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News and Press

Disaster Damage Prevention Planning

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Solid waste infrastructure, including buildings, plants, machinery and vehicles are critical to keeping a municipality functioning after a major flood event. There are pragmatic steps owners can take to better understand where they may have vulnerabilities, and then systematically develop and implement specific improvements that limit damage and other costs of being put out of business by flooding.

by Bruce Clark and Laurel Urena

Many building owners may not be aware of how vulnerable their facility may be during a severe flood event. That was the conclusion of the Hurricane Sandy Mitigation Assessment Team Report, a technical guidance published by the Federal Emergency Management Agency (FEMA) in 2013 after Hurricane Sandy ravished many communities on the East Coast. The Team's No.1 recommendation: perform a building/facility flood vulnerability assessment.

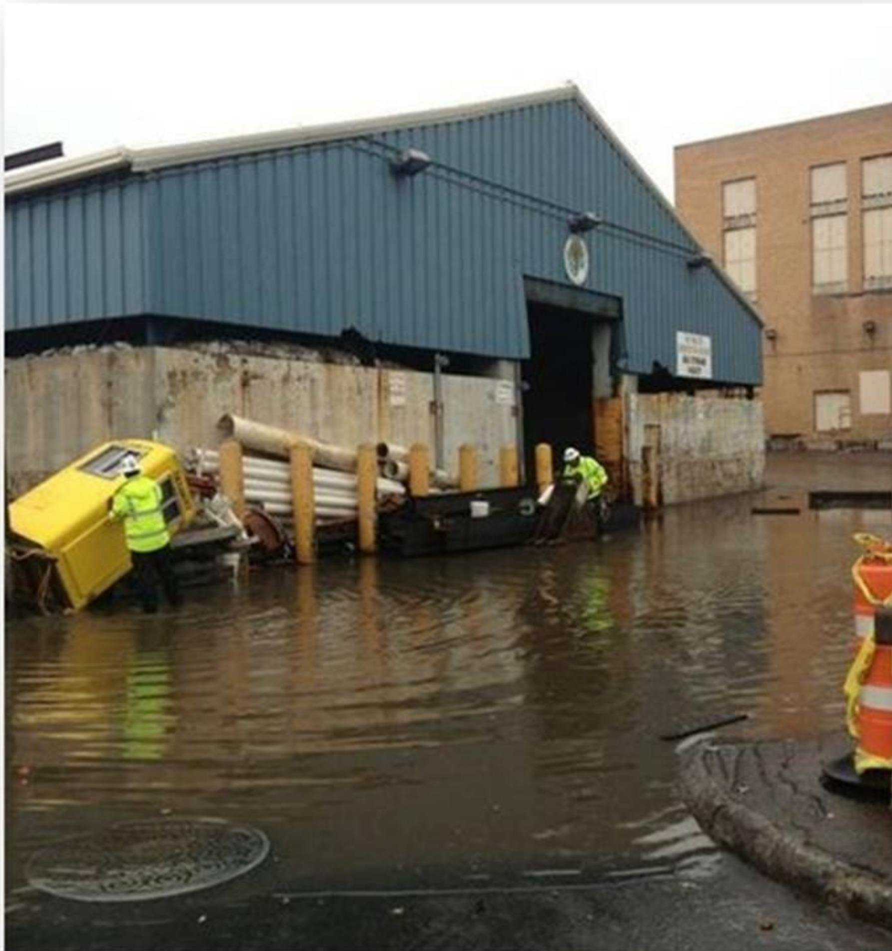
As a solid waste professional, you might be thinking, "I don't need that, I've been at this waste-to-energy plant, transfer station, landfill, etc. for 20 years and it has never flooded." This article will discuss the "why" behind disaster planning, understanding flood probability, how to prepare a damage prevention plan and a vulnerability assessment, and some flood proofing techniques.

Flood Events and Probability

Record flood events are happening all over the country. The recent record flooding in Houston by Hurricane Harvey was another wake-up call. Houston had an interstate highway under 10 feet of water!

Some examples of flooded solid waste facilities are shown in **Figures 1 through 4**. You could be next and damage prevention planning is the best way to be prepared and to limit damage and downtime to your facilities. Why do damage prevention planning? Here are a few reasons:

- Continuity of service
- Lack of insurance and flood insurance
- Insurance may not be adequate:
    - Lossof revenue
    - Limits not high enough
    - Environmental damage (i.e., fuel spills)
- Reduction in premium
- Loss of irreplaceable documents
- Loss of contracts
- Loss of employees
- Not all flood maps current
- Flooding may be getting worse



Are floods getting worse? According to flooding data pulled for this article, four of the top five FEMA Disaster Declarations were floods, the majority of which occurred in the past decade. Take a look at the findings in **Table 1** from floods in the last 20 years.

Flood Location /Year	Flood Magnitude
Cedar Rapids, IA – 2008	Crested 11 ft. over record.
New York, New Jersey – 2014	3 ft. higher than predicted 500-year flood.
Tualatin, OR – 1996	2 ft. greater than 100-year flood.
Red River, ND – pick any year (2009)	5 ft. greater than National Weather Service prediction.
Louisiana – 2016	Worst since Superstorm Sandy (2014).
Houston, 2017	Rainfall expected to break U.S. record

Table 1

Flood probability and severity is probably a topic not well understood by those of us in the solid waste industry. For example, when someone mentions a "100-year flood" that does not mean it occurs once every 100 years. The 100-year flood is defined as the flood that has," a 1 percent chance of occurring in any year". Looking at the graph in **Figure 5**, if we take a time period of 20 years, a flood has an almost 20 percent probability of exceeding the 100-year flood. Over 40 or 50 years, the expected life of a typical solid waste facility, the probability of exceeding the 100-year flood rises to 40 percent. That risk is significant and is backed up by the floods in Table 1.

The Vulnerability Assessment

Preliminary Planning

Many facility owners have plans to get their facility back online after a disaster, but fewer seem to have plans to really protect their facility to limit damage and downtime before the disaster hits. The tendency is to be reactive, rather than proactive. Perhaps this is because insurance will cover damages, the facility is not that critical to operations or because flooding preparedness tends to take a backseat to more every-day operational needs.

Part of the aim of this article is to shift the focus to a more preventative stance for solid waste facilities. This starts with a vulnerability assessment, which includes the following major items:

- Preliminary determination of "high value" facilities
- Identify applicable Code and Standards
- Identify flood event(s); 100 yr., 500 yr., historic (high water marks)
- Review flood mapping
- Identify affected areas, and characteristics
- Evaluate critical requirements
- Perform building, and mechanical and electrical vulnerability assessments
- Evaluate flood-proofing techniques and costs
- Perform Benefit/Cost Analysis

A vulnerability assessment usually starts with a meeting with the building owner to discuss the scope of the assessment, what facilities have been identified as "high-value properties" and would be included in the assessment, the severity of flood events to consider (i.e., 100-year and/or 500-year), exchanging of plans and engineering reports and other facility reference documents, timeframe for the work and what type of deliverable the owner needs. A list of high value facilities could include those below, which is by no means a complete list:

- Waste-to-Energy Plants
- Fleet Parking Areas
- Support Facilities at Landfills (Treatment Works, BFS, Office/Scales, etc.)
- Maintenance Garage
- Transfer Stations and Support Facilities
- Fueling Facilities
- Administrative Offices
- Material Recovery Facilities

Following the meeting, the consultant will do an initial review of facility design and construction plans, any existing topographic surveys, geotechnical reports (to understand depth of water table and characteristics of the soil and rock), site improvement plans, building permits, plans of major renovations and changes, and current insurance policies. This is so the consultant can get a better understanding of the physical features of the facility, elevations or height above grade of major equipment and building floors, major drainage conveyances, sub-surface features that can interact with flooding and increase the severity and surrounding features that can increase the impact of flooding such as embankments, solid walls, ponds, elevated terrain, and natural water bodies.

The facility's insurance coverage should be reviewed and discussed with the owner and their advisor to get a good understanding of the type of events that are covered and what events are not covered, and also the monetary coverage limits for repairs and replacement of structures and equipment. There certainly should be an understanding on the consultant's part that when the issue of cost of upgrades are determined, that they will likely need to provide an acceptable benefit to cost ratio and compare favorably to the monetary limits of coverage. The owner will decide in the end if, for other reasons than purely cost, that the recommended upgrades have other tangible benefits such as: reduction of downtime, continuity of service and revenue, reputation, and others listed in the beginning of the article.

The consultant and owner then need to identify the critical requirements the facility must meet during and after the disaster. Some of the common critical requirements are listed in the following:

- Access to site by workers
- Ensure supplies for production
- Ensure water and sanitation
- Ensure energy supply
- Ensure flood safety
- Ensure waste collection
- Ensure any hazardous substances on site are not released
- Indoor climate control

- Connection to network vital
- Access to the site by workers

Flood Mapping, Building Codes and Standards

Following the initial review, the consultant usually reviews the applicable building codes, flood standards and the available flood mapping references for the area in question. FEMA produces maps, known as FIRM (Flood Insurance Rate Maps), that define flood zones, flood severity, and in the case of the base flood (defined as the 1 percent chance flood or the 100-year flood), the elevation the floodwater would rise. Although FEMA FIRM maps are updated over time, they may or may not accurately reflect the current development state of the area. There may have been developments in the flood plain over time that could contribute to a higher flood level or larger area that shown on the map, such as large buildings, roads, dams, removal of extensive areas of marshes or outdated undersized drainage systems.

A portion of a FIRM showing the McKay Bay WTE plant in Tampa, FL is shown in **Figure 6**. Some parts of the plant are within the 100-year flood plain, however, most of the ground (elevation approximately 8.0) is elevated above that and is within the 500-year flood plain (the brown shaded area). The base flood elevation corresponding to the 100-year flood is elevation 10.0. Thus, important facilities should be elevated above this level. This area has been heavily studied and a computer model indicates a major hurricane could, theoretically, bring a storm surge of approximately 17 feet. It is important to note that this surge is only for planning evacuations and is not a building construction criteria.

Figure 6

There are organizations and authorities that have produced design standards for facilities that recommend minimum elevations and design requirements for critical parts of buildings and structures exposed to flooding. For example, the American Society of Civil Engineers (ASCE) is a well-known organization that has set design standards for decades and one that has revised their standards to reflect lessons learned from several major U.S. costal storms including *Superstorm Sandy* and *Hurricane Katrina*. The current ASCE recommended design criteria is Standard 24-14 Flood Resistant Design and

Construction. **Table 2** is a shortened summary from that standard of minimum elevations for three Coastal Flood zones.

Recommendation	Zone	Flood Design Class 2
Min. Elevation Lowest Floor	Zone A, Coastal Zone A and Coastal Zone V	BFE + 1 ft. or DFE whichever is higher
Elevation Below Which Flood –Damage Resistant Materials Should be Used	Zone A, Coastal Zone A and Coastal Zone V	BFE + 1 ft. or DFE whichever is higher
Min. Elevation of Utilities and Equipment	Zone A, Coastal Zone A and Coastal Zone V	BFE + 1 ft. or DFE whichever is higher

BFE = base flood elevation = 100 yr. flood
DFE = BFE in communities that regulate with FIRMs

Table 2

Other broadly recognized organizations that produce flood damage mitigation standards include The International Building Code (IBC) and the National Flood Insurance Program (NFIP). ASCE 24-14 is a referenced standard in the 2015 IBC and the 2015 International Residential Code (IRC). FEMA deems ASCE 24 to meet or exceed the minimum NFIP requirements for buildings and structures. Local building codes must be consulted and many already incorporate these same standards in their documents. Owners should be aware that when making improvements to older structures, most building Codes will require that other aspects of the structure be brought up to Code. Be prepared for additional expenses for those upgrades beyond those just for flood proofing.

The consultant would then advise the owner of the areas of the facilities that likely will be affected and the characteristics of the impact including potential level of inundation, or if there is wave action involved that will increase flood level. Wave action is not limited to coastal locations and can be expected to occur on large lakes and rivers as well. The facility vulnerability inspection is usually next and would encompass a detailed visual examination of the building or structure and important equipment, systems and utilities.

Vulnerability Inspection and Action Plan

The vulnerability inspection is typically conducted with a multi-disciplined team that may include, as necessary, an architect, an electrical and mechanical engineer, a civil engineer and a structural engineer. The inspection should confirm or have some reasonable certainty of at least the following items:

- Configuration and nature of building structural frame
- Materials of construction (interior and exterior)
- Support and foundation of floors at-grade
- Window or other openings and types on the first floor
- Age and condition of structure
- Any significant deviations from the plans reviewed
- Locations of electrical panels and route of feeder conduits (buried /overhead)
- Existence of regular doors and waterproof doorsor other openings
- If there is a basement and if criticalmechanical or electrical equipment is located there **(see Figure 7)**
- Emergency generators, location, energy source, and controls
- Location, size and type of storage tanks and nature of containment
- Onsite electrical switch yard or sub-station

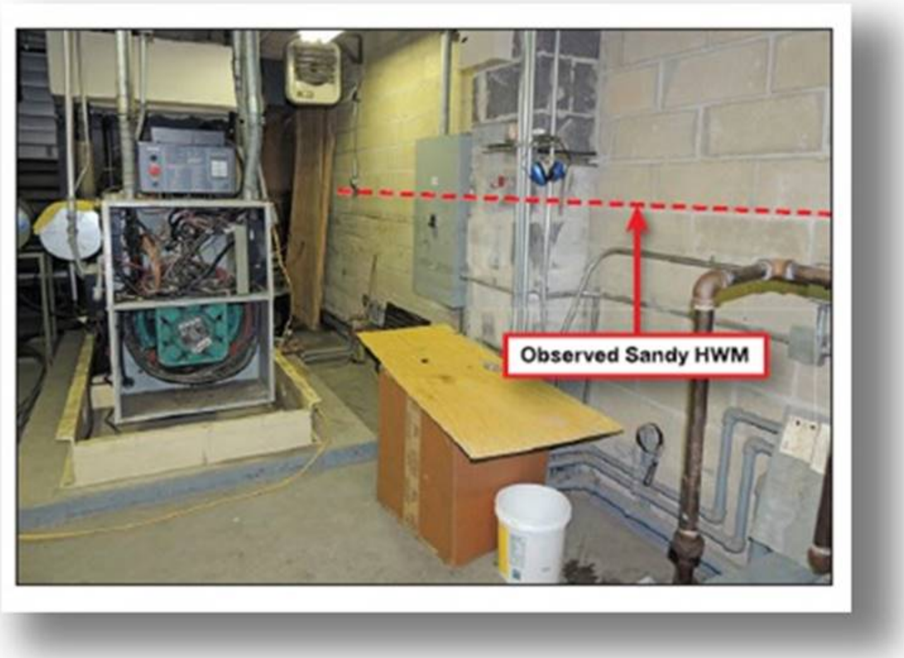


Figure 7a

Figure 7b

Following the vulnerability inspection, a report is prepared that would determine the locations and parts of the building that are vulnerable to flood waters, how the flood waters would impact the structural aspects of the building, including foundation and super structure, major equipment and systems that would be at risk, permitting issues, and a summary of ways in which openings in the building envelope could be sealed from flood water intrusion or other means employed, such as portable barriers that can hold back flood waters. In extreme cases some lightweight buildings and structures could potentially be raised. Preliminary cost ranges for the improvements can be prepared at this stage to assist in prioritizing facility modifications. The owner may request the consultant to also prepare a benefit/cost assessment of the various flood-proofing options.

The consultant and owner would then meet to discuss the findings, flooding scenarios, various flood-proofing measures, building modifications, if necessary, relocation aspects for equipment and systems, and cost estimates. This is a simplified overview of a process between the consultant and owner that could have several iterations depending on the complexity of the facility, flood impact, age of the facilities and budget considerations. This process will allow the owner to select and prioritize, if necessary, the facility modifications.

Although buildings are the subject mostly discussed herein, facilities such as fleet parking areas will not need the level of assessment described herein. Some entities may have the ability to relocate fleet parking to higher ground, either temporarily or permanently. Similarly, facilities that are separate from buildings, such as below grade pump stations, with all or some electrical gear located below-grade, may only need a simpler analysis of the flood level and if the structure should be raised or protected with a flood barrier, and electrical components relocated to elevated frame work above grade. The city of Miami Beach has used new barrier walls and relocation of electrical components to above grade to make their sewage pump stations and new drainage pump stations operable in their unique flood situation.

Once the facility modifications are prioritized, a Flood Proofing Action Plan can be prepared that would encompass specifically defined projects, budgeting, the consultants, if desired, the team assigned to the work, scheduling for activities that may include testing, construction plans and permitting, and construction, and impact on operations and maintenance. The action plan can be simple or more complex depending on the type of flood-proofing selected.

Flood-Proofing Techniques

There are many types of flood-proofing techniques (see the following list); some are suited for use in retrofitting an existing structure and some are more suited for integration into new construction. Although at first glance some of the techniques sound far-fetched, many of these have been used, some extensively in regions with a long history of flooding such as the Netherlands:

- Dry flood-proofing
- Wet flood-proofing
- Elevating structures
- Stilts
- Mounds
- Floating
- Amphibious
- Temporary/portable barriers (e.g. sandbags)
- Permanent barrier
- Maintenance

The details of the various flood protection techniques are extensive and will only be summarized briefly here and supplemented with some pictures. *Dry* flood-proofing refers to protections that are designed to keep flood waters out of the building as there is likely to be sensitive equipment and systems that may be too costly or impractical to move to a higher elevation **(Figure 8)**. This will result in additional hydrostatic forces on the building. *Wet* flood-proofing refers to rooms and spaces within the building where a decision has been made to relocate all sensitive equipment and systems to higher elevation above the flood water, and to allow flood waters to come into those rooms and pass-through the building. Wet flood-proofing is limited to smaller structures.

Structures that are enclosed and expected to be exposed to more than 3 to 4 feet of flood water may require a structural analysis to assess the additional forces on the foundation and superstructure and if the walls and frame have adequate strength. A building structural analysis, which is beyond the content of this article, is usually a 2-step process: visual assessment, then load analysis/design and testing. The load analysis would also include any proposed features that would be connected to the building for flood proofing such as physical barriers.

Barriers are perhaps the most versatile flood-proofing technique because they can be made portable and deployed only when needed **(see Figures 9 and 10)**. They also can provide complete perimeter protection of a structure without the added expense of custom barriers that have to be fitted to the building. However, they are limited with the terrain and generally need a relatively flat area to be most effective.

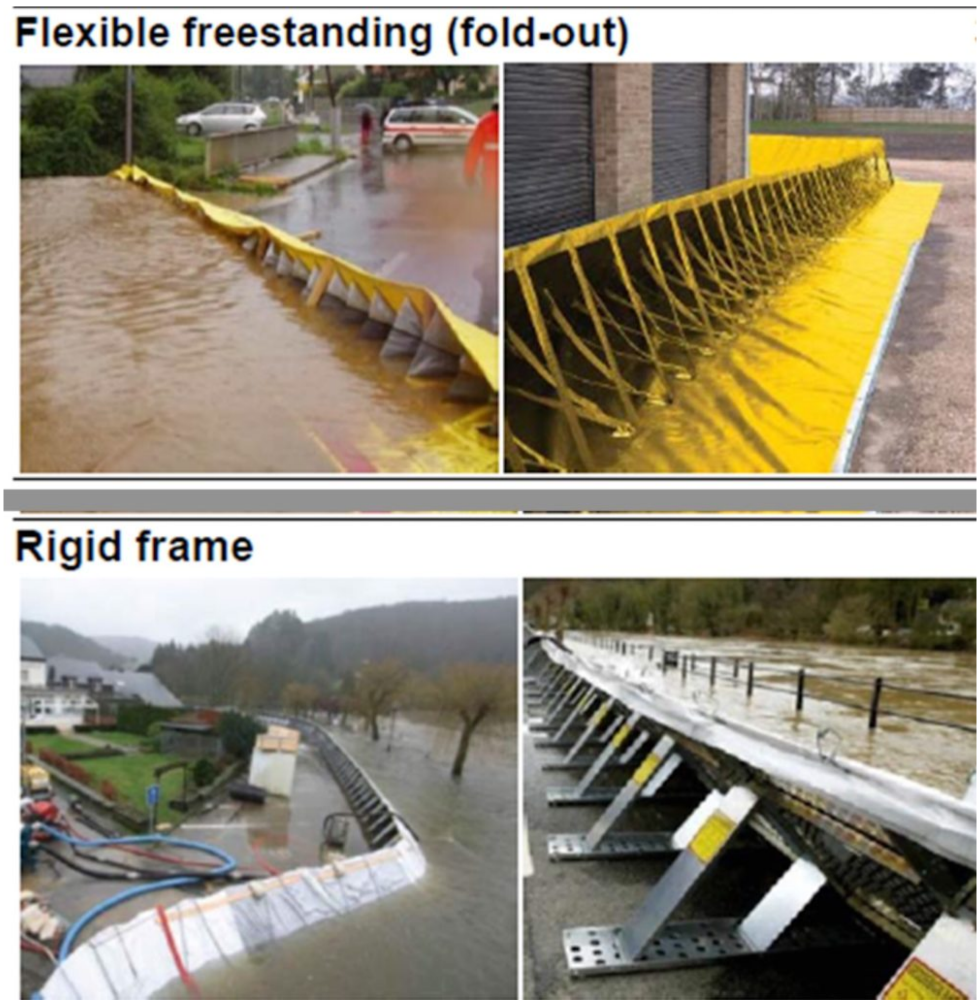


Figure 9

Figure 10

Routine maintenance of drainage systems can play a part in reducing flood impacts. Culverts, retention ponds, outfalls, and open channels can become overgrown with vegetation and filled with rocks and silt, which can severely limit their capacity and result in water backing up and causing worse flooding and collateral damage, than if they had been cleaned and their capacity restored. In some cases large channels that have to carry large flows should be lined with "hard armor" to better resist erosive forces during floods. These structures can also incur damage over time and if not repaired, could fail at a critical time when required to move flood flows.

Take the Right Steps

Prevention or reduction of damage to vital infrastructure from flooding is a task that goes back centuries. Natural disasters are not going away and no one can predict the severity and frequency of new ones. As our cities become more developed, areas such as marshes and wetlands that once reduced the brunt of flooding in many areas are disappearing under pavement, concrete and other impervious materials. As a result flood intensity is increasing.

Solid waste infrastructure, including buildings, plants, machinery and vehicles are critical to keeping a municipality functioning after a major flood event. Sandbags may not be the answer. There are pragmatic steps owners can take to better understand where they may have vulnerabilities, and then systematically develop and implement specific improvements that limit damage and other costs of being put out of business by flooding. Many new options for flood-proofing are available today that were not available years ago that can offer practical and cost-effective solutions to owners.

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