Disaster Debris Management – Planning Tools

Debra R. Reinhart, PhD, PE
College of Engineering
University of Central Florida
PO Box 162993
Orlando, FL 32816-2993

Philip T. McCreanor, PhD
School of Engineering
Mercer University
1400 Coleman Ave.
Macon, GA 31207

FINAL REPORT
September 24, 1999

Submitted to
US Environmental Protection Agency Region IV

TABLE OF CONTENTS

Introduction

When a natural disaster strikes a community, whether it is a flood, fire, tornado, hurricane, the "Storm of the Century," or an earthquake, huge amounts of debris are produced. For example, Hurricane Andrew generated 43 million yd^3 of debris in Metro-Dade County in 1992, the 1994 Northridge earthquake of California generated 7 million yd^3 of debris, Hurricane Inike in Hawaii generated 5 million yd^3 of waste, and Hurricane Hugo generated 2 million yd^3 of green waste alone in the Carolinas. These volumes can represent 5 to 15 times the annual waste generation rates of a community. Management of these wastes is often hampered by a lack of preparedness (insufficient planning and/or training of personnel), resulting in clean-up delays, cost escalation, and adverse environmental impact. Contractors may be inadequately monitored, recycling opportunities may be lost due to commingling of waste types, burning may create objectionable air pollution, and landfill waste capacity may be depleted ahead of schedule. The objective of this research is to produce information and tools that can aid communities in preparing and implementing a plan for disaster debris management.

Disaster debris characteristics are very much a function of the type of disaster generating the wastes. These wastes are produced directly by the disaster (for example green waste, rubble, and white goods), are generated indirectly (for example spoiled food due to power failure), or are generated as a result of a change in lifestyle (for example batteries and plastic water containers). Wastes vary significantly but generally consist of the following: concrete, asphalt, metals, green waste, plastic, sandbags, soil and rock, wallboard, wood, glass, white goods, brown goods, bricks, household hazardous waste, furniture, personal belongings.

The disaster type will affect both debris characteristics and quantity. Fires leave ash, charred lumber, wood, vegetation, smoke-damaged furniture, metal from burned vehicles or structures, concrete, soil, and foundations. Floods generate vegetation, mud and soil, household debris, sandbags, plastic sheeting, and demolition debris. Hurricanes and tornadoes generate demolition debris, batteries, plastic sheeting and bottles, and green waste.

Disaster debris is characterized as having a large number of valuable, still usable materials that are rapidly disposed of to avoid odors and adverse environmental impact. Significant quantities of recyclable materials are permanently discarded, often through incineration. This research focussed on disaster debris recycling.

Disaster Debris Management

The EPA's <u>Planning for Disaster Debris</u> document (1995) is often used as a framework for the development of a disaster response plan. It provides some general information on what to expect from different types of disasters, recommended planning actions, and brief case histories on the Northridge Earthquake (Los Angeles, Ca.), 1993 Midwest Floods, Hurricane Andrew, Hurricane Hugo, and Hurricane Iniki. Table 1 presents the debris categories associated with some common disasters as described in the EPA report.

Pre-planning for a disaster will greatly increase control of debris management and reduce costs. A good disaster recovery management plan will take an interagency approach to plan development. A few of the items a plan should address are:

- identification of potential equipment needs and suppliers,
- identification of collection and storage sites, and
- segregation of hazardous materials

Table 1. Major Debris Categories by Disaster Type.

Disaster Type	Damaged Buildings	Sediments	Green Waste	Personal Property	Ash and Charred Wood
Hurricane	✓	✓	✓	✓	
Earthquake	✓	✓	✓	✓	✓
Tornado	✓		✓	✓	
Flood	✓	✓	✓	✓	
Fire	✓			✓	✓

Planning suggestions based on insights from previous disasters include:

- make a long-term debris management plan,
- consider mutual aid arrangements,
- implement recycling programs,
- update the community's solid waste management plan,
- develop a communication strategy
- prepare for increased outreach and enforcement staffing needs,
- obtain equipment and supplies,
- select collection and storage sites,
- determine management options and goals,
- segregate hazardous waste,
- prepare contracts, and
- plan for Federal Emergency Management Agency (FEMA) and state reimbursement.

It is interesting to note that although the EPA's Office of Solid Waste and Emergency Response specifies that reduction and reuse are the preferred waste management strategies the implementation of debris recycling only receives passing mention in this document.

Valera (1998) reported on Hawaii's Department of Health's Office of Solid Waste Management effort to develop a State Disaster Debris Management Plan. The process began in November 1998 with completion anticipated in Fall 1999. The Plan will address both emergency management and solid waste management. The major goals of the plan are

- enhancing the protection of public health and safety,
- increasing the speed and efficiency of clean-up,
- minimizing the short and long term environmental impact, and
- reducing the economic cost of waste management on already strained communities.

The plan is anticipated to have four basic components:

1. forecasting the generation of debris by type, distribution, and volume using existing modeling techniques,
2. recommending, based on the debris generation estimates, best management practices for the various types of debris generated,
3. assessing the existing physical and administrative infrastructure and recommending how to strengthen the physical and administrative systems to implement the recommended best management practices, and
4. generating model plans that counties may use to develop their own plans.

The counties will be expected to adapt the State Plan to the issues specific to the individual islands.

Teaford (1995) presented a very comprehensive discussion of the content required in a disaster debris management plan. A disaster debris management plan should include the:

- types of disasters likely to occur,
- types and amounts of disaster debris likely to be generated by each disaster type,
- local resources available to manage disaster debris,
- preferred debris management strategy,
- public information dissemination strategy, and
- funding issues.

Co-lateral waste production should also be addressed. For instance, floods produce a large amount of sandbags in addition to the debris generated directly by flooding. Temporary shelters will consume a large quantity of single use materials and can be expected to generate large quantities of paper and plastic packaging.

Prior to the disaster, the availability of disaster response resources must be identified and checklists should be created. These checklists should include (at a minimum):

- rosters and contact information for the debris management teams,
- descriptions and locations of available equipment and supplies for debris removal and recovery,
- descriptions of mutual aid agreements,
- a list of recycling, reuse, and disposal facilities including site descriptions and locations,
- potential markets and end-uses for recovered materials,
- names of haulers and processors and their material capacities,
- names of C&D contractors and debris processors,
- descriptions and contact information for household hazardous waste and small quantity generator waste programs,
- waste exchange programs,
- temporary storage and processing sites,

- maps and diagrams of existing waste facilities and storage or processing sites and transportation corridors,
- non-profit and volunteer organizations, and
- news media contacts.

While a daunting task, pre-planning may also be useful when attempting to obtain federal funds. FEMA generally reimburses least cost and diversion programs if they mesh with existing policies. These policies must be approved by FEMA prior to the initiation of diversion programs.

Typically, there will be two major phases to a debris management strategy. The first is the removal of debris which could cause an immediate threat to public safety (highly unstable structures, clearing of roadways, etc.). Generally, the opportunities for diversion and recycling during this phase will be limited. The second phase is long-term debris removal associated with recovery. This phase provides the greatest opportunity for diversion and recycling. The use of curbside collection and/or drop-off bins may aid in material separation. However, if the public is not informed about the recycling effort, participation will be low and contamination will most likely be a problem. Communication may be difficult after the disaster thus, a variety of techniques such as newsprint, TV/radio, door hangers, flyers at shelters, and internet postings should be used.

After the disaster, increasing the capacity of the existing waste management programs will be a major issue. Developing, implementing, and permitting new practices will be extremely difficult which makes pre-planning even more important. To minimize impact on disposal capacity, local policies for diversion of disaster debris should be established well in advance. Debris clearance funded by FEMA must be completed within six months of declaration of the major disaster unless an extension is granted.

Aqualta (1995) produced an Emergency Response Planning Workbook that may be a good tool for preliminary development of a disaster management plan. The Workbook has a question, answer, and fill-in format that should ensure that main topics are addressed while opening the door for discussion of additional issues.

Recovering Construction and Demolition Debris

The techniques used to recover construction and demolition (C&D) debris may be used or adapted to disaster debris management. It is therefore useful to discuss certain aspects of demolition debris recovery including materials recovered, recovery techniques, costs, material end uses, and challenges.

Burgess and Giroux (1997) discussed preparations for the recovery of demolition debris. Prior to demolition of a structure, a hazardous material survey should be conducted. This survey should include a records search, query of employees, visual inspection, and sample collection and analysis. The testing techniques required for some of the hazardous materials most commonly encountered are presented in Table 2. Demolition costs will often reflect the amount of easily recovered materials in the structure. Costs can range from $0 for structures with a large amount of salvageable steel to $6/ft^{2} of floor area for large, multistory factory buildings. Table 2 presents some options for recycling the debris.

Table 2. Hazardous Material Testing Techniques (Burgess and Giroux, 1997).

Material	Testing Technique
Asbestos	Visual inspection by a consultant trained and experienced in asbestos abatement
Lead-based Paints	An experienced consultant may use a portable X-ray fluorescence detectors may be used for detection at the site by or samples may be sent to a laboratory for analysis.
Polychlorinated Biphenyls (PCBs)	Field screening kits are available for initial assessment, laboratory analysis is the only way to verify the presence of PCBs
Chemical and Petroleum Wastes	Inspection and characterization of containers, tanks, and vessels containing chemical products. Laboratory analysis will be required where labels are missing
Mercury	Visual inspection after removing switch and equipment covers
Building Materials	Sampling and laboratory testing of flooring materials in high risk areas (plating rooms, hydraulic equipment, etc.)

Table 3. Demolition Debris Recycling Options (Burgess and Giroux, 1997).

Demolition Material	Disposal/Recycling Options
Asphalt (paving and shingles)	Recycle into new asphalt pavement, disposal in bulky waste landfill, or use as clean fill on or off site if local and state regulations allow.
Earth/Soil	Recycle by incorporation into new asphalt pavement, disposal in bulky waste landfill, or use as clean fill on or off site if allowed by local and state regulations.
Electrical (fixtures and wiring)	Recycle metal components and dispose of remaining components in solid waste disposal area.
Insulation (non-asbestos, rigid polystyrene, fiberglass bat and roofing)	Disposal in bulky waste or solid waste disposal area as allowed by state and local regulations.
Masonry and Rubble (bricks, cinder blocks, concrete and mortar, porcelain, rock, stone, and tile)	Bulky waste landfill. May be used as clean fill and/or recycled if allowed by regulations; processing such as crushing may be required.
Metal (plumbing, electrical, gutters, sheet metal, structural steel, rebar and studs)	Recycle by selling to scrap metal dealer who will, in turn, sell the scrap to a smelter to be recycled.
Plastics (pipes, styrofoam, vinyl siding and laminate)	Dispose in bulky waste landfill or send to a recycler if local market exists.
Roof Materials ((non-asbestos shingles, built up roofing and tar paper)	Dispose in bulky waste landfill or recycle by use as an aggregate in asphalt pavements.
Vinyl (siding, flooring, doors, and windows)	Reuse if removed intact or dispose in bulky waste or solid waste disposal area as allowed by regulations.
Wood (treated and non-treated lumber)	Dispose in bulky waste landfill, reuse as structural timber as is or after remilling, recycle by processing and use as boiler fuel, landscaping, compost, animal bedding, or for engineered building products.
Wall Coverings (drywall and plaster)	Dispose in bulky waste landfill or grind up for use as a soil amendment or a substitute for lime on lawns (if regulations allow).
Glass	Dispose in a bulky waste landfill or collect and send to a glass recycling facility.

Kurre (1997) reported on regulations and sampling requirements for the characterization of lead in C&D debris. He indicated that taking grab samples from already demolished buildings may not be an accurate sampling method particularly if the sampling is done after the material has been transported to the processing site. Whenever possible, samples should be taken from the building prior to demolition.

McPhee (1996) reported on the recycling of construction and demolition debris generated by the construction of a new arena in Portland, Oregon. Materials were separated at the generation site into recyclable and waste materials. The drop-boxes used for material separation were inspected frequently to ensure material quality. One of the unique materials recycled was sheetrock (drywall). The sheetrock was processed to separate the gypsum from the paper backing material. The gypsum was then ground and sold to a mushroom farm as a soil amendment. Gypsum boosts the pH of the soil and is a source of calcium and magnesium. The paper was processed via a hammermill and then sold as bedding to a farm. Not only is this material cheaper than sawdust but, it is also an anti-bacterial agent.

Salzman (1997) discussed advantages to recycling demolition debris and ways to improve the recycling of demolition debris. Storing, processing, and selling salvageable materials on-site often reduces the cost of demolition. Once the easily salvageable materials have been removed, the remaining debris is usually landfilled simply because it is the least-cost alternative. Stimulating demand for the materials that are generated and reducing the costs associated with their recovery could increase the diversion of demolition debris. Techniques that could be used to increase the demand for the recovered debris materials include:

- inventorying the entire building prior to demolition and noting material condition,
- developing estimates of the volume and tonnage of material that cannot be reused or recycled,
- advertising the reclaimable material inventory to potential consumers,
- specifying the use of recovered materials in new construction wherever possible, and
- providing subsidies and tax-incentives for the reclamation and re-use of materials.

Demolition costs are a function of:

- the structure and its component parts,
- the presence of hazardous materials,
- the availability of on-site processing and storage space,
- the wages for labor, and
- the liability exposure.

These factors will also impact the cost of recycling debris materials. Identifying areas where recycling will increase and decrease costs is imperative when attempting to increase the rate of debris recovery. Systemized deconstruction will increase material quality and revenue from materials. It will also decrease costs associated with separation activities. However, systemized deconstruction requires more planning, management, and supervision than a traditional demolition operation.

Robert Brickner (1995) presented a study of C&D debris generation rates and markets in Washington State. The materials he reported on included asphalt shingle roofing, gypsum wallboard (drywall), concrete pavement, and asphalt pavement. His findings follow.

Asphalt shingle roofing is packaged in squares. Ten shingle squares is approximately one ton of material. The reuse options for asphalt shingling include:

- utilization as an energy source,
- use as an additive to cold-mix paving compounds,
- use as an additive to hot mix asphalt (greatest market potential),
- use in general paving mixtures, and
- production of roofing materials.

Market barriers to the re-use of asphalt shingling include concerns over asbestos content, regulatory approval, and project capitalization costs. Also, the recycling of asphalt shingles is not currently acknowledged when calculating recycling goals.

The amount of gypsum wallboard in a structure can be estimated using the following rule-of thumb, 1,000 ft^2 of surface area (32 – 4ft x 8ft sheets) is approximately one ton of material. The wallboard has two components, a heavy paper backing and a 3/8-in thick layer of gypsum. These materials must be separated and recycled separately, an extremely difficult task if the material is wet. The gypsum can be used in the manufacture of new wallboard, as a soil additive, as a fertilizer additive, in agricultural operations, and in composting operations. The gypsum will raise the pH of a soil and act as buffer. The paper backing can be shredded and used as animal bedding. The barriers to larger scale recycling of gypsum wallboard are product quality perceptions, economic issues, and product quality control.

Concrete pavement is recycled by processing (crushing) it into an aggregate material which can then be used as a base or fill material. There is a tremendous demand for recycled concrete in the pavement and paving industries and no significant barriers to the re-use of concrete pavement. It cannot, however, be used in structural applications.

Asphalt pavement is generally recycled directly into new pavement. It may also be used as an aggregate material. There are no significant barriers to the re-use of this material.

The composition of disaster debris will often be very similar to C&D debris (wood, concrete, asphalt, yard waste, gypsum wallboard, glass, brick, rock and soil) with contaminants (personal belongings, household hazardous waste, white and brown goods) plus disaster response materials (plastic sheeting, water containers, etc.). Some contamination is inevitable but the more these materials are mixed, the less likely recycling will succeed.

Solis et al. (1996) reviewed disaster debris management experiences in Canada. They determined that the viability of debris recycling will depend on:

- the existence of established local debris processors and infrastructure,
- the existing recycling programs and reduction strategies,

- the distance between the disaster area and debris processors and/or infrastructure,
- market demand for debris on a product by products basis,
- debris quality (a function of type of disaster, demolition techniques, and handling),
- local re-use and recycling policies (particularly material specifications), and
- sorting facilities or the ability to provide separate collection and transportation.

Potential savings associated with re-use include:

- the use of rubble as sanitary landfill cover,
- the use of rubble to reinforce embankments,
- utilizing clean debris for land reclamation,
- composting organic materials for re-sale to nurseries, and
- the use of wood chips as a soil cover and for erosion protection.

Factors that may make reuse a feasible option are presented in Table 4.

Table 4. Factors influencing the feasibility of disaster debris recycling (Solis et al., 1996).

Factor	Effect
Administrative measures	Free or low-cost debris disposal may not encourage separation
Communication failure	Lack of an information network for advertising material availability
Environmental conditions	Debris may be damaged by the elements and be unsuitable for re-use or recycling
Political considerations	Factors that call for fast debris clearance
Quality of debris	Lack of demolition experts and technology
Sanitation policies	Debris covered with lime or earth to reduce epidemic risks
Urgency of site clearance	No time for slow, organized salvage and separation operations

Case Studies

Midwest Floods of 1993. In 1993 the Midwest United States suffered from extensive flooding. Lincoln County, Missouri had the following experiences (US EPA, 1995). Mud and sand on the roads were cleared to drainage ditches to open the right-of-way. This material was eventually reclaimed and supplied to farmers. A significant amount of residential debris disposal was occurring at night that led to illegal dumping. Staffers at residential collection sites sorted debris into disposable, recyclable, hazardous, and questionable categories. Clean up was not required at the collection sites. The ban on landfilling of compostables was temporarily lifted. Approximately 350 homes were demolished. Once these homes were purchased by the county, county crews removed and separated salvageable items. The demolition contractor then had options on debris management (sell, give away, dispose). The shell, primarily wood, was then demolished and incinerated with an air-curtain incinerator. The remaining debris was landfilled.

Hurricane Andrew. In 1992, Hurricane Andrew struck Metro Dade County, Florida and generated approximately 6 million tons, 43 million yd^3, of debris (US EPA, 1995). Collection of residential garbage, due to the potential health risk, and clearing highways was prioritized. Three weeks after the hurricane made landfall, residential collection rates had doubled. Much of this increase was attributed to the continued electrical outages and the resultant spoilage of foodstuffs. Garbage collection and street clearing operations were running 7 days/week, 18 hours per day. Some employees were initially unable to work due to personal obligations. However, their unavailability was offset for the most part by other employees offering assistance. During the clean up operation, the collected debris had the following chronology:

- initially, primarily downed trees were collected from road clearing operations,
- household debris then began to contribute, and
- finally, C&D materials became more predominant as repairs commenced.

Wood, yard waste, appliances, and metals were taken to trash and recycling drop off centers where:

- wood and yard wastes were chipped for mulch (~500,000 tons) and
- appliances and metals were collected by scrap dealers.

The sites initially setup were quickly overwhelmed and neighborhood staging areas were set up in parks and other open areas. Residents presorted waste into burnable and non-burnable components for curbside collection. These materials were hauled to staging areas where hazardous materials were removed. The staging areas were tested for soil and water contamination after collection ceased.

Air-curtain incinerators were used initially to decrease the volume of the waste generated. Significant problems were encountered due to the mixed nature of the waste. In some cases, the operation was effectively open burning. This resulted in public complaints and the burning operations ceased three weeks after initiation. The ash residue from the burning was tested and then disposed of as hazardous or non-hazardous, depending on the results of the tests.

Donovan (1992) reported on the debris clean up effort following Hurricane Andrew. The main problems encountered were waste hauling and dumping logistics. Area landfills were at or near their permitted capacity. The operation of eighty burn sites was chosen over opening more landfills. This was done in an attempt to avoid the landfill crisis created in North Carolina by Hugo where 14 years worth of waste was landfilled during the clean up.

The service capacities of waste management companies were heavily strained due not only to increased collection but also by the service required by food kitchens, military food distribution centers, and shelters. Regional waste haulers had to tap branch offices and divisions in 20 other states for equipment and labor. The clean-up effort was also hampered by the displacement of 4- and 6-yd^3 containers by the hurricane. Some were found two miles from their usual service site. Medical waste haulers branched out and supplied pharmaceuticals, using clean trucks, to Red Cross field hospitals.

While a large amount of labor and equipment was volunteered, it was not well coordinated particularly with the smaller hauling operations. In particular, the donation of a shredder was not accepted which resulted in the equipment going to Louisiana instead.

Tansil et al. (1994) discussed the structural waste generated by Hurricane Andrew. This disaster generated 2.4 million tons of structural waste with approximately 20% of this waste generated during repair and rebuilding operations. During the cleanup operations, C&D debris represented 50% of the waste stream, 80% once tree waste was removed. The structural waste was generally unburnable and recycling was difficult due to contamination. The disposal of structural debris consumed more than five years of landfill space in the South Florida area.

Tansil's primary contribution was the information presented in Tables 5, 6, 7, and 8 that detail the structural components in buildings of various sizes and construction. The information in these tables can be combined with estimates of the number, size, and type of buildings in an area to determine debris quantity and composition.

Table 5. Structural Composition of a Small (800 ft^2) Two Bedroom Home in South Florida – all units tons (Tansil, et al., 1992).

Structure and Roof Type	**Glass**	**Wood**	**Concrete**	**Roofing Material**	**Total Weight**
Concrete structure with asphalt roof	0.77	2.26	26.80	6.07	35.13
Concrete structure with fiberglass shingle roof	0.77	2.26	26.80	4.75	33.81
Concrete structure with clay tile roof	0.77	2.26	26.80	7.92	36.98
Wood structure with asphalt roof	0.77	14.00	0.00	6.07	20.83
Wood structure with fiberglass shingle roof	0.77	14.00	0.00	4.75	18.76
Wood structure with clay tile roof	0.77	14.00	0.00	7.92	21.93

Table 6. Structural Composition of a Large (2,000 ft^2) Two Bedroom Home in South Florida - all units tons (Tansil, et al., 1992).

Structure and Roof Type	**Glass**	**Wood**	**Concrete**	**Roofing Material**	**Total Weight**
Concrete structure with asphalt roof	1.34	4.07	54.94	15.25	75.86
Concrete structure with fiberglass shingle roof	1.34	4.07	54.94	12.15	72.48
Concrete structure with clay tile roof	1.34	4.07	54.94	20.25	80.58
Wood structure with asphalt roof	1.34	25.94	0.00	15.25	41.46
Wood structure with fiberglass shingle roof	1.34	25.94	0.00	12.15	38.08
Wood structure with clay tile roof	1.34	25.94	0.00	20.25	46.19

Table 7. Roof Components in a South Florida Home (from Tansil, et al., 1992).

Roof Type	Materials	
	Component	**Weight (lb/ft^2)**
Asphalt-Gravel	Insulation	1
	Gravel	5.5
	2"x4" trusses and sheeting	3
	Electrical	2
Fiberglass Shingle	Insulation	1
	Gravel	3
	2"x4" trusses and sheeting	3
	Electrical	2
Clay Tile	Insulation	1
	Gravel	9
	2"x4" trusses and sheeting	3
	Electrical	2

Table 8. Structural Components in a South Florida Home (from Tansil, et al., 1992).

Structure Type (exclusive of roofing)	Materials	
	Component	**Weight (lb/ft^2)**
Concrete	Concrete block heavy aggregate	55
	Concrete tie-beam	67.2
	Gypsum dry wall (exterior)	2
	Gypsum dry wall (interior)	4
	Glass and window trim	8
Wood	2"x4" trusses	2
	½" exterior plywood and plastic sheeting	16
	Gypsum dry wall (exterior)	1.45
	Gypsum dry wall (interior)	4
	Stucco	4
	Glass and window trim	8

Hurricane Hugo. In 1989 Hurricane Hugo made landfall on the North Carolina Coast (US EPA, 1995). Mecklenberg County, NC saw 2 million yd^3 of green wastes (shrubs, leaves, grass, tree materials) generated over night. The County had been prepared for medical, housing, and communication needs but was completely unprepared for the enormous quantity of debris. Only 2.5 years of capacity remained in the county's only municipal landfill and existing air pollution problems eliminated burning as a management option. Green waste, the largest waste category, was collected and shredded for use as mulch and boiler fuel. Eleven public properties including former, present, and future landfill sites as well as parcels at the Charlotte Airport were used for green waste drop-off. Private citizens also volunteered land. Four hundred thousand tons of green wastes were collected during the first 10 months. This material had an extremely low contamination level due in part to the county's policy of accepting all storm-related non-green waste free of charge (6,300 tons of primarily C&D waste) for the first three weeks of recovery. Also, the green-waste site entrances were staffed during operating hours and material prohibitions were strictly enforced. Normal curbside collection resumed in two days that provided convenient disposal of other wastes. The staging of wood wastes prior to shredding was a fire hazard issue. Mulch storage for more than a month may result in fires due to the heat generated by the decomposition process. One such fire took a week to extinguish. The shredding operations continued for 16 months and cost $7 million.

Hurricane Fran. Tandy (1996) reported on the clean-up efforts following Hurricane Fran. Most counties reported that operating regular waste collection routes, the increase in waste receipt, and debris removal overwhelmed them. Chatham County had widespread power outages that rendered the compactors at twelve of their collection sites inoperable for a week. Waste had to be hauled away four times more often than when the compactors were operating.

Los Angeles, CA Earthquake. Berg (1995) reported on the processing of the waste produced by the 1994 Los Angeles, Ca earthquake. Rubble and mixed waste from the disaster were being generated at more than 5,000 tpd and may eventually total 2 million tons. Processing of this waste included a two-pronged recycling effort:

- source separation of materials at curbside and
- debris processing at special processing sites

The cost of separating and processing the quake waste was estimated to be more the $1/ton less than landfilling ($13.45 per ton for hauling and recycling versus $14.83 per ton for collection and landfill disposal). On a tipping fee basis, the cost of recycling was the same or slightly higher than landfilling depending on which processors and landfills were compared. One of the primary processors charged $30.08/ton while tipping fees at area landfills ranged from $25/ ton to $30.04/ton.

Existing C&D recycling facilities were contracted for debris processing. These facilities were quickly overwhelmed. Initial projections indicated a 300-tpd receipt rate while over 1,000 tpd were actually received. The debris composition was also found to be significantly different from standard C&D and varied with time. Initially, the stream was predominantly hard demolition type materials (concrete, asphalt, brick, block). Gradually, it shifted to softer interior waste materials (wallboard, carpet, wiring, etc.). It took approximately two months for the primary facility to adapt to the new condition during which time the gates were closed while the plant re-tooled and re-organized the processing equipment.

Initially, approximately 30% of the quake waste stream was being recycled through one C&D processing facility. Eventually, two more C&D processing facilities were added and the recycling rate increased to 80%. Recycling contracts, not material resale, paid for the operation of the facilities. Some materials were sold (metals, fuel-grade wood chips, crushed red brick), while others were given away (mulch), all of the remaining materials were removed at a cost to the facility. Ninety-two percent of the total stream was reclaimed for other uses through the C&D facilities as well as ten other recycling operations.

Crown Recycling, one of the main C&D operations, processed the incoming material in the following way:

- Load was dumped and then fed into a trommel to remove dirt, small rocks, woody organic waste (trommel unders).
- Remainder was sent to an eight-man picking belt that removes:
  - brick, metal, paper, and plastic into individual containers,
  - scrap wood, larger tree limbs, and other green waste is ground and then separated into two sizes by a trommel screen (a single spotter removes contaminants from the larger material), and
  - waste stream remaining on the belt is clean concrete and some glass.
- Dirt, small rocks, wood organic waste (trommel unders) are processed on a second line:
  - an air knife lifts dirt and organics off the rocks,
  - a two deck screen sifts out dirt,
  - a magnet removes nails and metal pieces,
  - a six-man crew grabs wood, trash and other debris, and
  - remainder was clean concrete and small glass pieces.
- All wood materials are combined and then processed with a tub grinder. This material is then sorted by size into oversize (fuel grade) and undersize (mulch) chips.
- The concrete is further processed at another site into smaller pieces for use as underbearing in road construction.
- The glass is crushed into sand.
- Metal is sold to scrap dealers.
- The brick is crushed and solid as decorative landscaping but has questionable value.

Coke (1995) detailed the recycling operations conducted by Hayden Brothers Engineering Contractors, Inc. following the Los Angeles Earthquake. The contract executed required that 80% of the debris processed be recycled. The contract stipulated a base rate of $25/ton of earthquake debris processed with provisions to pay $27/ton for achieving a 90% recovery rate. The contract further specified the recovery of specific items including dirt, yard waste (tree trimmings), metals, concrete block, and wood. The Los Angeles Sanitation District utilizes the dirt, crushed concrete, and yard waste at the landfill while the contractor must market the remaining materials. During the startup phase, the operation was able to process 500 tpd and eventually reached a 1500-tpd processing rate with consistent recovery rates of over 90%. During the first six months of operation, an average recovery rate of 93% was recorded with the diversion of 554 tons of metal; 1911 tons of wood; 47437 tons of dirt; 41,873 tons of concrete; 1532 tons of green waste; and 31 tons of cardboard.

Hyogoken-nambu, Japan Earthquake. Hayashi and Katsumi (1996) reported on the generation and management of debris following the 1995 earthquake in Hyogoken-Nambu, Japan. This earthquake measured 7.2 on the Richter scale and generated 20 million tons of debris. Approximately 200,000 public and private buildings collapsed. The general waste management strategy was to identify sites as one of three types prior to initiating clean up. The three site designations used were:

1. least controlled sites where safe, stable wastes are present,
2. controlled sites where safe but unstable wastes are present, and
3. strictly controlled sites where hazardous wastes are present.

The overall waste management plan was divided into three phases:

Phase I - immediate Response including rescue, secondary disaster prevention, and security,
Phase II - recovery mainly securing the integrity of the road network, and
Phase III - restoration that includes restoration activities and preservation of property.

The waste management at a given site was then broken down into four stages;

1. demolition,
2. transportation,
3. intermediate treatment, and
4. final disposal

Twenty-seven percent of the demolition was accomplished in the two months immediately following the earthquake and 58% was completed in four months. Impacts on air quality were of particular concern during the recovery process. Target buildings were covered and watered to limit dust production. Asbestos release was monitored as necessary. The impact of damaged and abandoned appliances on air quality and safety was also a concern.

During the transportation operations, the coordination of trucking and the processing capacity of disposal sites was an issue. Mingling of materials resulted in some long-term stockpiling at the temporary storage sites. These storage sites provided intermediate treatment which primarily involved the separation of the received materials into incombustible, wooden, and residential materials. The separated materials were recycled when possible. Incineration was also used at some of the temporary storage sites as a size reduction process. In some cases, illegal (open) incineration was allowed at these sites, although only during the first three months of clean up. Some instances of demolition contractors dumping and incinerating illegally were recorded. Pollution and ashes were a significant public concern. Testing indicated a negligible deterioration in environmental quality, except for the detection of dioxin near some of the burning sites.

The final disposal options consisted of recycling, coastal reclamation, landfilling, and incineration. Japan has a significant land shortage thus, coastal reclamation with clean aggregate materials is commonly used as a disposal option. The speed at which demolition took place contributed to mingling of materials which limited disposal options and increased the difficulty and cost of processing. The least controlled sites generally had the most contamination. The majority of the debris material was reclaimed, approximately 40% was disposed. Coastal reclamation is considered material re-use.

Hurricane Opal. Camp Dresser and McKee (1996) documented their involvement in the clean up of the Bay County, Florida area following Hurricane Opal. Sixty-five thousand tons of debris including C&D materials, uprooted trees, and vegetative wastes were generated. The clean up program was accomplished in two-phases. The first phase was the development of a clean up plan. The county did not have an existing disaster clean up plan. The second phase was the implementation of the cleanup plan. The management goals identified in the clean plan were:

1. cleanup debris from rights-of-way,
2. utilize a minimum number of qualified contractors,
3. minimize opportunities for fraud,
4. provide acceptable accountability to state and federal agencies, and
5. maintain communication between Bay County and its citizens.

In order for a contractor to qualify for inclusion in the bidding process, they had to meet the following requirements:

- local offices,
- ability to obtain substantial bonding,
- access to comprehensive equipment and resources, and
- regional revenues in excess of $5 million.

Hurricane Georges. Gray (1998) reported on the debris clean up in the Florida Keys and Escambia County, Florida following Hurricane Georges. The advance of Hurricane Georges was particularly slow which allowed for significant planning and organization prior to landfill disposal and greatly facilitated clean up efforts. Debris removal crews began to clear debris from major thoroughfares while the eye of the storm, approximately one hour, passed over Key West. The majority of the Key West clean up effort was completed in three weeks. During this time period, 100,000 yd^3 of debris was processed at an 11-acre facility set up at an old fairgrounds. The debris was processed with tub grinders after removing plastics and metals by hand. Despite the effort to remove contaminants, the processed material was still not clean enough for land application. Approximately 80 % of the mulch was hauled to Miami landfills. The remaining 20% of material was burned through unspecified methods. The rapid pace of the Key West clean up was due, in no small part, to the anticipation of a major festival in late October which attracts large numbers of tourists.

The remainder of the Florida Keys required approximately four months to achieve significant recovery. Nearly 800,000 yd^3 was ultimately processed, 30 to 40 % was incinerated and the remainder shipped to Broward or Dade County landfills.. The largest logistic difficulty encountered was the size of the islands. Not only are the islands small but significant portions of them are wetlands. Four staging areas, all less than ten acres, with tub grinders were ultimately established.

Escambia County, located in the Florida Panhandle, was also impacted by Georges. The local landfill saw an additional 200 tpd delivered during the ten weeks of clean up operations. The wood wastes collected were ground to 4-in minus specifications and then shipped for use as boiler fuel at a paper mill.

1998 Central Florida Tornadoes. In mid-evening, on February 22, 1998, a swarm of four tornadoes tore through the Central Florida area inflicting severe damage on Orange, Volusia, Osceola, and Seminole Counties. Volusia and Osceola counties were most heavily impacted. Table 9 summarizes the damage in each county.

Table 9. Damage summaries for Florida counties impacted by the February 1998 tornadoes

County	Casualties	Devastation
Orange	Three confirmed fatalities, 70 people were treated at Orange County hospitals, 15 of those were admitted.	114 buildings were destroyed, 99 buildings suffered major damage, and 147 structures suffered minor damage. Most of the damaged and destroyed buildings were homes
Volusia	Two confirmed fatalities, 3 treated for minor injuries at area hospitals	Thirty-nine houses and mobile homes were destroyed, and 601 houses, mobile homes and apartments were damaged.
Osceola	Twenty-one confirmed dead and 150 people injured of which 20 were admitted to area hospitals.	Initial estimates indicated about 430 buildings were damaged or destroyed. Final numbers were not published.
Seminole	Eleven confirmed dead, thirty-seven people were treated at area hospitals	300 houses and mobile homes were destroyed or damaged throughout the county, and additional 166 homes were damaged and 36 houses and seven mobile homes were destroyed in the Sanford area

A total of $37 million of damage was inflicted on nearly 1,000 homes and business through out the Central Florida area. Figures 1 and 2 dramatically illustrate the power of these tornadoes and the magnitude of the damage they caused. In Figure 2, a car can be seen resting vertically on its nose inside a home.

In addition to the damage to structures, hundreds of cars and trucks were destroyed. One-ton vehicles were tossed around like toys by the twisters and some vehicles were just gone. Residents were robbed of their ability to travel, a very basic need following a disaster. This crisis was heightened by an inability to bring public transportation into the hardest hit areas. Auto-insurance adjusters indicated that the average claim processed was about $1,400.

Osceola County estimated that 250,000 yd^3, essentially one year's waste collection, of rubble was generated throughout the county. An outside company, Grubbs Construction, was contracted for debris clean up at a contract cost of approximately $8 million. This relieved the strain on the local waste service operations and enabled them to continue normal garbage collection. County officials indicated that the selection of Grubbs was based on its previous experiences with disaster clean up and a Grubb Vice-President's previous position as an executive director for FEMA. The debris management plan utilized a 20-acre section of land adjacent to a local landfill for debris processing. This site was used to separate recyclables, grind wood waste, and burn waste with an air-curtain incinerator.

Seminole County had their roads cleared of debris in three days. Four days after the storm, power had been restored to all inhabitable buildings. This unprecedented recovery effort was the result of combined community and government efforts, the streamlining of permitting by the county, and the county's "Just Do It" philosophy.

Figure 1. Debris at the Ponderosa RV Park in Osceola County (Red Huber, The Orlando Sentinel).


Figure 2. Damaged Osceola County home with a car resting inside its walls (Red Huber, The Orlando Sentinel).

While the debris removal operations happened fairly quickly, one year after the tornadoes struck some areas and residents were still struggling with rebuilding efforts.

It was noted in several places that an important difference between a hurricane and a tornado is that most hurricanes cause moderate damage over large areas whereas a tornado touch down causes complete destruction in an isolated area. The nickname ‘twister’ also fits a tornado because of the impact of the intense, rotating winds on the debris generated. Metal, trees, and other assorted materials will be twisted by the winds into a massive knot of intertwined material. Once this knot has been formed, it is virtually impossible to separate, and in some cases transport, the materials due to safety issues.

Additional relief expenditures included $3 million from the FL Department of Labor to create jobs for displaced workers and $2.5 million in relief services from the Red Cross.

Hurricane Iniki. Hurricane Iniki was one of the most powerful and destructive hurricanes to hit Hawaii. It struck on September 11, 1992, passing over the island of Kauai in two hours.

Kauai is 39 miles wide with a population of 50,000. It is a rural island, relying largely on the tourism and agriculture for income. Some 1.2 million tourists visit the island each year.

Records show sustained winds of 130 mph with gusts over 160 mph. However, a gust of 227 mph was reported on one of the higher ridges of the island. The hurricane caused large storm surges with elevations ranging from 10.5 to 12.5 feet above mean lower low water (mllw) at Kekaha to 12.5 to over 20 feet above mllw at Poipu Beach (Ayscue, 1996). Table 10 provides a summary of Hurricane Iniki characteristics as compared with Hurricanes Andrew and Hugo. Figure 3 shows a satellite image of the hurricane as it passed over the island.

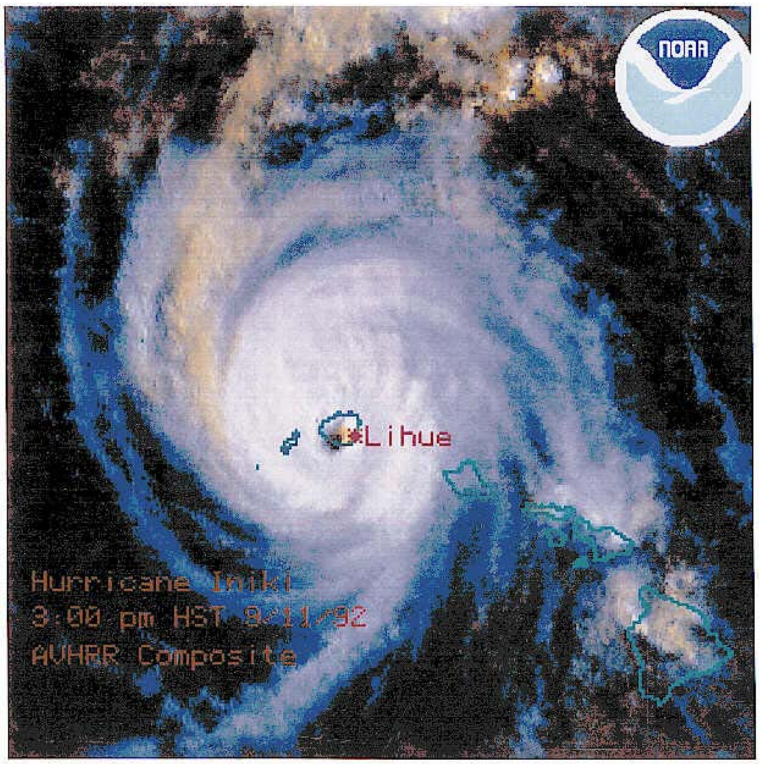

Figure 3. Satellite Picture of Hurricane Inike as it Passes over the Island ofKauai.

Damage attributed to Hurricane Iniki exceeded $3 billion. Approximately 90% of the buildings on Kauai were damaged or destroyed, including over 14,000 homes and 70 hotels (all of the hotels on the island) (Tuneski, 1996). One third of the population was left temporarily homeless. Ninety percent of the utility poles were snapped in half. The macadamia nuts and sugarcane crops were destroyed, as was the newly planted coffee trees and guava crop. Unemployment immediately rose from 6% to 25% and then leveled off at 16%.

Several unique features of Kauai contributed to the extent of the damage. Most of the buildings were constructed with corrugated metal roofing material. Ninety percent of the homes lost much of their roof due to inadequate fastenings, which exacerbated water damage and provided a source of wind-blown debris. The mountainous topography produced high-localized wind speed. In addition, structures were damaged by wave-borne floating volcanic rocks.

Table 10. Physical Characteristics of Hurricanes Hugo, Andrew, and Iniki (Ayscue, 1996)

Characteristic	Hugo	Andrew	Iniki
Category	4	4	3
Sustained winds (mph)	134	145	130
Maximum gusts (mph)	160	175	160
Eye-wall diameter	30	20	10
Hurricane-force winds (miles from eye)	140	45	50
Storm surge (feet)	5 – 20	5 - 17	12 – 24
Rainfall (inches)	5 - 10	2 - 5	Not available
Forward speed at landfall (mph)	27	18	20

Hurricane Iniki produced over 800,000 tons of solid waste. Table 11 provides a summary of the total waste generated and the management of these wastes. Debris management was hampered by inaccessibility to the only landfill on the island (Kekaha), inoperable transfer stations (due to a lack of electricity and damage), roads clogged by debris, and stunned county workers. Consequently, several illegal dumps were established that required eventual cleanup.

A unique feature of waste management was the collection of household hazardous waste generated by homeowners and businesses. A two-day collection was held on October 3 and 4, 1992 at four locations across the island. A total of 24,970 lbs was collected including wastes described in Table 12. Wastes were shipped off island to an interim storage facility owned by the private contractor operating the collection. Liquids such as paint and oils were bulked and drummed.

At the time of the hurricane the Phase I of the Kekaka Landfill (opened in the 1970s) was operating. It was obvious that the existing landfill capacity would soon be exhausted. Consequently Phases II and III of the landfill were permitted for waste disposal. Phase I ceased receiving waste on October 7, 1993. The landfill received refuse, blown debris, green waste, and construction and demolition debris generated by the hurricane. Phase I received approximately 120,000 tons of refuse. As of June 1994 Phase II had received over 140,000 tons.

As an emergency measure, five temporary hurricane-debris-receiving sites (THDRS) were established across the island. Initially, putrescible wastes were burned and/or buried at these sites. A no-burn order was issued within a few weeks and thereafter wastes were placed in trenches.

In order to preserve landfill capacity, the county elected to attempt to recycle as much of the debris as possible. As seen in Table 11, significant amounts of waste were indeed recycled. The success of this program is attributed to an immediate and aggressive public education program. Source-separated green wastes were delivered to two composting sites at Moloau and Waipa Farms. Other source-separated materials were delivered to the THDRS for stockpiling and processing.

Table 11. Hurricane Iniki Waste Management*

Waste Type	Total Waste, tons**	Percent Recycled	Waste Management
Mixed waste	356,500	8.8	Burned or buried
Green waste	111,300	52	Composted
Metal	9,400	68	Baled and shipped off island or buried
Wood	187,400	44	Processed into biofuel for use in commercial boiler or buried
Gypsum wallboard	9,100	48	Sorted, pulverized, used as soil additive or buried
Aggregates	67,000	31	Crushed, used as road base or buried
Plastic sheeting	900	45	Sorted, baled, converted into plastic lumber or buried
Roofing material	21,800	43	Recycled as roofing material or buried
Mixed Construction and Demolition Debris	39,600	34	Biofuel, recycled or buried
Bulky waste	5,300	2	Shredded and buried
Total	808,300	28	

*County of Kauai
**As of June, 1994

Table 12. Hazardous Waste Collected Following Hurricane Iniki*

Waste Type	Quantity (pounds)
Oxidizing substances, liquid and solid	130
Aerosols (flammable)	440
Poisonous liquids & solids	13,480
Corrosive solids & liquids	800
Batteries (dry KOH)	540
Tars, liquid	2,040
Paint related material	6,000
Bromine	100
Caustic alkali liquids	500
Mercury	100
Selenium Oxychloride	40
Flammable liquids	400
Halogenated used oil	400
Total	24,970

*from Simmons, 1994

Hurricane Iniki provided the following lessons:

- Plan ahead and stick to your plan.
- To minimize open dumping, solid waste disposal options must be available immediately.
- Source separation is key to successful recycling.
- Public information is important to successful recycling as well through radio announcements, newspapers, signs, and bulletin board notices.
- Private contractors must be educated as well regarding recycling.
- Waste management must be well documented and distinguished from non-disaster debris.
- Putrescible wastes must be managed immediately, therefore provisions should be made for back up to conventional landfills should they become unavailable.
- Open burning is quick and inexpensive but will bring complaints, is environmentally unacceptable, and generated an ash that must be managed as a hazardous waste.
- Waste must be processed quickly to avoid combustion in temporary dumps or stockpiles.

Oklahoma Tornadoes. On May 3, 1999, a funnel cloud up to a mile wide with wind speeds ranging from 261 to 318 mph touched ground in Oklahoma (Savidge, 1999). Before it left the area, the tornado had claimed 44 lives, seriously injured 800 people, destroyed more than 9,000 homes, and generated 1.6 million cubic yards of debris (Swartz, 1999). The total damage has been estimated to be $500 million.

The local USACE district chief hastened initiation of debris removal operations by tapping into the Mobile, AL district's pre-arranged Indefinite Delivery Indefinite Quantity (IDIQ) contracts. These contracts are reserved for emergency situations and were bid out in 1997 by the USACE Mobile district. DRC won the bid and was brought in to handle debris removal nationwide in

Corps directed projects. The Mobile contract was simply extended to Oklahoma. Clean up operations started 10 to 14 days sooner than they would have if emergency contracts had to be sent out to bid. DRC coordinated the clean up in 16 counties.

Community economic interests were addressed by using local trucks, equipment, and manpower as much as possible. Thirty local crews including some solid waste management companies were hired by DRC.

A centrally located 40-acre plot of land near a commercially operated landfill was used as a debris-processing site. This site became a staging area for hazardous wastes, recyclables, and biodegradable materials separation. Debris was sorted into four categories: recyclables, non-recyclables, compost, and hazardous waste. A 1000-horsepower grinder was used to process non-recyclables and debris. Materials were reduced to approximately 30% of their original size. Materials recycled include vegetative debris, rocks and bricks, wood, drywall, and vehicles. As much waste as possible was mulched for use as landfill cover material. Residents were encouraged to separate as much of their waste as possible prior to putting it curbside for collection. In particular, an effort was made to inform the public that residential garbage and debris should not be mixed. These materials are further separated at the staging site (Swartz, 1999).

Not all areas were able to recycle debris, however. In some areas, direct burial and burning were used since they are time and cost efficient. Some wastes were disposed of in unlined fills with the hope that hazardous wastes would be handled properly. One emergency burial site was approved by regulators. One official was quoted as saying "We have relaxed every state rule to the maximum. The last thing we want to do is be an impediment to recovery taking place (Killackey et al, 1999)."

Some cities hired their own contractors with the understanding that they would receive 100% reimbursement if they recycled when appropriate. Hauling costs paid by some of the cities hiring independent contractors are contained in Table 13.

Table 13. Hauling costs paid by cities hiring private contractors (Killman, 1999).

Area	**Contractor**	**Hauling Cost, $/yd^3**
Midwest	Waste Management Inc.	16 (4 week contract)
Del City	Grubbs Construction	20
Moore	Silver Star Construction Co (a Moore company)	16

The State of Oklahoma has an active emergency management system and runs simulations with the co-operation of its cities. Oklahoma City is particularly well prepared for disasters in part due to the bombing of the Murrah Federal Building in 1995. Many of the organizations and response teams put into effect during the bombing recovery simply switched back on. An emergency operations center equipped with phone lines and coordinators from the fire and police departments, City Attorney's office, and public works was set up in a church gymnasium close to the affected areas. The Oklahoma officials have had emergency training and can make informed decisions about what to do and what type of equipment to provide for various emergency situations. They also have ready contacts with services and businesses that can provide the supplies needed to respond to a disaster.

The first priority in response to the disaster was to clear streets for emergency vehicles. Initial efforts to co-ordinate this process were hampered by the overload placed on local cellular phone networks. City officials were unable to contact utility companies to direct street clearing operations. However, by the time FEMA arrived, Oklahoma City had hauled hundreds of truckloads of debris to an area landfill to clear the way for emergency vehicles. Once the hardest hit areas were identified and delineated, rights of way were cleared for emergency vehicle access. Damaged power and gas lines were shut down prior to allowing rescue workers into an area. Area access was restricted until all health hazards had been addressed. The remaining rights of way were then opened and finally, with homeowner permission, private property was cleared. In the worst hit areas, FEMA contracted bulldozers to clear the land after residents searched for valuables and momentos.

A volunteer group seventy strong with a brush chipper, a stump cutter, and a tub grinder in tow traveled from Pella, Iowa to aid in the clean up of outlying areas. The group broke up into four 15-person teams once they reached the impacted area. More than 175 stumps and 140 tons of wood were chipped during their two-day trip. The mulch produced by the grinding operation was used to prevent soil erosion.

In Mulhall, a town of 200, 50 miles north of Oklahoma City, the citizens had already organized into teams and were using the town's equipment to move debris into the streets for pickup by the Corps. While almost 95% of the town was lost, the majority of the debris had been moved to the rights of way by the time the Corps contractors arrived.

Transportation Issues

The movement of emergency vehicles, equipment for debris removal, and collected debris may be a critical issue following a disaster event. Traffic in San Francisco was paralyzed for three months following the 1989 earthquake. While personal travel will be affected following a disaster, the movement of freight will be a major issue for a efficient and timely recovery operation. Identifying the type of debris generated may aid in prioritizing transport. Debris generated directly by a disaster will be primarily non-degradable C&D materials. While these materials are the obvious result of the disaster, the spoilage of foodstuffs, an indirect result of the disaster, and the generation of waste at response sites may be of a higher priority to ensure public health. Some of the decision variables that must be evaluated when assessing transportation options include:

- the amount of debris,
- infrastructure,
- region (coastal, etc.),
- land use, and
- the type of debris material.

When evaluating these variables the resource needs, landfill and recycling facility capacities, and hauling times should be defined. Finally, the recovery and transportation operations can be prioritized as follows:

1. dangerous (unstable structures),
2. organic (odor and health risk), and
3. inorganic (rubble).

The transportation issues at this point will be mobility (road outages and bottlenecks), emergency response, and timely debris removal. In most cases, timely debris removal is accomplished by transporting the collected material to a temporary storage sites where separation operations may or may not take place and then to a recycling or disposal site. While this may be the most efficient for quick removal of debris, it is not as cost effective as direct transport from the point of collection to the recycling or disposal site.

A commonly overlooked cost impact of clean up operations is road damage by the transport vehicles. The use of large and overweight, trucks on roads designed for lightweight traffic will most likely occur during response operations. Minimizing these impacts will be very challenging but may be accomplished by developing a transportation network. When developing this network, the following items should be addressed:

- classification of roads based on their projected use,
- pre-negotiation of transportation costs,
- vehicle labeling requirement,
- reduction of debris volume,
- access control options,
- dissemination of maps,
- utilization of Intelligent Transportation Systems (ITSs), and
- equipment availability and abilities.

Recycling Disaster Debris Workshop

A Recycling Disaster Debris Workshop was held on August 6, 1999 on the campus of the University of Central Florida. The goals of the workshop were to learn about past disaster debris recycling experiences and discuss ways that we can improve disaster debris recycling efficiency in the future. The US EPA Region IV, Florida Center for Solid and Hazardous Waste Management, and the UCF College of Engineering sponsored the workshop. The one-day workshop was designed to meet the needs of the local emergency response personnel, recycling coordinators, and private waste recyclers providing frontline response to disasters. Approximately 300 brochures were sent to potential attendees in the southeast (brochure provided as Appendix A). Approximately approximately 42 people (see Appendix B) attended the workshop.

Presentations were made by representatives from FEMA and FDEP, university researchers, consultants, emergency response coordinators, and private recyclers (see Appendix C). Copies of the presentations, where available, are provided in Appendix D. Abstracts are presented below.

Florida Department of Environmental Protection – Disaster Debris Overview, Mr. Peter Graselle. Recycling disaster debris has never enjoyed widespread support among Florida communities. Past events, such as Hurricane Andrew, have illustrated both the shortcomings and the potential of a coherent recycling policy. FEMA estimates that approximately 70% of all disaster related debris is construction and demolition debris, whereas the remaining 30% is yard trash. MSW figures for FY 1997 indicate approximately 5.5 million tones of C&D material is recycled in Florida and approximately 3.4 million tons of yard wastes are collected each year in Florida, whereas about 53% is recycled. This annual figure of material collected is comparable to the amount of debris generated after Hurricane Andrew. The 20,000,000 cu yds. of solid waste disposed of in the 12 months after Andrew presented special problems for which little guidance existed. It also began a long-term analysis of special issues such as Residual Screen Material (RSM), which continues today. Can the composition of our daily waste stream be used to anticipate future short-term disasters? This, as well as the logistics involved, and some of the lessons learned from this event, will be discussed. Careful planning involving Federal, State and local agencies is imperative if effective Disaster Debris Recycling is to be achieved. The solid waste community must have a centralized response in place today to effectively cope with massive debris disposal problems the magnitude of hurricane Andrew.

Transportation Issues in Recycling Disaster Debris, Haitham M. Al-Deek, Ph.D., P.E. – Associate Professor, University of Central Florida. Effective transportation planning of disaster debris is crucial for the health and safety of people and the environment. Medical care, transportation of victims, fire fighting, provision of shelter, food, clothing, and water supplies can be all delayed due to transportation difficulties as a result of debris-blocked roads. Therefore, transportation planning of disaster debris must be based on a systems approach, whereby every component is functional in itself and is coordinated into a cohesive working response. It is essential to establish a transportation network and define roads for public use, for use of emergency vehicles, and define highway linkages to debris recycling destinations. The transportation plan may address the following issues: clearing access to essential service buildings, hauling time to recycling sites, adequacy of landfill capacities, disposal of hazardous wastes, potential damage of roads by trucks hauling debris, setting priority for site clearance, establishing accumulation sites, and debris volume reduction before transportation. Estimating the amount of debris that will be generated by a disaster is a very complex task and is very uncertain since a great number of variables must be taken into consideration. It is possible to estimate in advance the actual availability of the municipalities' personnel and emergency debris transportation management capability. These, together with an assessment of the amount of debris generated during the disaster, will allow municipalities to estimate the external support needed, the expected removal time, work schedule, and cost.

Private Recycler's Perspective, Mr. Louis DiVita – Delta Recycling Corp. Delta currently owns and/or operates eight MRFs in the State of Florida, three landfills and several types of collection vehicles including roll-off and grapel trucks. Delta is actively involved in the development of new processing techniques that enable the maximum amount of recovery of recycled material from solid waste. We have seen changes in C&D recycling from the site separation of concrete and steel at demo sites to commingled materials being fully processed at the Material Recovery Facilities (MRF).

The 1996 legislature required C&D facilities to provide financial assurance for closure and post-closure, operating plans, groundwater monitoring, certified operators and spotters and hydrological reports. This requirement has reduced the number of C&D landfills to approximately 90 in 1999. These changes, coupled with the evolution of minimal site separation such as steel and concrete to commingled C&D materials being fully processed at the MRF, has resulted in an increase in the number of C&D MRFs. This presentation shared the basic operation of a C&D MRF and discussed recommendations in using MRFs to enhance disaster debris recycling.

What We Learned From Cleaning Up After Andrew, Deborah Higer - Miami- Dade Department Of Solid Waste Management. Picture a Category 4 hurricane slamming into a Metropolitan county of over 2 million residents. As you try to picture this level of devastation, consider the scope of your current Solid Waste Management Disaster Plan. Metropolitan Dade County is located in one of the most hurricane vulnerable areas of the United States. Hurricane Andrew hit landfall August 24, 1992, generating more than 6 million tons of debris – equivalent to ten years of normal trash collection.

Many lessons were learned from Andrew. The Miami-Dade community of 2 million residents proved to be more resilient than imaginable in coping with cleanup and living in "trashed" neighborhoods. We learned the potential limitations of mulching/composting debris as well as the drawbacks of burning debris as a temporary emergency measure. We learned that we could successfully minimize the long-term effects of a major hurricane on our local disposal system capacity and quickly establish systems, which would speed the cleanup process – which in the case of Andrew took 4 years.

These lessons have been incorporated into the Miami-Dade Department of Solid Waste Management (DSWM) Hurricane Plan. From pre-season preparedness through hurricane recovery, we feel we are ready for the next big one.

The Oklahoma Tornado Recovery and the Realities of Recycling, Mr. John DeLoach, Disaster Services Coordinator for PBS&J. This presentation discussed the most current large scale debris effort in Oklahoma, the most devastating tornado in recent history. The presentation focussed on the perspectives and motivations of the major players in the cleanup effort and the cross-purposes at which the different levels of government often work. It then examined the realities of these conflicts and the negative impacts they have on a coordinated recycling effort. The presentation concluded with a few suggestions to improve the environment and attitudes toward recycling.

Construction and Demolition Waste Recycling, Dr. Timothy Townsend – Assistant Professor, University of Central Florida. This presentation discussed C&D waste composition and generation, C&D materials and markets, recycling options, and environmental issues.

Federal Emergency Management Agency, Mr. Robert H. Mair – Senior Emergency Management Program Specialist. The presentation addressed FEMA response categories, contractual procedures for procurement, and environmental and historical review of FEMA responses. Robert Mair presented a discussion on the Stafford Act and how it can be a helpful tool in preparing for the removal of disaster debris.

Eligible applicants for the Stafford Act are:

- state
- city
- county
- town/village
- political subdivisions
- private non-profit organizations
- Indian tribes/Alaskan villages

For debris removal to be effective a disaster plan must be in place and documentation of the plan is crucial. Without documentation, there is confusion, inefficiency, and loss of funds. Before the actual plan is set up, certain factors must be taken into account, such as: type of debris, location, volume, land use, and possible locations for storage, collection, and separation sites. Once these vital factors are dealt with, then the plan can be created. The actual plan must be flexible, but also consist of the specifics listed below:

- mission statement,
- organization of whom has responsibility for debris removal,
- concentration of operation,
- templated contracts,
- identify temporary and permanent site selection,
- priorities for debris removal,
- establish central emergency service,
- detail specific responsibilities to each department involved,
- list specific actions to update plan,
- identify response capabilities in your plan,
- identify who has authority with local,
- logistical requirements,
- definition of what you will be dealing with,
- location/status of sites/landfills, and
- maps/written descriptions of sites/landfills.

For specifics on these and other related topics, please see the Public Assessment (Stafford Act) sections 403 and 407 in the FEMA Manual 286

Conclusions and Recommendations

While it is well recognized that disaster debris recycling is necessary to minimize utilization of disposal capacity, and the knowledge and infrastructure to recycle disaster debris are largely available, recycling of disaster debris is not occurring. The following reasons are offered for lack of recycling:

- ♦ The cost associated with the separation of recyclable material adds to the total project cost. Often low bid, lump sum procurement procedures lead to disincentives to recycling.
- ♦ Often the large quantity of recyclable materials generated overwhelms the local market, making recycling non-cost effective.
- ♦ Politically necessary expedience of recovery reduces priority given to recycling.
- ♦ Recycling requires the support of local debris management contractors.
- ♦ If disposal is occurring at privately owned landfill, there may not be an incentive to recycle debris.

The following recommendations are offered.

- ♦ Recycling must be included in the community disaster debris management plan. Historically planning for recycling "after-the-fact" has not been successful.
- ♦ Planning must be ensure that recycling is cost effective and the approach is streamlined to avoid delaying cleanup.
- ♦ Planners must work with recycling coalitions to identify available recycling infrastructure.
- ♦ The political and regulatory environment must support creation of the infrastructure necessary to recycle disaster debris.
- ♦ Intelligent Transportation Systems have not been employed in disaster response to date but may be an excellent tool for the dissemination of current traffic and travel information including best speed (not distance) routes from point to point.
- ♦ While the workshop opened the door to some interesting possibilities, a follow-up is warranted. This could be in the form of a round table discussion where representatives from the public and private sector and academia could discuss ways to implement an effective recycling program.

References

Aqualta, Emergency Response Planning Workbook, 20th Floor, 10065 Jasper Avenue, Edmonton, Alberta T5J 3B1, 1995.

Asyscue, J. K., "Hurricane Damage to Residential Structures: Risk and Mitigation," Natural Hazards Research and Applications Information Center web site www.coloradao.edu/hazards/wp/wo94.htm, November, 1996.

Berg, Tom, "Processing L.A.'s Quake Waste," Waste Age, pp. 59-66, Jan. 1995.

Brickner, Robert H., "Researching Debris Generation," Recycling Today, pp. 46-52, Sept. 1995.

Burgess, Paul and B. Giroux, "Preparing for Recovery of Demolition Debris," Solid Waste Technology, pp. 24-28, May/June 1997.

Camp Dresser and McKee, "Bay County Hurricane Opal Storm Debris Cleanup – After Action Report, February 1996", Emergency Preparedness Seminar Proceedings, Section 4, Sept. 24, 1997.

Coke, Janet L., "Recycling Program Diverts Debris from Earthquake Cleanup," Public Works, pp. 50-51, June 1995.

County of Kauai, Dept. of Public Works, "Report on the Management of Hurricane Iniki Debris," Presented at the Recycling Association of Hawaii, Disaster Response Debris Management Conference, Kauai, Hawaii, January 1994.

Donovan, Sharon, "Hurricane Andrew: Waste Haulers and Managers Ease Crisis," Waste Age, pp. 24, 126, Oct. 1992.

El Kurre, John, "Characterizing Construction and Demolition Debris for Lead Contamination," Waste Age, pp. 117-125, July 1997.

EPA, Planning for Disaster Debris, EPA530-K-95-010 USEPA, Office of Solid Waste and Emergency Response, Dec. 1995

Gray, Kevin, "The Grind After the Storm," BioCycle, pp. 38-41, Nov. 1998.

Hayashi, Haruo and T. Katsumi, "Generation and Management of Disaster Waste," Special Issue of Soils and Foundations, Japanese Geotechnical Society, pp. 349-358, Jan. 1996.

Killackey, Jim, D. Zizzo, and R. Medley, "Death Toll Reaches 43," The Daily Oklahoman, May 13, 1999.

Killman, Curtis, "Feds Head Twister Cleanup," Waste News, vol. 5, Issue 1, Man 17, 1999.

McPhee, Marnie, "C&D Recycling in the Home Court," BioCycle, pp. 30-32, March 1996.

Salzman, Steve, "Demolition Debris and Resource Recovery: Making a Good Thing Even Better," Waste Age, pp. 236-247, May 1997.

Savidge, Martin, CNN Web site, US Story Page, http://cnn.com/US/9905/08/clinton.tornadoes.02/, May 18, 1999.

Solis, Gabriela Y., H. C. Hightower, J. Sussex, and J. Kawaguchi, Disaster Debris Management, The Disaster Preparedness Resources Centre, The University of British Columbia, July 1996.

Simmons, G. "Collection of Household Hazardous Waste and other Hazardous Waste from Hurricane Iniki," Presented at the Recycling Association of Hawaii, Disaster Response Debris Management Conference, Kauai, Hawaii, January 1994.

Swartz, N. "Picking Up the Pieces," Waste Age, pp. 44-52, August 1999.

Tandy, Pamela, “Towns Face Tons of Debris from Storm,” The News Observer, Raleigh, NC, September 17, 1996.

Tansel, Berrin, M. P. Whelan, and S. Barrera, “Building Performance and Structural Waste Generation by Hurricane Andrew,” Housing Science, Vol. 18, No. 2, pp. 69-77, 1994.

Teaford, Bonnie, “Preparing for Armageddon: Are You Ready for a Disaster?,” World Waste, pp. 44-48, June, 1995.

Tuneski, Alexander, “Kauai’s Ongoing Recovery After Hurricane Iniki,” www.people.cornell.edu/pages/agt3/kauai.htm, November 1996.

Valera, John, “Hawaii - Formulating Solid Waste Disaster Debris Management Plan,” www.solidwaste.com, Sept. 9, 1998.