- Gas;
  - o hydrogen sulphide, from the breakdown of gypsum in plasterboard, which is odorous and also toxic in high concentrations;
  - o methane, from the breakdown of organic matter, which is a simple asphyxiant and can be explosive at concentrations of 5 to 15 percent by volume in air;
  - o carbon dioxide, from the breakdown of organic matter, which is a simple asphyxiant
- Community opposition
- Restrictions on future land use due to types of materials deposited.

In identifying potential locations for disposal sites (for examples gullies or public land close to the city) a number of general criteria should initially be used. Criteria for site selection can be prioritised into primary and secondary criteria. Primary criteria are intended to be used for a coarse desktop screen to identify potential locations. Secondary criteria are intended to be used to assess individual locations.

- Primary criteria
  - o land ownership;
  - o proximity to flood plains;
  - o proximity to surface water or groundwater supply catchments;
  - o distance from sites of natural or cultural significance;
  - o land area of site.

- Secondary criteria
  - o slope;
  - o soil class;
  - o access/roading;
  - o topography;
  - o proximity to surface water;
  - o site engineering and sediment control requirements;
  - o susceptibility for leaching to groundwater;
  - o susceptibility to erosion (of surrounding land);
  - o services;
  - o distance from affected areas areas/transport cost;
  - o potential for nuisance to site neighbours;
  - o area available for disposal;
  - o availability of cover material.

Disposal activities could also include incineration of a portion of vegetation or wood wastes. For example, MAF has a mobile air curtain incinerator for carcass disposal. It should be noted that the use of incineration in debris management is potentially controversial. Public criticism of incineration following both Kobe earthquake (Kobayashi 1995) and Hurricane Andrew in Florida, 1992 (EPA,1995) led to the withdrawal of that method as a treatment option.

Another possible disposal method would be to deposit earthquake debris into local harbours and other coastal marine areas. While dumping in the coastal marine area is prohibited in most regional plans, the lack of alternative accessible disposal sites may result in use of the emergency provisions of the Resource Management Act 1991 (RMA) to deposit debris in, or on, the foreshore or seabed.

Suggested actions – New disposal sites

Action	Identify potential methods for debris disposal
Include	Land disposal
	Incineration, if applicable
	Reclamation, if applicable
Action	Identify potential areas/locations for debris disposals sites
Include	Site selection criteria appropriate to expected debris types
	Preliminary environmental and regulatory assessment
	Site development and operational requirements

3.6 Hazardous waste identification and handling

Following the 1995 Hanshin-Awaji earthquake in Kobe, Japan, the following observations were made in respect of hazardous waste (Lauritzen, 1998):

- An immense quantity of waste was generated by the demolition and dismantling of buildings and structures. These wastes were a serious problem, because they contained asbestos and other hazardous substances. The quantity of waste greatly exceeded the existing treatment/disposal capacity.
- Large amounts of wastes contained hazardous substances which contaminated the surrounding soils.

It will be necessary to outline ways in which how hazards will be managed, particularly hazardous substances. Hazardous substances and wastes in earthquake debris can include:

- biological material (human remains, animal remains, food);
- fuels and oils;
- gas bottles and canisters;
- asbestos;
- chemicals;
- mercury from light bulbs;
- refrigerants;
- household hazardous wastes.

Dust from earthquake and demolition debris will likely have a range of hazardous constituents, depending on a buildings construction and/or activities undertaken and materials/chemicals used or stored within the building.

When demolishing buildings following the Hanshin-Awaji Earthquake the Environment Agency undertook an investigation of atmospheric quality (Irie 1995). It reported that the concentration of asbestos in the atmosphere was slightly higher than the general standard value. In addition the concentrations of aceto-aldehyde and some other hazardous substances were also detected. However, concentrations did not reach levels that would have an immediate impact on human health.

Based on these observations, The Environment Agency indicated the following actions as being appropriate:

- Spraying water or chemicals to prevent asbestos being dispersed during building demolition; and
- Separating wastes that might emit hazardous substances during burning.

Mixing hazardous materials or substances with non-hazardous debris can increase the quantity of debris requiring special treatment and result in contamination of temporary storage sites and disposal sites. During clean up and debris removal operations every effort should be made to identify hazardous materials and substances and keep them separate from other debris as it is being collected, removed and taken to a temporary storage site or disposal site.

Where possible hazardous materials and substances should be isolated, collected and treated and/or disposed of separately in order to avoid double handling of hazardous materials, mixing with non-hazardous debris and spreading contamination to debris storage sites and/or disposal sites.

It will be necessary to identify facilities and/or sites where hazardous materials and wastes can be treated and disposed.

Suggested actions – Hazardous materials

Action	Identify likely hazardous/harmful materials in debris
Include	Precautions / procedures required during demolition, collection, transport and disposal
	Available isolation, treatment and disposal processes
Action	Identify existing hazardous material handling and disposal facilities and resources

3.7 Mutual aid arrangements

Many emergency management organisations, including Civil Defence Emergency Management Groups enter into mutual aid agreements to provide emergency assistance to each other in the event of an emergency.
As identified in this report, plant, equipment and expertise will be in short supply following an urban earthquake. Getting assistance from neighbouring jurisdictions to help with all aspects of debris disposal should be a key part of mutual aid arrangements. An up-to-date shared inventory of available resources and facilities (including privately owned resources) would also be a beneficial part of an MOU arrangement to facilitate effective resource sharing during an event.

3.8 Pre-event debris management contracts

The US emergency funding organisation, FEMA, is currently offering incentives to local bodies to create debris plans. As part of that process they are offering increased emergency response funding levels if the local body has pre-event contracts for debris removal and management contractors established (EPA 2008). Contracts with disposal facilities, recycling facilities and markets should also be considered pre-event.

Generally contracts for immediate emergency response are on a time-cost basis and rates agreed upon pre-disaster.

Having pre-event contracts established will have many benefits including:

- eliminating price hiking
- reducing response times
- already established relationships, roles and lines of communication
- resources and capacities are known

3.9 Coordination and dissemination of public information

Citizens will play a key role in the effective disposal of earthquake debris from residential and business properties. It is essential that they understand the correct action to take and when and how to dispose of earthquake debris and the waste from their normal activities.

This critical information in a post-disaster environment presents many challenges for controlling authorities. It is helpful to develop a communication strategy ahead of time. There is a role for communities to be involved in creating the plan so they are aware of what to do rather that only being informed afterwards.

Suggested actions – Communications

Action	Develop a communications plan
Include	Emergency services
	Government agencies (local, regional and national) including civil defence
	Debris management team
	Refuse collection, transport and disposal contractors
	Local communities
	Public

3.10 Organisation structure and roles and responsibility

Roles and responsibilities for debris management operations need to be established pre-event. Debris management involves a number of differing social, economic and environmental stakeholders. In any disaster response in New Zealand the following groups are likely to be involved in the debris management process:

- Ministry for the Environment (MfE)
- Department of Labour
- Ministry of Health (MoH)
- Earthquake Commission (EQC)
- Civil Defence Emergency Management (CDEM)
- Ministry of Works
- Transit
- solid waste contractors, facilities and operators
- local authorities (regional and local councils)

To facilitate an effective and timely response, coordination / organisational structures, roles and responsibilities and overall debris management objectives should be established pre-event.

Suggested actions – Organisation structure and roles and responsibility

Action	Identify all disaster debris stakeholders
Action	Develop organisational structure
	Roles and responsibilities
	Communication strategy

3.11 Funding / financing measurements

The responsibility for payment of demolition, debris clearance, collection and disposal varies from country to country and from event to event. In New Zealand, a number of regulations and policies exist to cover recovery costs from disasters. Details are outlined in the National Civil Defence Plan and individual CDEM Group plans.

The United States emergency funding organisation FEMA's regulations stipulate debris removal to be in the public interest, not only to protect life, public health, and safety, but also to ensure economic recovery of the affected community (EPA 2008). The speed and effectiveness of a debris management programme will largely depend on the effectiveness of the financing mechanisms available. This includes the role of insurance, private property owner responsibilities, local and national emergency funding structures.

As discussed in Section 3.2, the Australian government elected to provide a free demolition and debris removal service to all Victoria Bushfire victims to expedite the recovery process and minimise the potential for detrimental public health and environmental effects. Ordinarily, like in the US, insurance would pay for this service on private properties and public funding (shared between emergency funding mechanisms and local authorities) would facilitate collection, treatment and disposal systems.

The extent of debris funding mechanisms also affects the type and effectiveness of debris removal programmes. FEMA's funding policy stipulates that only lowest cost bids will be eligible for reimbursement considered (FEMA 2008). This, it seems is independent of the debris management strategies and environmental or social benefits of the options. In some cases this criteria does not allow disaster debris managers to meet the goals of long-term (or even current) waste management strategies (Lauritzen 1995), where, it could be argued that environmentally preferable management options are too costly and/or slow in a disaster response situation.

Suggested actions - Funding / financing measurements

Action	Understand existing funding mechanisms
Include	Available funding sources
	Eligibility criteria
	Record keeping required for reimbursement
	Insurance
Action	Assess alternative funding structures

3.12 Land-use planning issues

In recent years many New Zealand councils have had experience with flooding events and have developed experience managing debris removal (see Appendix 1). The issue of disaster debris removal has also been raised in recovery planning of most CDEM groups. Research by Becker *et al*. (2006) has explored the role of pre-event recovery planning and established a framework for councils to address many common recovery issues before events occur.

Land use planning in respect of earthquake debris disposal provides a number of challenges due to unknown factors including:

- Scale of event(s) and consequent damage;
- Likely location of most affected areas;

- Quantities of debris requiring removal;
- Effects on existing transport and disposal infrastructure.

As a result it is difficult to plan for the use of specific disposal routes and sites. Therefore, planning should concentrate on identifying options and outlining the processes to be used in final option selection and implementation.

Allowance for these processes can be made in the appropriate local and regional planning instruments (district and regional plans as well as solid waste management plans).

Considerations for pre-event land use planning include:

- Siting criteria appropriate for types of debris expected;
- Identification of potential temporary and/or permanent debris disposal locations;
- Updating of disposal locations as land uses change or development occurs;
- Sensitive environments requiring protection, or local environmental issues that need to be addressed;
- Local companies, organisations, communities and individuals and Iwi that should be involved in, or consulted during, option identification and implementation.

The disposal of debris immediately following an earthquake would likely be covered under Section 330B of the RMA, 'Emergency works under Civil Defence Emergency Management Act 2002.

Section 330B (1) states:

> *If any activity is undertaken by any person exercising emergency powers during a state of emergency declared under the Civil Defence Emergency Management Act 2002, the provisions of sections 9, 12, 13, 14 and 15 of this Act do not apply to any activity undertaken by or on behalf of that person to remove the cause of, or mitigate any actual or adverse effect of, the emergency.*

The person authorising the activity must advise the appropriate consent authority within 7 days and if the activity contravenes any of sections 9, 12, 13, 14 or 15, and the adverse effects of the activity continue, the person who authorised the activity must apply in writing to the appropriate consent authority for any necessary resource consents within 20 working days of the notification.

This would allow the immediate deposition of earthquake debris onto land, or into water, without the usual requirement to first obtain resource consent(s). If consent application is made within the 20 days then the activity may continue until the application for resource consent(s) and any appeals have been determined.

Identification of potential disposal areas, and disposal site design and operational requirements before the event can facilitate the use of the most appropriate disposal locations and methods, and thereby reduce the potential for adverse effects. In addition it will provide basis for consent application documentation and justification for disposal sites, or method used when consents are applied for ongoing activities and discharges.

Depending on the specific locations, nature of the debris and regional and district plan requirements, the following resource consents may be required:

- land use consent from the district council or regional council, or both (section 9 of the RMA);

- discharge permit from the regional council to discharge contaminants onto or into the ground (section 15 of the RMA);
- discharge permit from the regional council to discharge contaminants into water if there is a potential for leachate (section 15(1)(a) and 15(1)(b) of the RMA);
- discharge permit from the regional council to discharge contaminants into the air (dust) (section 15(1)(c) of the RMA);
- water permit from the regional council for the diversion of water (if required) and sediment retention ponds (section 14 of the RMA);
- coastal permit for the deposition of materials in, or on, the foreshore or seabed.

Pre-planning for debris collection, storage/staging areas, recycling, and disposal and identification of potential areas for temporary or permanent disposal of debris, coupled with prioritisation of identified options will improve decision making immediately following an earthquake and assist in implementing options with the least long term adverse effects on the environment.

Careful documentation of options and the process of assessing potential effects on the environment and comparative effects will also assist when resource consent applications are made.

Suggested actions – Planning issues

Action	Identify and evaluate applicable planning instruments
Include	National legislation (Resource Management Act, Civil Defence Emergency Management Act)
	National policies (Coastal Policy Statement)
	Regional policy statements and plans
	District plans
	CDEM Group plans
Action	Develop a regulatory contact list
Include	CDEM Controllers
	Regional, district and CDEM managers
Action	Identify and assess potential legislative conflicts in disaster debris management
Include	Environmental, economic and social assessment of conflicts in disaster situation

4.0 SUMMARY

Disaster events can generate large quantities of debris and the management of this debris can present a major challenge. Having guidelines and procedures in place for the management of disaster debris assists in the timely and efficient removal of debris, followed by appropriate recycling and/or disposal to appropriate locations. An inefficient or poorly planned response can impose additional social, economic and environmental burden on an already impacted community.

4.1 What can be done to prepare for disaster debris?

Drawing on the information in this report and other reviews a list of ten key steps is proposed.

1. Develop debris disposal plans at a regional and local level, or make appropriate provisions in existing solid waste management plans. Plans should include a detailed strategy for debris collection, temporary storage and staging areas, recycling, disposal,

hazardous waste identification and handling, administration, and communication with the public.
2. Identify potential locations or sites for the temporary and/or permanent disposal of debris. Outline a process for final site selection/confirmation in response to post-event requirements.
3. Prepare a communication strategy ahead of time. You will need to tell your community when, where, and how normal rubbish collection will resume, and give special instructions for reporting and sorting disaster debris.
4. Prepare for increased demands on council staff in terms of public information, operation and enforcement of debris management systems. This may require additional staff resources to manage the increased workload.
5. Make arrangements for additional equipment and supplies to deal with disposal ahead of time. Identify the types of equipment and supplies that staff and contractors will need to carry out operations.
6. Develop mutual aid agreements with neighbouring councils (and/or CDEM groups) for plant, equipment and expertise.
7. Establish pre-event debris management contracts with private contractors.
8. Establish possible organisational structures, roles and responsibilities and authority between various stakeholders, regulatory authorities and decision-makers including Ministry for the Environment, Department of Labour, Ministry of Health and within local authorities.
9. Determine financing strategies at local and national level for differing size and type of disaster events.
10. Assess and develop an approach to potential impact of disaster debris management on normal environmental processes and standards. For example, undertake a Strategic Environmental Assessment identifying practical strategies to minimise environmental and social impacts.

4.2 Future research direction

With limited experience in debris management after large scale events in New Zealand, there would be benefits from research into debris management following large scale international events. Research will improve understanding of the impact of debris management on the overall recovery process and how to best manage the debris. The research should generically focus on the issues raised in this report, in addition to the more holistic and systemic topics listed below:

- The impact of funding structures on debris management programmes and recovery including national, local, insurance, private and donation financing schemes.
- Organisational structures for debris management within the emergency management system.
- Environmental, social and economic impact of various debris management options including the relaxation of environmental regulations, degree of resource recovery/recycling, speed of debris management/ recovery, public participation and involvement. Assessments may include cost-benefit analyses, environmental impact, public perception and analysis of economic and social recovery.
- Pre-event review of RMA plans.

5.0 ACKNOWLEDGMENTS

This report was prepared as part of a research contract from the New Zealand Earthquake Commission (EQC Project 562). The report was review by Julia Becker and Jon Mitchell.

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Key websites

FEMA Debris Management Guide: http://www.fema.gov/government/grant/pa/demagde.shtm

EPA Planning for Disaster Debris:

http://www.epa.gov/garbage/disaster/disaster.htm

CDC Emergency and Terrorism Preparedness for Environmental Health Practitioners

http://www.cdc.gov/nceh/ehs/ETP/

APPENDIX 1 SUMMARY OF REFLECTIONS ABOUT DEBRIS DISPOSAL BASED ON THE 2004 FLOOD EXPERIENCES (GLAVOVIC & MCINTYRE, IN PREP)

This case study of debris disposal experience in the aftermath of the 2004 Lower North Island floods highlights a number of key issues:

Nature and scale of event

The February 2004 storm and flood event was essentially a regional rural hazard event that had major impacts but it wasn't a calamitous disaster. Notwithstanding the hardship and difficulties experienced by many in the region for many months, the response and recovery effort was by and large effective. For the most part, debris disposal took place in situ because of its nature and location – primarily silt, trees and logs dispersed across the region; and flood-damaged goods and materials from small rural towns were disposed of in landfills. The debris disposal challenge was thus largely a practical matter of prioritising and coordinating efforts – ensuring road access; securing critical infrastructure; cleaning flooded homes; disposing of carcasses; clearing silt-laden lands; removing debris from river channels; and so on. Effective coordination of efforts, for example through the roading and infrastructure Task Force, helped to 'get the job done.' Under these circumstances, little would have been gained by more detailed pre-event planning for debris disposal or by setting aside areas for storage and / disposal. However, a major earthquake event in Palmerston North resulting in extensive building debris, or a catastrophic stopbank failure resulting in the flooding of thousands of homes, presents a completely different scenario. Pre-event planning for debris disposal, among other things, would be invaluable under such a worst case scenario.

Planning provisions for debris disposal

The emergency provisions of the RMA were seen to work very well for dealing with debris management and disposal issues in the aftermath of the February 2004 storm. There is little provision for dealing with disaster debris in current regional and local policies and plans. There is a need to investigate this issue further; and, in particular, to ensuring consistency between relevant provisions.

Dilemma of speedy recovery versus sustainability impacts

In the aftermath of a major hazard event, there is an overwhelming imperative to take actions that facilitate speedy recovery. This imperative may result in hasty actions that could have negative long term environmental and social impacts. Moreover, taking proactive steps to promote sustainability (e.g., sorting debris for reuse and recycling) is difficult in a post-disaster situation. Pre-event planning for disasters can help to anticipate the issues that arise from this dilemma. However, in practice, this dilemma is likely to persist and pose a challenge in future hazard event response and recovery efforts. Securing the services of a suitably qualified 'sustainability advisor' may be a constructive step to take in building recovery teams.

Practicality and usefulness of pre-event debris disposal plans and pre-selected disposal sites
The value of pre-event planning and disposal site selection was not deemed to be of much merit in the case of an event such as the 2004 storm and flooding. However, such provisions would be invaluable for facilitating effective and efficient recovery in the aftermath of an urban centred disaster with significant damage to buildings and infrastructure.

Critical importance of communication and coordination
The establishment of Task Force teams was identified as a major contributing factor to the effectiveness of the February 2004 storm response and recovery effort. Developing good communication between key role-players prior to an event to facilitate effective coordination of post-disaster efforts is arguably the most important proactive step that needs to be taken to ensure effective response and recovery efforts, including debris disposal.

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