

Broward County's Web-Based Hurricane Debris Estimation Tool (HurDET)

By Diana Umpierre, GISP, PBS&J and

Glenn Margoles (Broward Co Emergency Management Agency)

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Abstract

A web-based tool was developed to help planners with estimating the potential amounts of debris that hurricanes could cause in Broward County, Florida. It uses parcel, tree canopy and storm surge data to calculate potential debris amounts at the Traffic Analysis Zone (TAZ) level. This interactive tool uses ASP and ArcIMS to calculate the three main types of debris caused by hurricanes: construction & debris (C&D), vegetation-related (downed trees/ branches), and sediment (from surge effects). This paper will present the logic behind the model, as well as some of its pros and cons, and comparison to other models.

Introduction

On September 16, 2004, the Florida Panhandle was hit with the fury of Hurricane Ivan. It landed as a Category 3 near Gulf Shores, Alabama, just west of Escambia County, Florida (the right side of the storm!). Using information from the County website, the following were the debris totals two months after the storm hit the County. Could we model this? Yes. Perfectly? No. No model could. Then, why model?

Escambia Co Reported Totals (as of 12/15/2004)	
Vegetation	4,495,999 cy
C&D	841,299 cy
Sand	925,667 cy
Truck Loads	223,902

Debris modeling helps government officials during pre-disaster planning activities when training exercises are performed and other critical activities are conducted. These activities include:

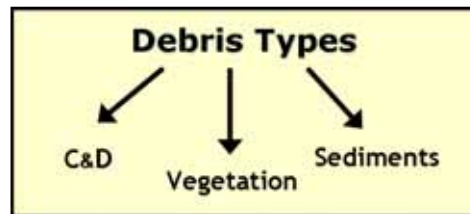
- Identifying temporary staging sites
- Procurement of standing debris removal contractors and 3rd-party monitors
- Ensuring inter-agency and multi-aid agreements are in place
- Updating debris management plans
- Identifying debris-reduction and landfill options
- Predicting temporary labor needs
- Estimating impacts to landfills and other waste management facilities
- Anticipating potential hazardous debris amounts and handling needs

Broward County Estimation

During preparations for the 2004 hurricane season, PBS&J updated the hurricane-related debris volume estimates for Broward County, including updating a web-based estimation tool. Below we summarize the approach used to calculate the debris estimates.

There are very few debris models available. USACE has had a model since the 1990s and it is probably the one most commonly used during pre-planning activities. However, we find that this model may not properly handle the complexities of mixed and dynamic development that are so typical in Southern Florida. Therefore, PBS&J, with input from Broward County, opted to provide an alternative approach that is more dependant on the use of county-specific data in an effort to reflect the land characteristics that may otherwise be too simplistic in other models or too complex in others. PBS&J's web-based version of this model is referred to as the Hurricane Debris Estimation Tool (HurDET) and is the main subject of this paper. Below is a brief description of the underlying methods used for the preparation of the HurDET solution. We will also discuss its advantages to other models but also its limitations and possible refinement ideas.

The HurDET methodology produces estimates for 3 main types of debris: vegetation, construction & demolition (C&D) and sediments. Within the C&D category, a sub-type was added to account for the presence of hazardous materials (HazMat). Although this debris type may be small in terms of weight or volume, it represents an important consideration in debris estimation, due to its unique handling/disposition needs.



C&D and HazMat

To estimate construction and demolition (C&D) debris quantities, the HurDET approach encourages the use of site-specific land use information. In the case of Broward County, the best source for this information is the county's Property Appraiser's parcel-level data. Zoning or land use information derived from aerial or satellite imagery were not specific enough and could not provide the type of desired input for the model. Parcel use classifications are based on those provided by the Florida Department of Revenue (DOR). There are about 100 different DOR use codes that could be assigned to a parcel. For modeling purposes, each parcel use was associated with one of 7 land use types:

- Single Family
- Apartment / Condo
- Commercial Low
- Commercial Medium
- Commercial High
- Green Space
- Water

For each parcel use type and storm category, we assumed a given debris volume. The assumed debris quantities were based on PBS&J's professional experience in cleaning debris from other natural disasters and its professional opinion of what are some reasonable potential quantities that could be produced for each land use type and storm category. Parcels that represented apartments and condominiums (multi-family dwellings) were analyzed differently. For these, we assumed a given debris volume for each unit, not per parcel. This would help to take into account that the more units a condo parcel has, the more the debris amounts it would generate. For estimating hazardous materials, we used the same approach with different volume assumptions.

Vegetation

To estimate vegetation debris, the HurDET approach relies on the use of vegetation information that can be used to derive the number of trees and the tree types. In the case of Broward County, we were very fortunate that the county produced a tree canopy layer. This was provided by the Broward County Planning Department. This coverage is based on 1996 scanned CIR imagery used to identify tree cover using remote sensing analysis software. Their method was aimed at identifying tree-related vegetative cover only (not shrubbery). (Morrow, 2001). The information provided to us consisted of the total tree canopy area for each one-square mile PLSS section in the developable area of the county. Because this information was originally obtained from 1996 aerial images, we updated some of this information using 2003 aerial photography. We limited this update to PLSS sections that appeared to have a significant visible difference in tree coverage from the aerials. Since a 1996 aerial was not available in GIS-ready format, the comparison was done between a 1999 and a 2003 aerial.

We assumed 2 main tree types: hardwood trees (e.g. oaks) and softwood trees (e.g. palms). Broward County's tree canopy layer unfortunately did not have tree type information. Therefore, based on general observations in the field, PBS&J assumed a certain ratio for these (40% to 60%, respectively).

Our vegetative debris estimates are calculated by assuming a given square footage per tree, a given debris volume per tree type and assumptions on the percentage of trees that could be affected in each storm category.

Sediments

To estimate sediment debris resulting from storm surge in coastal areas, we used the County's storm surge inundation GIS layers. Sediment volumes were estimated by assuming a given depth of sediment for each storm category. The depth of sediment was only considered for surge areas that lie within $\frac{1}{2}$ mile of the coastline. This is where PBS&J estimates tidal forces would make the most significant deposition of sediments, based on our experience with previous storm events. Also, since the surge polygons include certain areas (such as buildings and canals) that would not make sense to include in this calculation, we also assumed that only a given percentage of the surge area would experience deposition.

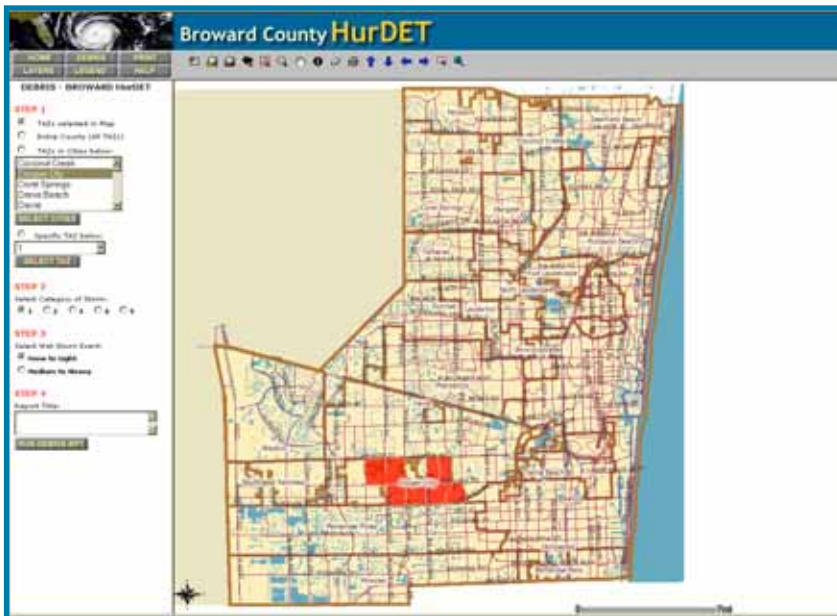
The Web-Based HurDET Application

Although PBS&J debris modeling approach could be calculated via the means of spreadsheets and some desktop GIS analysis, Broward County found it would be very valuable to have an interactive tool where users could specify model parameters and run the model in different geographic areas of interest. Making it web-based would also allow the County to share this tool with other officials outside of their agency. PBS&J developed the HurDET tool to address this need.

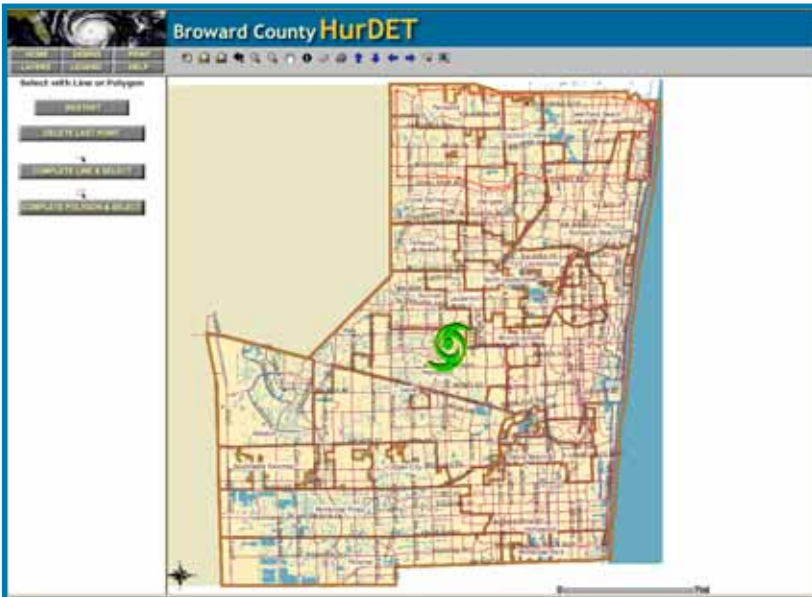
HurDET uses traffic analysis zones (TAZ) as the basis of spatial selection and analysis. The County data (such as parcel use, tree canopy and surge inundation areas) were modified to this level. The size and shape of TAZ polygons made them a better choice over census blocks or tracks. For instance, TAZ boundaries tend to follow municipality boundaries better than blocks and tracks do.

HurDET was developed using ArcIMS technology and Microsoft ASP to add database-driven interactivity. Its interface is simple, but it effectively allows the end users to specify the TAZs of interest in a number of ways, as demonstrated below.

Selecting TAZs by Municipality



Selecting TAZs by using a polygon drawn by the user

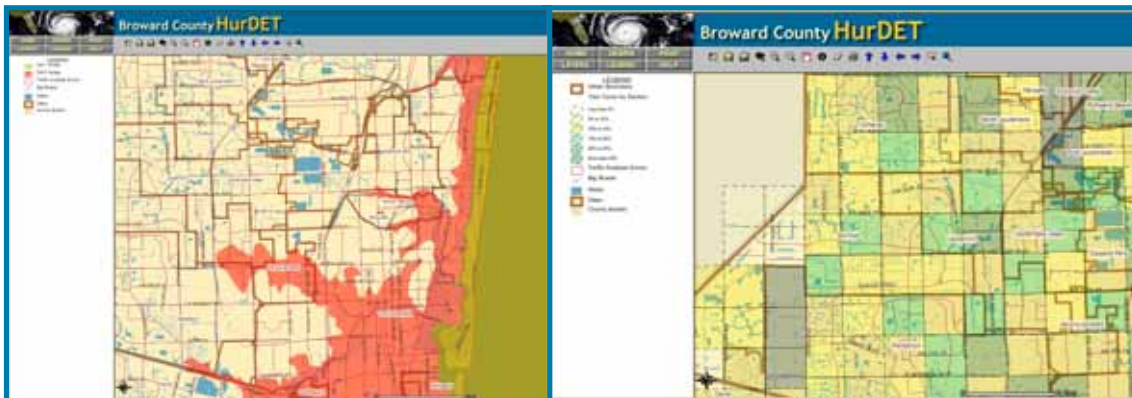


After the user specifies the TAZs of interest, it produces a report that contains the debris estimates using PBS&J custom approach as well as the USACE approach, to allow for comparative analysis. PBS&J debris estimates are broken down by the 4 debris types and provided in cubic yards, as well as tons.

SAMPLE REPORT, CATEGORY 2, WET EVENT: NONE TO LIGHT	
Broward HurDET Debris Estimation Model Results	
Report Date: 5/3/2005 Estimated Area (Ac): 42,774.9	
Property Appraiser Assessments for Selected Area	
Land Assessment:	\$7,724,587,060
Building Assessment:	\$15,136,225,850
Total Assessment:	\$22,860,812,910
<small>Note: Assessment values represent data from the Property Appraisers and has not been manipulated based on Hurricane Category or any other variables.</small>	
USACE Hurricane Debris Estimation Model In Cubic Yards	
<small>Formula: Q = H(C)(V)(B)(S)</small>	
Estimated Population in Selected Area:	248,479
Estimated Households (H): (Population/3)	82,826
Storm Category Factor (C):	8 cy - Category 2 Storm
Vegetation Characteristic Multiplier (V):	1.1
Commercial / Business / Industrial Use Multiplier (B):	1.0
Storm Precipitation Characteristic Multiplier (S):	1.0
Estimated Debris Quantity (Q):	728,872 cy

PBS&J Hurricane Debris Estimation Model In Cubic Yards	
VEGETATION	1,410,801 cy
CONSTRUCTION / DEMOLITION (C & D)	
Single Family:	596,860
Apartment / Condo:	169,233
Water:	1,020
Green Space:	1,605
Commercial Low:	10,304
Commercial Medium:	25,170
Commercial High:	63,618
Total C&D Debris:	867,810 cy
HAZARDOUS MATERIALS	
Single Family:	59,686
Apartment / Condo:	56,411
Water:	0
Green Space:	0
Commercial Low:	6,440
Commercial Medium:	8,390
Commercial High:	6,915
Total HazMat Debris:	137,842 cy
SEDIMENT - 3.5" average (505.0 Ac)	
Total Sediment Debris:	95,052 cy
TOTAL DEBRIS: 2,511,506 cy	

HurDET also displays important GIS data used in the model, as well as basemap information for reference purposes, such as the parcel properties, TAZs, tree canopy and inundation zones.



Other Assumptions and Limitations

All models carry assumptions and have limitations. Understanding these allows for better use of predictive models and avoid the misuse of the model output. For example, it is important to note that there are other variables that can affect debris quantities. The purpose of the HurDET approach is not to include every possible variable as this would be a daunting task. It would also require more site-specific data that is hardly available. We were also not trying to recreate FEMA's Hazus-MH model but to provide a simple, yet site-specific, approach that could serve the need of planners to come up with "ball-park" estimates for use in the update of debris management plans and other pre-disaster planning activities, as described in the Introduction section of this paper.

Some of the other variables not currently taken into account in the HurDET model that could affect actual debris volumes generated by hurricanes include:

- number of buildings in a parcel,
- types of building construction,
- building dimensions and contents,
- proximity of tall trees to buildings,
- available protection from potential air-borne missiles,
- tree heights,
- other effects caused mainly from hurricane-related flooding

The characteristics of the storms themselves can also affect the resulting damage. These include the storm track, translation speed, size of the storm, and wind speed/distribution. The HurDET model assumes that for each storm category, there is a uniform wind distribution throughout each municipality or any other selected geographic region used in analysis. Experience demonstrates that this is really not the case. For example, a category 3 storm hitting the county near Fort Lauderdale and moving northwest, may demonstrate wind gusts near the category 4 level along the coast on the northeast sector of the eye wall. However, the southwest section of the county might only experience winds at a category 2 level. Since the purpose of the HurDET model is for ball-park estimation, especially in pre-disaster planning, then assuming a uniform storm may serve the purpose.

Comparison to the USACE Model

Based on our experience, the HurDET model may yield more accurate and useful debris estimates than USACE's hurricane debris estimation method. This is because the USACE methodology produces only one debris estimate in a given geographic area by using primarily the number of households and only multipliers to account for other land uses and vegetation present. It also assumes that 30% of debris is woody debris and 70% mixed C&D. According to FEMA, the USACE model is a simple model "intended to be used for estimating debris produced by single-family residential building only" and that the "major limitation of this model is the inability to take into account various construction and usage classes". (HAZUS-MH Technical Manual). In the example below, we show how the USACE's methodology could underestimate debris for areas that are highly commercial and but have low or no population. The areas shown below are TAZ polygons and the numbers represent total 2000 census population.



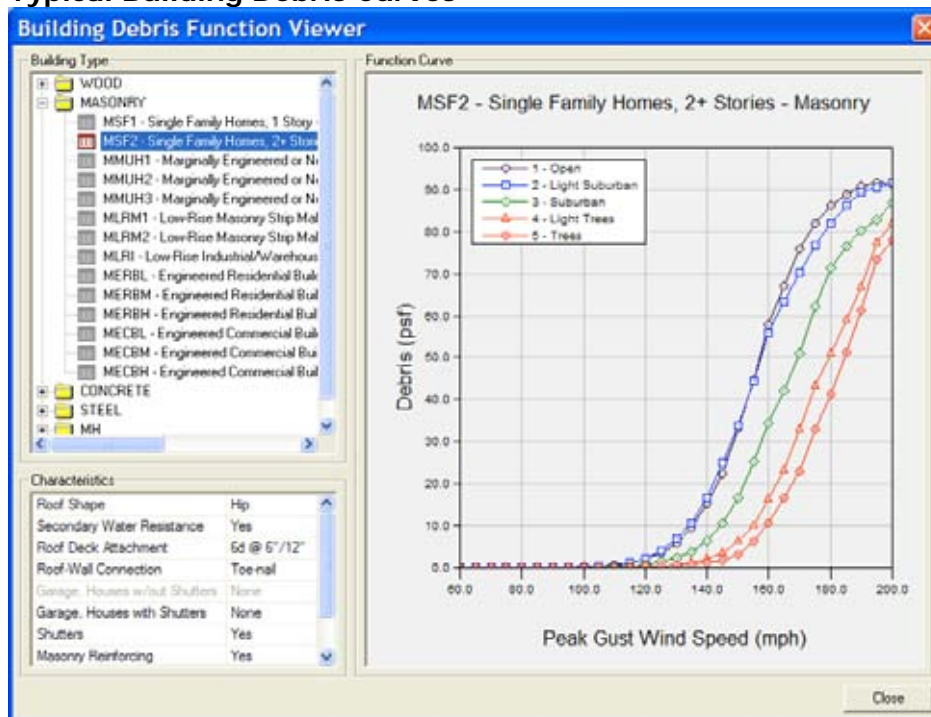
Comparison to the Hazus-MH Model

The most scientific approach to debris estimation is probably FEMA's HAZUS-MH (Hurricane Module). The model was developed over a long period of analysis and input from various professionals.

The basic formula is: Debris = C&D + Tree Blow down

The model takes into account various storm-specific parameters, such as translation speed, radius to winds, max winds, central pressure and track latitude/longitude values. C&D calculations include both debris generated during an event and that generated during rebuild. The methodology accounts for approximately 39 building types, 33 building occupancies, several building characteristics (roof shape, roof deck types, shutters, etc.), tree stems per acre for trees that are \geq than 30 feet high, tree heights, vegetation type, and several other parameters to derive loss curves used in for debris estimation (see example below). Data, without customization, is based on several national databases. A more thorough discussion of the model is described in the HAZUS-MH Technical Manual.

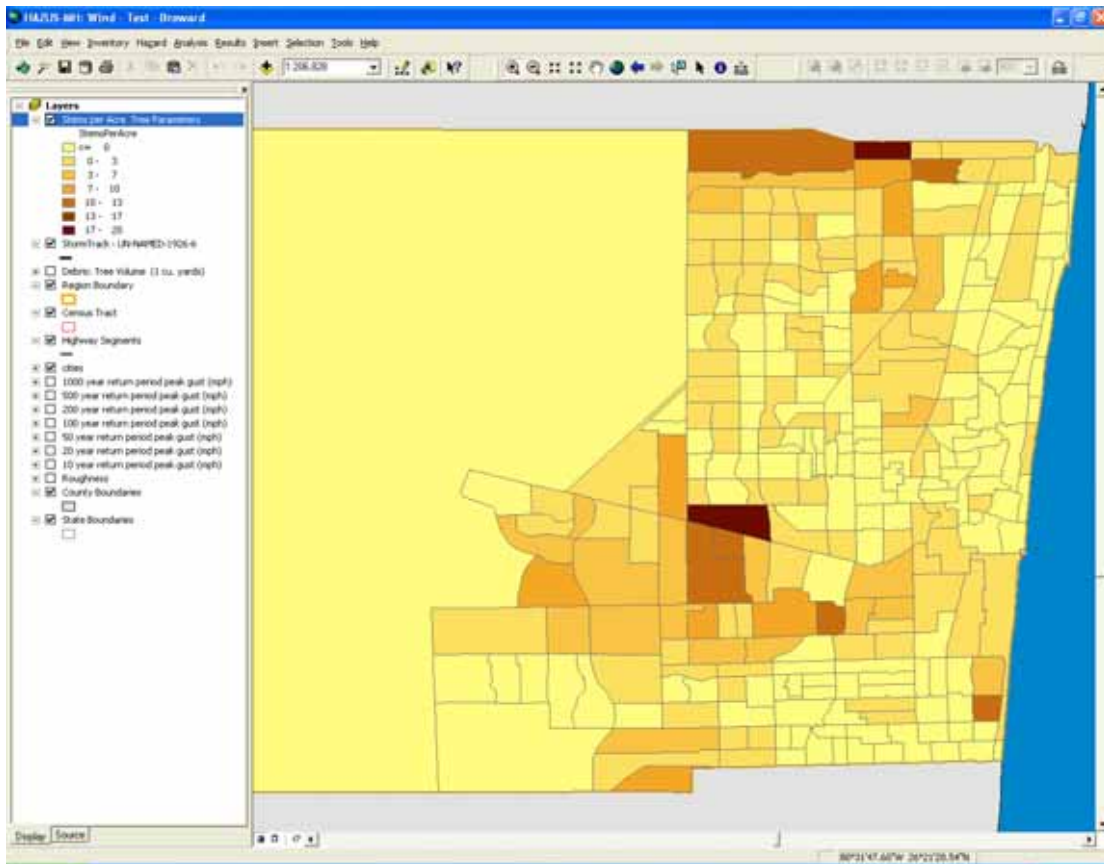
Typical Building Debris Curves



The HurDET model is not meant to be a substitution or an attempt to reproduce what HAZUS-MH is able to do. One of the most important uses of HAZUS-MH is to quantify the potential benefits of mitigation and evaluating which mitigation projects may yield the highest protection to property and life and lowest economic impacts. By modifying building characteristics and other building-code driven changes, planners are better able to grasp the benefit and give them the necessary backup to pass changes in local building codes and implement other mitigation projects. Therefore, we are supporters of FEMA's efforts to encourage the use of this estimation tool and its commitment to keep improving it.

The HurDET model, however, may be considered by planners as a useful optional tool when they are only interested in only "ball park" figures during pre-disaster planning. HurDET also tries to limit estimation to debris that could be eligible for reimbursement and/or directly related to the storm event. For purposes of planning, these are probably the most critical estimates that planners look for in order to identify temporary staging areas and other resources required for clearing debris in roads and other debris usually subject to reimbursement.

To those planners that want to use HAZUS-MH debris estimating capabilities, we cannot overemphasize the importance of customizing the underlying databases used by the model to ensure that the data is replaced by more local and up-to-date inventories. The technical manual and other documentation that comes with Hazus-MH provides the details for technical personnel to implement these changes. An example of the issue with implementing HAZUS-MH (out of the box) for debris estimation is demonstrated by seeing the data that came for Broward County, Florida. The figure below shows the density of trees (tree stems per acre). The figures are very low. Most of the county shows as having a density of less than 3 trees per acre (the lighter yellow/orange colors).



Conclusion

Although debris modeling is an important aspect of pre-disaster planning, it would be unrealistic to expect any model to yield consistent and very accurate estimates due to the chaotic nature of weather and the complexity of accounting for the various land-related variables. Post-event assessment will always be critical when determining the actual extent of damage.

However, the HurDET model, as long as its limitations are understood, can be a very useful tool during pre-disaster planning. In the future, we plan to explore some enhancements, such as including additional land use types (especially separating mobile homes as a separate category) and being able to account for building sizes (especially in commercial properties).

Re-calibrating the models is one of the most important elements in increasing the accuracy of the models, as well as updating the base data used in the model. If your community profile is very dynamic and land uses are frequently changing, then it will be critical to update your base data at least yearly, prior to entering the Hurricane Season. Calibration can be an easier exercise if electronic databases are used for recording debris quantity, debris type and location associated with truck tickets. An example is PBS&J's Debris Removal and Operations Management System (DROMS) that are employed to serve their clients, including Broward County.

Virginia Debris Removal Operations Management System

Ticket Information Form Main Menu

Ticket Number:

Prime Contractor:

County / Town:

City Number:

Truck Number:

Debris Quantity Percent:

Debris Quantity in Tons: (Optional)

Debris Classification:

Sector:

Route / Street #/Name: (Format xxxx for SR)

Dumpsite / Permit:

Are you entering Ticket on behalf of Inspector? Yes No

Load Date:

S	M	T	W	T	F	S
25	26	27	28	29	30	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31	1	2	3	4	5

Load Time:

Will you enter Dump Time manually? Yes No

Dump Date:

S	M	T	W	T	F	S
25	26	27	28	29	30	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31	1	2	3	4	5

Dump Time:

Inspector's Employee Number:

Acknowledgments

(By the Primary Author)

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Author Information

Diana Umpierre, GISP
Sr GIS Developer
PBS&J
2001 NW 107 Ave
Miami, FL 33172
Ph: (305) 592-7275
Email: dumpierre@pbsj.com

Glenn Margoies
Recovery & Preparedness Branch Chief
Broward Emergency Management Agency
201 NW 84 Ave
Plantation, FL 33324
Ph: (954) 831-3933
Email: gmargoies@broward.org