The Future of EPA's Waste Estimation Support Tool-17227

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ABSTRACT

The Environmental Protection Agency's (EPA's) Waste Estimation Support Tool (WEST) is a GIS-based decision support tool for estimating the characteristics, amount, and residual radioactivity of waste generated from remediation and cleanup activities after a radiological incident, including those involving radiological dispersal devices, improvised nuclear devices, and nuclear power plants. WEST has been released to the public and has been used in numerous national level exercises and planning scenarios; however, it continues to be improved and refined to add additional functionality and performance. Since its inception, WEST has undergone a myriad of updates, routinely ensuring compatibility with ESRI's ArcGIS and FEMA's Hazus, a tool for estimating potential losses from earthquakes, wind, and flood events. Furthermore, recent enhancements have added reporting and mapping features and multi-state support. Over time, this progress has strained WEST's Microsoft© Excel based platform. The inherent limitations of Excel have limited the capacity of WEST and narrowed the scope of potential enhancements.

Recent collaborative efforts between the Department of Homeland Security's (DHS's) Science and Technology Directorate (S&T) and EPA will see the introduction of a new software platform for easing memory limitations and new and innovative features for improving the accuracy of waste estimates. The planned enhancements include:

1) Systems approach: measure or predict the outcome of decisions associated with disaster response (e.g., decontamination efficacy vs. waste) and to a greater extent, the overall resource demand (e.g., cost, time, etc.);

2) Custom infrastructure data and international support: accommodate non-US building information where available and also add new data and information on recently used decontamination technologies as applied in a real-world incident;

3) Additional waste factors: addition of waste factors that are unique to wide area scenarios such as vehicles and trees as they will likely contribute in a significant manner to the overall waste stream;

4) Site analysis and logistics: apply spatial information and analysis technologies to locate and prioritize potential waste staging or storage sites; and use GIS-based logistics planning to better organize, route, and estimate the cost, time, and logistical requirements (i.e., resource demand) associated with transporting large volumes of waste from a disaster-stricken area to waste staging or storage sites;

5) Decontamination technologies: introduce new decontamination technologies, better understand the feasibility and efficacy of new and preexisting decontamination technologies when applied to a wide area incident, and use historical incidents to ground truth waste results; and

6) Resource demand: ability to estimate resource demand information associated with decontamination technologies, waste staging and storage, and logistical information for transporting waste.

This paper will describe the next version of WEST (WEST 4.0), and how the aforementioned enhancements will contribute to improving the planning and response capabilities of the tool.

INTRODUCTION

Recovery from a radiological incident, of all potential threats, could possibly be the most costly and time consuming [2]. Recovery can be largely a function of decontamination and waste management strategies, policies, timelines, available resources, and public sentiment. Historically, these factors have been decoupled from each other. Through a series of recent national-level exercises and planning activities, it has become apparent that to minimize the economic, environmental, and public health impacts of such an incident, these factors must be simultaneously considered using a “system-of-systems” approach, where decisions in one area (e.g., decontamination) profoundly affect decisions in another area (e.g., waste management). Decision makers must also account for the topological, geographic, and geometric properties of the impacted area as these considerations will largely influence the magnitude and characteristics of waste generated by decontamination activities. These considerations are especially significant for urban areas where factors such as infrastructure density, construction materials, and abundance of vegetation vary greatly [2]. Based on the previous incidents in Chernobyl and Fukushima, there is no “one size fits all” solution when considering decontamination, demolition, and cleanup approaches [2]. Each approach is just as unique as the geographic location itself.

The U.S. Environmental Protection Agency (EPA) Homeland Security Research Program (HSRP) is in the process of updating the Waste Estimation Support Tool (WEST) to help decision makers and planners better understand the impact these mechanisms have on waste management considerations. Based on user feedback and continuing interest in adding to the capabilities of the WEST tool to epitomize the “system-of-systems” approach, several significant changes and enhancements are planned for future releases. This paper will explore ongoing and future research and development that will expand the capabilities of the WEST.

METHODOLOGY

Current Approach

For emergency planners and federal responders to scope out the waste and debris management issues resulting from a radiological response and recovery effort, it is critical to understand not only the quantity, characteristics, and level of contamination of the waste and debris but also the implications of response and cleanup approaches regarding the quantity and rate of waste generation. To achieve this understanding, WEST fuses the spatial characteristics of a given contaminated area with a prescribed decontamination strategy. This approach allows for an estimate of the quantity, characteristics, and level of contamination of waste as a function of demolition/decontamination decisions that are specific to the geographic features of that location (i.e., outdoor and indoor characteristics and surface area). These geographic features are captured using a set of polygons to indicate the deposition concentration or activity using a geographical information system (GIS). The resulting spatial characteristics (i.e., infrastructure and surface media information) are fed into a spreadsheet calculator for conducting a series of analyses based on the prescribed decontamination strategy. The methodology is further demonstrated in Figure 1.

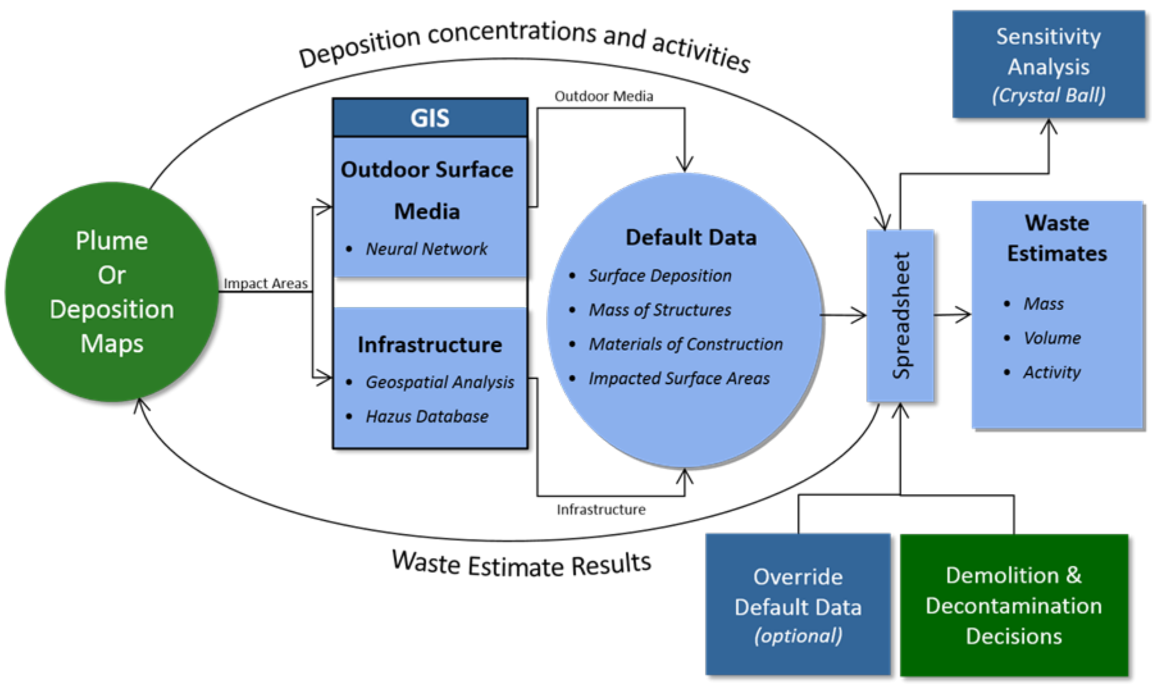

Figure 1. Current WEST Methodology

A Change in Paradigm

Recent updates to WEST have focused on maintaining compatibility with FEMA's Hazus software. WEST relies substantially on building and infrastructure data from the underlying databases of Hazus and the continued ability for WEST to be able to utilize that information has required substantial resources to maintain compatibility between platforms. Future versions will begin to decouple WEST from Hazus to allow WEST to utilize a more self-sustained infrastructure dataset within the tool itself. This transition will facilitate the use of more custom datasets and lay the groundwork for the capability to create international scenarios. Furthermore, a number of challenges remain with the current MS Excel-based framework. A large portion of the data processing capability of WEST will transition out of Excel into a more flexible and robust database platform which decreases data processing times and overall memory use.

Mostly importantly, future versions of WEST will see a paradigm shift in waste management. Historically, chemical, biological, radiological, and nuclear (CBRN) incident response decision support tools have solely focused on one particular problem or outcome, whether it is the identification of sampling locations for characterization purposes, cost of decontamination, or the management of waste. Most of these tools focus on the individual activities at hand and often do not completely address the impact of decisions on the incident as a whole. Disaster response for wide area incidents, like any large-scale system, is dynamic and complex, interacting as a structured cohesive unit where decisions made within these units can affect the output of the system. Disaster response works in a similar way as decisions made at various points of the response planning process can have impacts in multiple areas. The ability to measure or predict the outcome of any one of these decisions on other operations (e.g., decontamination efficacy vs. waste) and to a greater extent, the overall resource demand, would greatly enhance recovery operations. This concept of pooling resources (e.g., cost, time, etc.) and operations (decontamination, waste staging and storage, logistics, etc.) is known as the system of systems approach. This change in paradigm will encourage the consideration of other impactful mechanisms when planning for or managing large quantities of waste following a wide area incident.

In its current form, WEST attempts to contribute to the systems approach to remediation planning by allowing the capability to evaluate multiple independent decontamination scenarios and then evaluate the impact of various decision points on the resulting amount of estimated waste. As research and ongoing events (i.e., Fukushima) lead to a better understanding of the waste management paradigm and the mechanisms that shape it, WEST too must transition from a one dimensional waste estimation platform to a multi-dimensional waste management tool. To accomplish this transition, several focus areas have been identified where future development efforts will be prioritized:

- Infrastructure and international support: custom infrastructure and Outside Continental United States (OCONUS) support,
- Additional waste factors: inclusion of waste factors that can significantly add to the waste stream, such as vegetation and vehicles,
- Site analysis and logistics: methods for identifying potential storage locations and logistical requirements,
- Decontamination technologies: immediate access to up-to-date decontamination technologies being developed in the laboratory, and
- Resource demand: cost, time, and economical considerations.

A diagram showing the systems approach to waste management is shown in Figure 2. The following section will further describe these enhancements and their role in waste management.

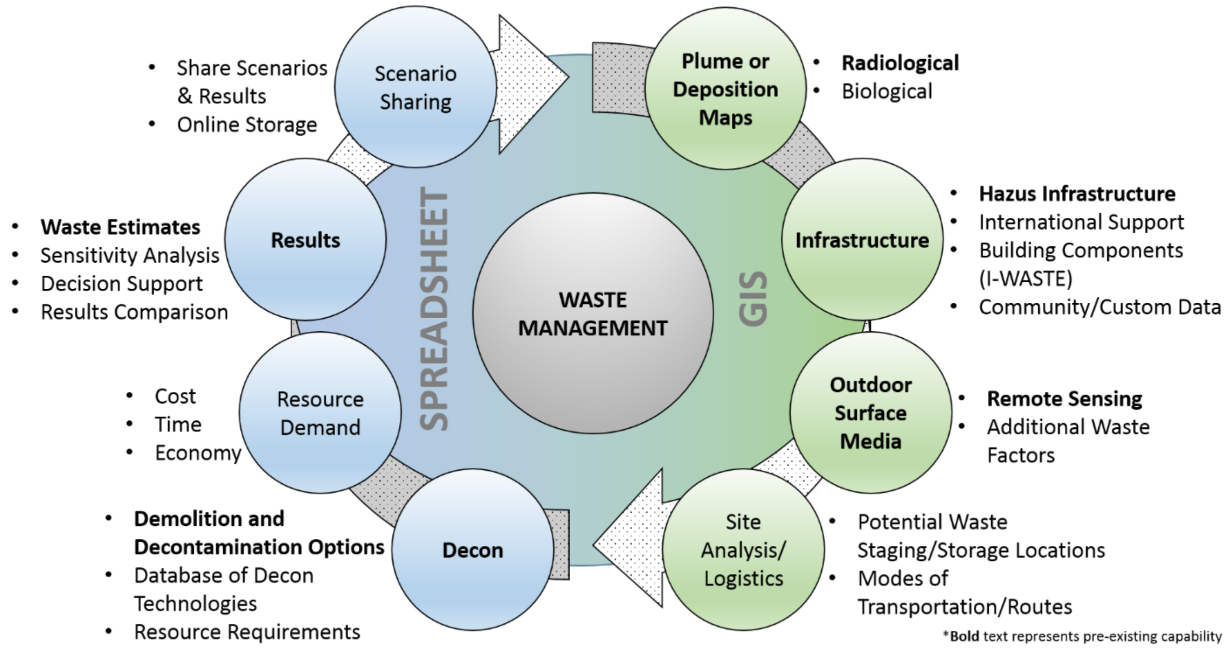

Figure 2. A Systems Approach to Waste Management

Future Enhancements

Custom Infrastructure Data and International Support

WEST is currently limited to the ability to create scenarios for the continental United States. WEST relies on the Hazus building and infrastructure data that do not extend beyond the US territory. Clearly, as chemical, biological, and radiological incidents are not isolated only to the US, there is a need to expand the capability of WEST to be able to create international scenarios. The recent events in Fukushima serve as an opportunity to redesign WEST to be able to accommodate non-US building information where available and also add new data and information on recently used decontamination technologies as applied in a real-world incident.

As part of the Fukushima recovery effort, Japan conducted a “Decontamination Model Project” where a series of towns were selected to test various decontamination technologies [1]. The decontamination approach and results of these tests were published in a series of reports. In an effort to test the viability of international scenarios, the authors selected the Hirono town as a test case. An aerial image showing Hirono town, with the study area outline in purple, is shown in Figure 3. A polygon representing three distinct areas of contamination was developed (WEST requires three zones of contamination for determining waste activity). Hirono town infrastructure and surface media information were collected using OpenStreetMap, Google Search and EPA’s I-WASTE and WEST. Buildings were then classified according to existing Hazus Specific Occupancy Classification categories (Figure 4). The affected area and building information was manually modified to allow import into WEST.

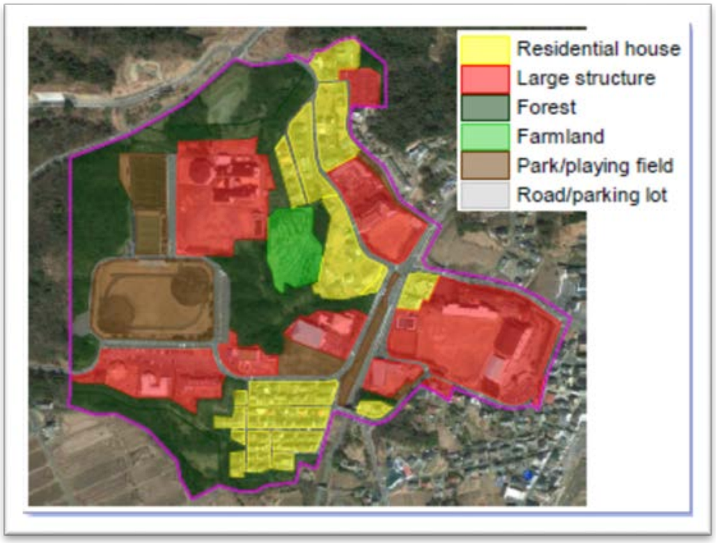

Figure 3. Aerial Image of Hirono Town, Japan, with Usage Areas Identified

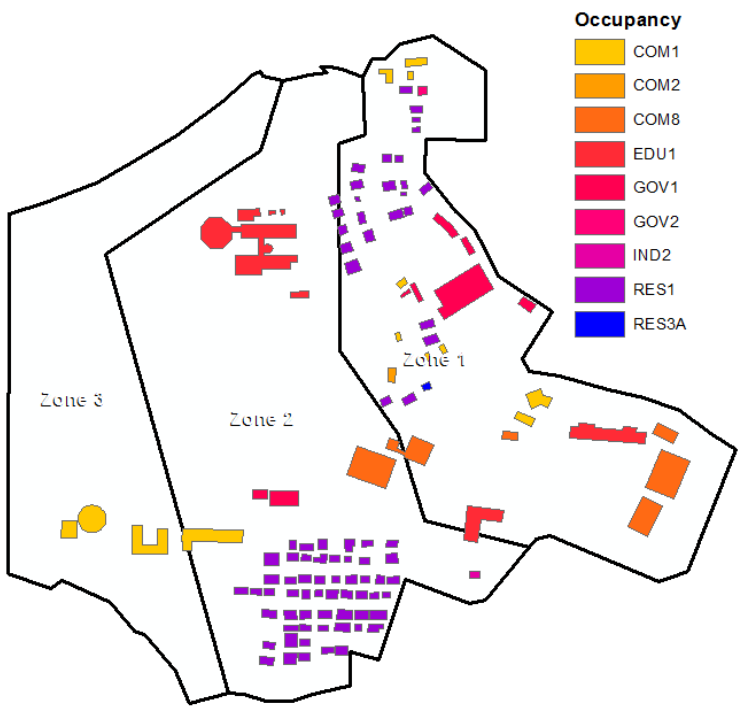

Figure 4. Building Occupancy Classifications for Hirono Town, Japan

The actual decontamination strategy applied to Hirono town and the resulting waste factors calculated from those decontamination efforts are shown in Table 1. The decontamination parameters that can be specified within WEST were modified to match that strategy and are shown in Table 2.

Table 1. Decontamination Methods for Japan Decon Model Project [1]

Decontamination Method	Solid Waste Volume per Unit Area (L/m^2)	Solid Waste Mass per Unit Area (kg/m^2)	Liquid Waste Volume per Unit Area (L/m^2)	Liquid Waste Mass per Unit Area (kg/m^2)	Decon Method Distribution[1]	Relative Surface Type
Mowing	12	1.4	None	None	17%	Grass
Stripping (turf)	50	70	None	None	17%	Soil
Stripping (litter)	50	7	None	None	27%	Trees
Removal (gravel)	30	48	None	None	6%	Concrete/gravel
Pressure Wash	None	None	20	20	15%	Roof
Shot Blasting	3	7.22	None	None	0%	NA[2]
Dry Cleaning	1.5	2.6	None	None	18%	Asphalt
Artificial Turf	20	NA	None	None	0%	NA[2]

Table 2. Decontamination Methods for Japan Decon Model Project

Current Classification Method	Decontamination Method	Decontamination Method Distribution
Soil	Stripping (turf)	62%
Concrete	Removal (gravel)	6%
Asphalt	Dry Cleaning	33%
Roof	Pressure Wash	100%

Table 2 shows the distribution of surfaces fit to the existing surface categories utilized by WEST, but consolidated based on the actual surface distributions found in Hirono; 62% of the total ground surface is classified as “soil,” 6% as “concrete,” and 33% as “asphalt.” WEST calculates the surface area (m^2) for each of the four surface types based on the distribution percentage and the total surface area determined for the affected area based on the surface imagery analysis. Once the component surface areas are estimated and the decontamination strategy specified, the waste factors (e.g., solid waste volume generated per unit area, in kilograms per square meter of surface area decontaminated using that method) are multiplied by the corresponding surface area for which a particular decontamination method is applied (e.g., 100% of concrete surfaces decontaminated using removal) to generate the waste estimate. The individual waste estimates are calculated for each unique combination of surface type/decontamination method applied. After specifying the decontamination strategy within the WEST scenario for Hirono Town, the tool was successfully run to generate waste estimates. Two different scenarios were performed: one assuming decontamination included both outdoor surfaces and interior floor surfaces, and a second assuming that only outdoor surfaces were decontaminated (indoor floor surfaces were not decontaminated). The resulting waste estimates indicate that if interior floor surfaces were to be decontaminated, they would constitute the overwhelming majority of the solid waste stream, on a

[1] Decontamination method distribution was estimated based on the relevant distribution of the targeted surface type
[2] Support for this surface type does not currently exist in WEST

volumetric basis (56% by volume), followed by soils (27% by volume) (Figure 5). Conversely, if the interior floor is left alone, soil would constitute the bulk of the solid waste stream at 61% by volume (Figure 6).

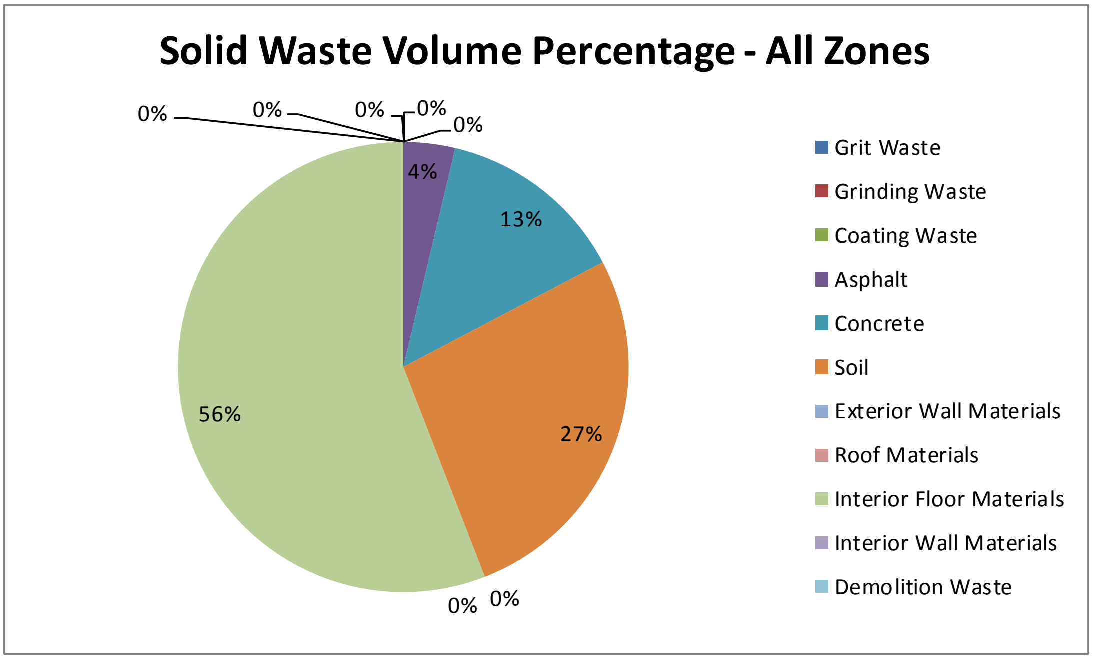

Figure 5. Estimated Distribution of Solid Waste Materials Resulting from Decontamination Including Interior Floor Surfaces

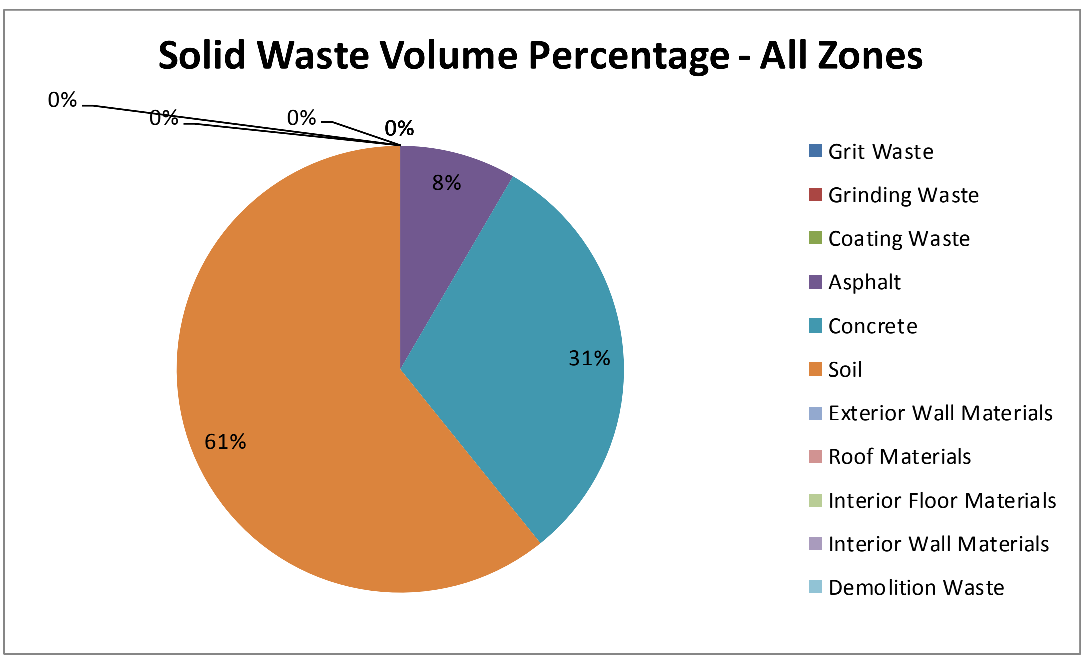

Figure 6. Estimated Distribution of Solid Waste Materials Resulting from Decontamination Excluding Interior Floor Surfaces

This preliminary finding supports previous observations from other scenarios which indicated that the decontamination of ground surfaces by excavation of soil contributes overwhelmingly to the total waste stream, regardless of the urban/suburban landscape.

The Hirono Town test case showed that, with the right data, international scenarios are possible. However, a significant level of effort was required to retrieve building occupancy information, identify building footprints and square footage, and import the referenced decontamination technology. Work continues on automating this capability for inclusion in the next version of the WEST.

Additional Waste Factors

In the event of a wide area incident, additional waste factors such as vegetation or vehicles may be significant contributors to the waste stream. In its current form, WEST does not account for these types of wastes. To expand WEST's capabilities in the future, two potential methods are being explored: 1) LandScan and 2) remote sensing. LandScan is a GIS-driven system that is capable of providing global population distribution, at a 30 arc-second (1 km) resolution, representing an ambient population (average over 24 hours) [3]. By combining diurnal movements and collective travel habits, LandScan can estimate the distribution of a population in motion rather than by domicile [3]. By marrying this approach with vehicle ownership and availability statistics, an estimate can be made in regards to the number of vehicles on the road at a given time. Another potential solution being investigated is remote sensing. Remote sensing involves the scanning of earth by satellite or aerial vehicle for the purposes of obtaining information. Two common forms of remote sensing are imagery or a surveying method such as LiDAR, which is capable of measuring the height of objects on the ground. By fusing imagery and LiDAR data, not only can the composition of a particular object be estimated, but by knowing the height of that object, the object on which that surface resides can also be identified. For example, trees, shrubs and grass typically have similar spectral signatures. By associating a height with a given color range (e.g., tall green objects), an inference can be made as to what that object might be. The same method can be applied to other objects such as vehicles as well. Examples of using imagery to extract surface media information and LiDAR to extract surface heights are shown in Figures 5 and 6.

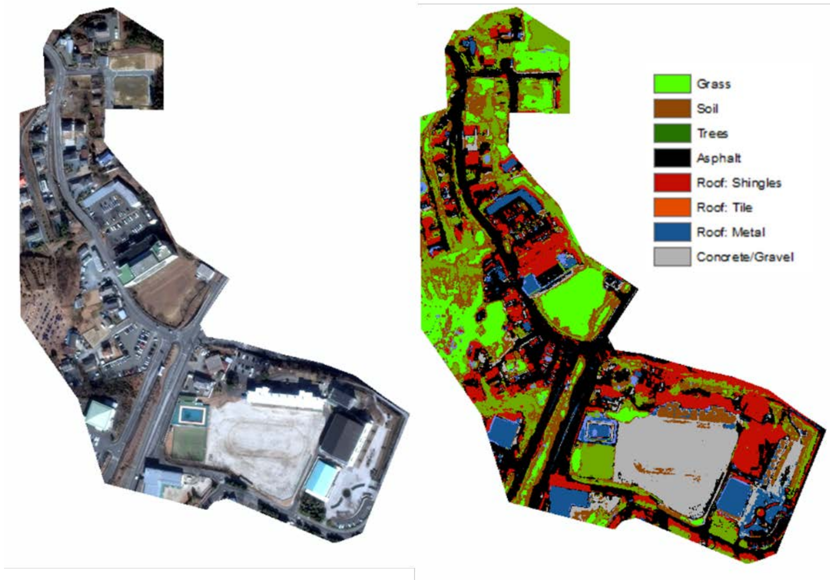

Figure 5. Example of Image Classification

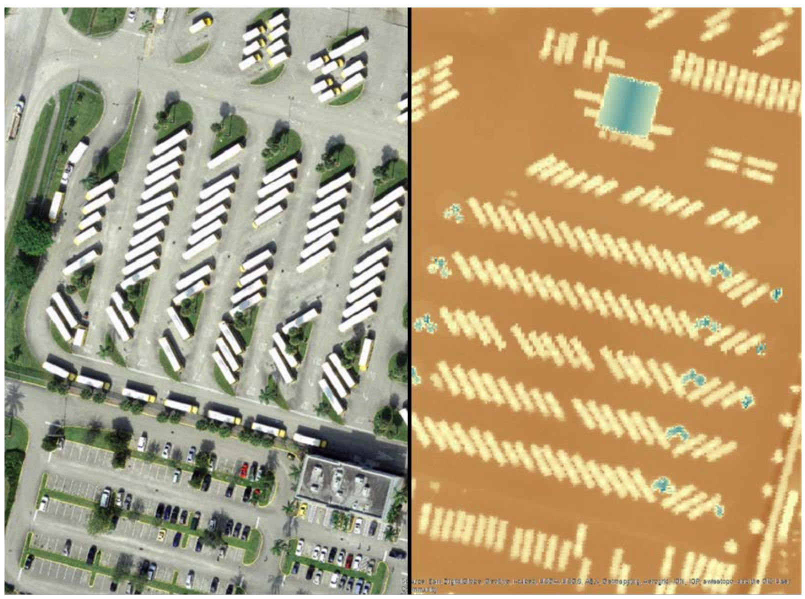

Figure 6. Example of LiDAR Data

Site Analysis and Logistics

Private industry has used GIS for decades to develop suitability models for identifying optimal or worst case locations for given objective or infrastructure. Future versions of WEST will use spatial information and analysis technologies to locate and prioritize potential waste staging or storage sites. This method will consider implicating factors such as social, transportation, resource demand, and the fate and transport of contaminants to provide a range of potential sites that best fit these criteria. This feature will provide decision makers with a defendable and agile approach for waste storage and staging site selection.

Similar to the site analysis feature, GIS-based logistics planning has been used by the military and industry to support the movement of people, facilities, or supplies. This capability could be applied to waste management to better organize, route, and estimate the cost, time, and logistical requirements (i.e., resource demand) associated with transporting large volumes of waste from a disaster-stricken area to waste staging or storage sites. In addition to cutting fuel use and reducing carbon footprints, this capability will provide decision makers with a means for selecting the optimal transportation method according to an available resource demand and lend to selecting waste triage and storage locations.

Decontamination Technologies

Following its response to Fukushima, Japan published a significant amount of literature detailing decontamination methods that included data describing resource demand information (i.e., cost and time). These data represent a rare opportunity to ground truth waste results, introduce new decontamination technologies, and better understand the feasibility and efficacy of new and preexisting decontamination technologies when applied to a wide area incident. Furthermore, disseminating these data, especially as new research becomes available, has been a challenge. A large number of tools collectively leverage these data to support decision makers for a wide range of hazards. However, they individually consume separate sources of data that are susceptible to becoming obsolete and are costly to update – WEST being included. A database capable of providing WEST and other decision support tools with state-of-the-art decontamination data supported by current and future research efforts would not only reduce the level of effort for development, but also increase its accuracy. Future versions of WEST may introduce the ability to download the latest decontamination technology data for use in cleanup scenarios or may include access to high quality infrastructure data for large metropolitan areas.

Resource Demand

In this context, resource demand is defined as the output of resources or capital (e.g., cost, time, materials) required to fully recover from a disaster. Decisions made early on in disaster response can have far reaching implications on the resource demand. For instance, a decontamination technology requiring large amounts of wash water will directly impact disposal costs later on. The system of systems approach seeks to create an equilibrium between operations (i.e., response and recovery) and resource demand, which in return provides greater insight and improves decision making. This process is visualized in Figure 7. Future versions of WEST will embody this method by allowing the user to see how their decisions impact other operations (e.g., decontamination vs. waste) and the overall resource demand. To produce this insight, future versions of WEST will include resource demand information associated with each decontamination technology, waste staging and storage, and logistical information for transporting waste. Waste results will continue to feature quantity, volume, and characterization information based on a particular decontamination approach, as well as, the cost and time required to implement it.

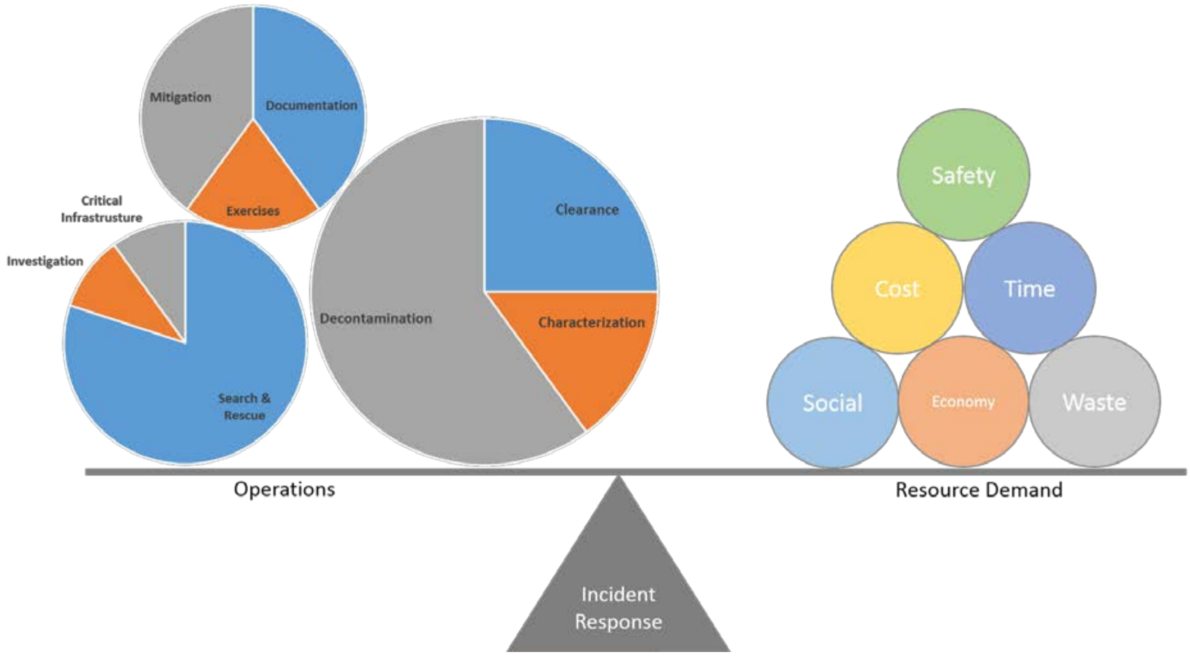

Figure 7. Systems Thinking Approach for Wide Area Incidents

CONCLUSIONS

Research as well as the introduction and use of WEST in a variety of exercises over the years has helped fuel a shift in the disaster response paradigm. It is now readily evident that every phase of disaster response and recovery should consider the implications of decisions regarding decontamination and waste management on the resource demand and to a greater extent the success of recovery. For instance, the transport and storage of waste may require a significant level of resources to complete, and therefore, a decontamination approach that requires an increased removal depth for soil and produces a large amount of waste as a result may not be feasible. To better understand these intricacies and to model their impacts on the waste stream before implementing them in the field, EPA has identified new enhancements to WEST that it hopes will lead to a better understanding of the waste management paradigm and the mechanisms that shape it. The next version of WEST (WEST 4.0) is expected to be released in FY18

DISCLAIMER

The U.S. Environmental Protection Agency through its Office of Research and Development managed the research described here. It has been subjected to the Agency's review and has been approved for publication. Note that approval does not signify that the contents necessarily reflect the views of the Agency.

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