APPENDIX A
USACE HURRICANE DEBRIS ESTIMATING MODEL

U.S. Army Corps of Engineers
Hurricane Debris Estimating Model

Background

- The U.S. Army Corps of Engineers (USACE) Emergency Management staff has developed a modeling methodology designed to forecast potential amounts of hurricane generated debris.
- Based on actual data from Hurricanes Frederic, Hugo and Andrew.
- The estimated quantities produced by the model have a predicted accuracy of ± 30%.
- The primary factor used by the model is the number of households in a developed urban/suburban area.
- Other factors utilized are:
  - Cubic yards of debris generated per household per storm category.
  - Vegetative cover.
  - Commercial density.
  - Precipitation.
- Household debris includes damage to the house, contents and surrounding shrubs/trees.
- Vegetative cover includes all trees and shrubbery located along public rights-of-way, parks and residential areas.
- Commercial density includes debris generated by damage to businesses and industrial facilities.
- Private contractors will remove the majority of commercial related debris; however, disposal/reduction space is still required.
- Very wet storms will cause ground saturation, increasing tree fall.

Initial Planning Data

- For planning purposes, the worst case scenario should be used for the subject area.
- The most accurate process is to determine the defined areas by using Doppler Radar (National Weather Service Broadcasts) and Geographical Information Systems (GIS).
- Doppler radar will define the storm's intensity and the exact track of the eye of the storm in relation to the affected area.
- Track the storm and plot the eye path and 5-mile wide bands out from the eye to define areas and estimate wind speeds.
- The wind speed of the eye wall normally determines the reported storm category with the outward or 5-mile bands being a lesser category.

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- Track the storm inland until the wind speeds dissipate below hurricane strength.
- Divide outlined areas by storm category.
- Enter coordinates into a GIS database to determine areas and demographic information, such as:
    - Population.
    - Schools.
    - Businesses.

STEP 1—ESTIMATING DEBRIS QUANTITIES

The formula used in this model will generate debris quantity as an absolute value based on a known/estimated population or a debris quantity per square mile based upon population density per square mile.

- Determine population (P) in the affected area.
- For example, 1990 census data for Harrison County, MS, is 165,500.
- P = 165,500.
- The assumption of 3 persons per household (H) is used for this model.
- Known/estimated population (P) for a jurisdiction may be used to determine a value for H or H=P/3.

Example

A category 4 storm passes through Harrison County, MS. The area is primarily single family dwellings with some apartment complexes, schools, and shopping centers. Vegetation characteristic is heavy because of the proliferation of residential landscape shrubbery and trees throughout the area. The storm is very wet, with rain before and continuing for a few days after the hurricane.

Formula: Q= H(C)(V)(B)(S)

H= P/3= 165,500/3 = 55,167 (3 persons/household)

C= 50 (Factor for a Category 4 storm)

V= 1.5 (Multiplier for heavy vegetation)

B= 1.3 (Multiplier for heavy commercial due to schools/stores/apartments)

S= 1.3 (Multiplier for wet storm event)

Then Q = 55,167 x50x1.5x1.3x1.3 = 6,992,374 cubic yards of debris or 7 million cy

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The Model Formula: Q= H (C)(V)(B)(S) where:

Q is the quantity of debris in cubic yards.

H is the number of households.

C is the storm category factor in cubic yards.

V is the vegetation characteristic multiplier.

B is the commercial/business/industrial use multiplier.

S is the storm precipitation characteristic multiplier.

C is the storm category factor as shown below. It expresses debris quantity in cubic yards (cy) per household by hurricane category and includes the house and its contents, and land foliage.

HURRICANE CATEGORY	VALUE OF "C" FACTOR
1	2 cy
2	8 cy
3	26 cy
✓4	✓50 cy
5	80 cy

V is the vegetation multiplier as shown below. It acts to increase the quantity of debris by adding vegetation, including shrubbery and trees, on public rights-of-way.

VEGETATIVE COVER	VALUE OF "V" MULTIPLIER
LIGHT	1.1
MEDIUM	1.3
✓HEAVY	✓1.5

B is the multiplier that takes into account areas that are not solely single-family residential, but includes small retail stores, schools, apartments, shopping centers, and light industrial/manufacturing facilities. Built into this multiplier is the offsetting commercial insurance requirement for owner/operator salvage operations.

COMMERCIAL DENSITY	VALUE OF "B" MULTIPLIER
LIGHT	1.0
MEDIUM	1.2
✓HEAVY	✓1.3

S is the precipitation multiplier that takes into account either a "wet" or "dry" storm event. A "wet" storm for category 3 or greater storms will generate more vegetative debris due to the uprooting of complete trees.

PRECIPITATION CHARACTERISTIC	VALUE OF "S" MULTIPLIER
NONE TO LIGHT	1.0
✓MEDIUM TO HEAVY	✓1.3

NOTE: **Steps 2 and 3 of this model can also be applied to other debris generating events once an estimated quantity of debris is established.**

STEP 2—DEBRIS STORAGE SITE REQUIREMENTS

- Estimate debris pile stack height of 10-feet.
- 60% usage of land area to provide for roads, safety buffers, burn pits and household hazardous waste areas.

1 acre (ac) = 4,840 square yards (sy)
10 foot stack height = 3.33 yards(y)
total volume per acre = 4,840 sy/ac x 3.33 y = 16,117 cy/ac

- From the example above, the acreage required for debris reduction sites is:

7,000,000/ 16,117 cy/ac = 434 acres (required for debris storage only, no buffers, etc.)

- To provide for roads and buffers, the acreage must be increased by a factor of 1.66.

434 ac x 1.66 = 720 acres or, since one square mile (sm) = 640 acres 720ac/640as/sm=1.12 sm.

- If you assume a 100 acre storage site can be cycled every 45 to 60 days or one time during the recovery period, then 720/2 = 360 ac or four 100 acre sites would be required.
- The number of sites varies with:
    - Size.
    - Distance from source.
    - Speed of reduction (mixed debris is slower than clean woody debris).
    - Removal urgency.
- The USACE commonly removes approximately 70% of the total volume generated with local governments, volunteer groups, and private individuals removing the remainder.

If 7 million cy were estimated, the USACE would estimate removing approximately 4.9 million cy of debris.

STEP 3—CATEGORIES OF DEBRIS

Debris removed will consist of two broad categories:

- Clean wood debris.
- Construction and demolition (C&D) debris.

- The clean debris will come early in the removal process as residents and local governments clear yards and rights-of-way.
- The debris removal mission can be facilitated if debris is segregated as much as possible at the origin along the right-of-way, according to type.
- The public should be informed regarding debris segregation as soon as possible after the storm.
- Time periods should be set for removal, the first 7-10 days clean woody debris only, then followed by other debris, with the metals segregated from non-metals.
- Most common hurricane-generated debris will consist of the following:

  30% Clean woody debris
  70% Mixed C&D

  Of the 70% mixed C&D:

42%	Burnable but requires sorting
5%	Soil
15%	Metals
38%	Landfilled

- Based upon the above, 7,000,000 cy of debris would break down as follows:

  2,100,000 cy Clean woody debris
  4,900,000 cy Mixed C&D

- Of the 4,900,000 cy of mixed C&D, 2,058,000 cy is burnable but requires sorting, 245,000 cy is soil, 735,000 cy is metals, and 1,862,000 cy is landfilled.
- Burning will produce about 95% volume reduction.
- Chipping and grinding reduce the debris volume on a 4-to-1 ratio (4 cy is reduced to 1 cy) or by 75%.
- The rate of burning is basically equal to the rate of chipping/grinding, about 200 cy/hr. However, chipping requires on-site storage and disposal of the chips/mulch.