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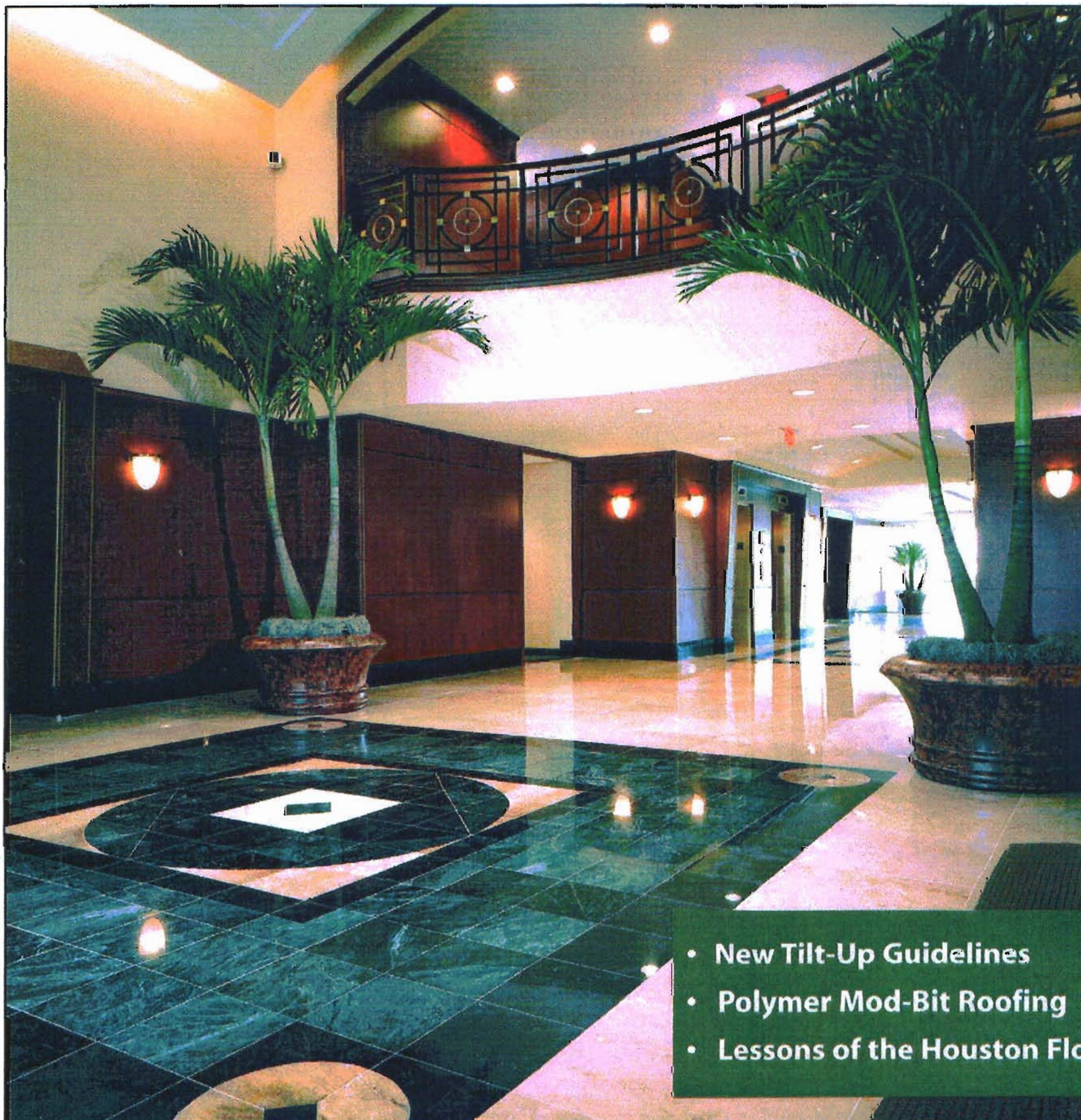

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ABCD's and Don'ts of Flood-Proofing

Lessons of the Houston floods

by Arie Kepets

Tropical Storm Allison, also known as The Storm of 2001, was concentrated in a rather small area over the Texas Medical Center in Houston, Texas. This event occurred over the weekend, when workers and emergency crews were at skeleton levels and unable to effectively implement flood control measures already in place.

The bulk of the flooding occurred between midnight and 2 a.m. on Saturday June 9, when 216 mm (8.5 in.) of rain fell over a two-hour period over the already saturated Texas Medical Center. According to condensation and atmospheric saturation levels, as well as dew points, the Houston area is capable of handling rainfall at the rate of 403 mm/hour (15 in./hour). Needless to say, it did not reach its rainfall potential—not by a long shot. Not this time around.

The storm is blamed for the loss of 22 lives, not to mention all the equipment destroyed, merchandise lost, and damaged property that amounts to billions of dollars in replacement costs. Drawings and records for buildings, utilities, drain lines and waterlines were washed away from the basement of the buildings department downtown, ensuring confusion and delays for years to come. Toxic mold outbreaks and other health dilemmas forced facilities to remain closed months after the waters subsided. Police, fire stations, and schools were expected to remain closed for months while workers attacked the mold.

Was Allison special?

As storms go, Allison did not rank very high. "One hundred-year" storms (events whose intensity is likely to occur only once every 100 years) of the past 50 years dumped more rain in a shorter amount of time than Allison in 2001. In the Houston area, Hurricane Alicia (1983), Tropical Storm Claudette (1979), The Great Rainfall of October 1994, June 1960, or July 1943 were all storms of greater intensity and duration—yet, they all caused less damage.

Several factors contribute to flash flooding, but the two key elements are rainfall intensity and duration. This time around, however, additional key elements such as topography, soil conditions, and ground cover played a more prominent role than ever before.

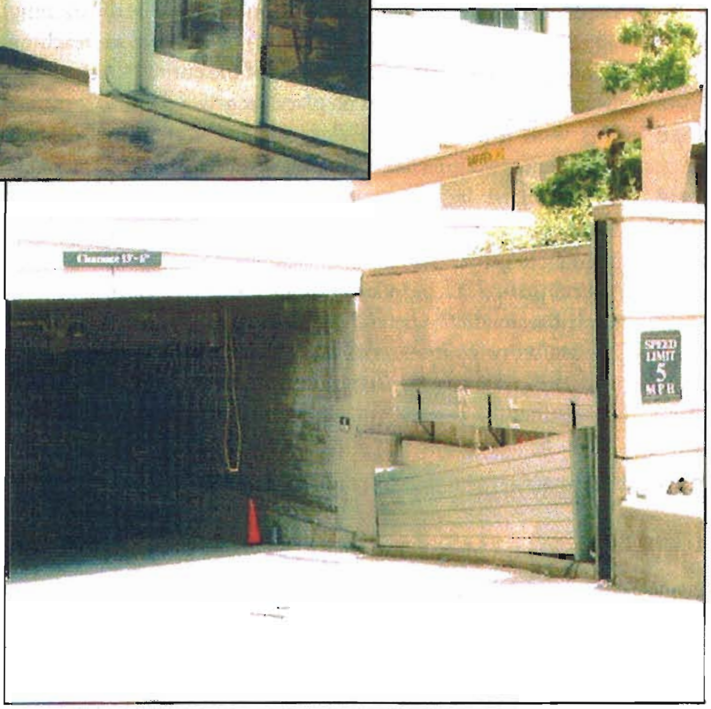
Annual flood losses continue to worsen despite the fact that floods are the single most predictable natural hazard. Damage from storms continues to rise due to greater concentrations of "value" and population that are, ironically, the major cause of flooding in the first place. New construction, road paving and flood control measures contribute to increased flooding by replacing land area that used to store floodwaters. Continued damming of natural flood streams and spillways increases flood flows, which in turn raises flood levels and impacts other areas and communities downstream.

Increases in the amount of paving, streets, sidewalks, and roofs throughout the watershed affect runoff and flood levels. Development in the immediate area, as well as upstream, has caused an increase in the calculated flood level to the point where the previous and current flood levels are under review. We have to realize that storms and flooding are going to happen, and with greater frequency. They are going to cause more and greater damage unless lessons are learned and flood mitigation measures are taken. While flooding is a communal issue requiring coordinated actions, much can be done to correct and protect individual properties.

The scene of the crime

The Brays Bayou serves as the main collection point for water runoff for the entire Texas Medical Center, and will not start flooding until 152 mm to 203 mm (6 in. to 8 in.) of rain has fallen between eight and 12 hours, or less. Back in the 1960s, however, the entire Brays Bayou region was capable of handling 305 mm to 381 mm (12 in. to 15 in.) of rain before reaching flood levels. The rapid development of the entire Houston area over the last 40 years leaves no place for urban runoff. Combine this with lower building elevations caused by decades of subsidence (the area has been sinking due to a drop in the water table caused by the watering requirements of a nearby municipal golf course), and it stands to reason the problem is going to get worse.

Comprising 42 individual units along with the operating unit, the medical center had already implemented a flood protection program—mostly as a result of the floods of 1973 and 1994. The primary form of protection is a passive system consisting of a carefully manicured, landscaped earthen berm



Left: Aesthetically pleasing flood-proofing. The gate is stored in a false ceiling and can be lowered into place in minutes.

Below: At the Texas medical center, crane operated stop-logs intended to prevent water ingress were never put into place.

surrounding the medical center campus. Access areas such as driveways and access ways have been equipped with active flood protection in the form of stop-log floodwalls and floodgates. Unfortunately, the passive system has been breached in areas by careless landscaping and repair work, and in one case, a walkway that was carved-out to comply with *Americans with Disabilities Act* (ADA) access regulations.

For a variety of reasons, these measures were for the most part not put into operation. Stop-logs at driveway entries are uncharacteristically heavy and long, requiring extensive manpower and equipment to put them into place. Some require mechanized equipment in the form of in-place cranes that swing the logs into position. Few, if any, were put into operation at the medical center. Other logs and gates were found to be locked in place with keys not readily available. Others were missing components and gaskets to be considered effective.

A system of underground tunnels and connecting passageways caused connected buildings and structures to be flooded from a single source and one point of entry. This same scenario was replayed throughout downtown Houston as well; buildings got flooded through no direct fault of their own.

What to do about it

When it runs out of places to flow, flood waters have no choice but to go higher—a characteristic that further increased flood levels in the medical center's vicinity. (By a stroke of luck, a four-story deep excavation—ready to accept yet another addition to the center—

The Long and Short of Flood-Proofing

Principles of design

- **Existing and future developments will experience flood depths above current mapped flood hazard areas.**
- **Flood levels need to be evaluated periodically and flood-proofing measures adjusted accordingly.**
- **Relying on others to provide flood protection is inviting disaster. Every facility and structure should be self-reliant. Redundant systems of backup gaskets should provide protection in the event of failures (particularly in the case of air inflated gaskets).**
- **Back-up systems such as hand and foot pumps, emergency generators, and alternate power supplies should be readily available, preferably mounted on the flood gates themselves to ensure air supply in the event of a power failure.**
- **Do not store irreplaceable items in areas that may be subject to flooding. Rather, move them to safer, higher ground. This includes electrical and communications equipment, which should be safe from flooding, even under the worst of circumstances.**
- **While equipment is replaceable, time and lost business are not.**

Principles of operation

- **Passive systems have to be identified as such, and continually inspected and monitored for accidental/intentional breaches. Unlike equipment and gates that can be tested and inspected, the maintenance of a landscaped berm requires considerable attention.**
- **Flood-proofing measures need to be easily placed into operation, requiring minimal time and manpower. Gates that can be lowered or swung into place should replace multiple component stop-logs and sandbags.**
- **Equipment needs to be inspected on a regular basis to assure its readiness. Current flood-proofing technology offers a variety of gates and doors designed for ease of operation and maximum protection.**
- **Do the best you can. A full-height watertight door may not be 100 percent effective in a corridor with a false ceiling or pipes and conduits that will let the water through anyway once it has reached full height. Consider a second door or gate to handle the overflow.**
- **Do not overlook the air intake make-up vents, shafts, and passageways.**
- **Install check-valves on drains, and water-proof utility conduits to prevent water in an overloaded drain system from entering the facility through the back way.**
- **Have trained personnel execute your flood control plans.**

Looks

- **Active flood-proofing (gates and barriers) does not have to look obvious, nor does it have to be industrial in appearance. It can be both functional and aesthetically pleasing.**

acted as a retention basin during Allison. The water collected likely spared at least one institution from severe damage, besides reducing the amount of water that could have flowed into the already flooded institutions.)

Flooding will occur where drainage is inadequate and incapable of directing water to its final collection point. In some cases, existing conditions make total flood-proofing unattainable at reasonable cost and effort. A dam system in the form of a series of gates and barriers, as well as pumps and drainage systems, could be used to contain and handle flooding when flood-proofing is less than 100 percent.

In many cases, it is not the costs associated with flood-proofing that deter conscientious owners, but aesthetics. They are concerned these measures will be ugly and diminish the value of their property while chasing away customers, patients, and citizens. In some cases, appearance considerations affect operation and application, forcing less than ideal flood-proofing to be installed.

More and more, local building codes across the nation are being amended to ensure new construction and renovations conform to Federal Emergency Management Agency (FEMA) guidelines. Some measures written into building codes are relocation and elevation, and wet and dry flood-proofing.

Before deciding on the method of flood protection, flood levels and extent of area usage should be determined. Flood levels are based either on locally available flood zone maps for new construction or markings left by previous floods. Add to this measurement an additional 300 mm (12 in.) to account for "floatables," increased water levels caused by winds, and the inevitable storm that surpasses the 100-year level. Flood levels should be determined for every opening within the facility to accommodate varying grades and locations.

In the immediate area of the medical center, engineers and architects are grappling at establishing new "safe" flood-proofing levels. Once an area has been flood-proofed, they need to defend against increases in street water levels caused by all the water stored in basements, tunnels and excavation digs that will have nowhere to go but into the streets and undersized sewers.

Once levels are established, usage should be defined. Frequency of usage, wheeled vehicle traffic, and equipment and wheelchair accessibility should be considered. This information will help you determine the best flood-proofing options.

Relocation and elevation

The most obvious form of flood-proofing is relocation to higher ground, and it applies to both an entire facility or its key components. If relocating a building or an entire complex is not

Bulkhead doors are watertight and protect entrances to basements, tunnels, and galleries, and can be designed to provide total protection under meters of standing water.

or replaced inexpensively. For example, an addition to the administrative building at one facility was placed on columns and the ground level served as a parking lot. In the case of a flood, the parking lot would become submerged while the higher levels remained dry.

Dry flood-proofing

Dry flood-proofing completely seals a building's exterior to prevent any water entry, and should be considered when relocation is impractical or interrupts sensitive operations, or when sensitive or expensive equipment cannot be moved quickly. Usage and application determine the choice of dry flood-proofing mechanisms, but removable floodgates and barriers are typically fitted over doors, driveways, windows, and vents. Again, because they are subjected to hydrostatic pressure, dry flood-proofing equipment suitability and integrity should be considered carefully during design.

Dry flood-proofing is typically more expensive than wet, but depending on the equipment involved or an area's flooding history, it may well be worth the investment. (In the case of the medical center, flood-proofing expenses would have realized a 100:1 return on investment when measured against incurred or preventable loss.)

an option, then at the very least critical equipment and items should be relocated above flood levels to minimize damage and loss, and to assure continued operations in the event of a breach in the flood-proofing system. Components such as electrical supply transformers, generators, communications gear, data processing, and control apparatus can all be elevated above flood levels. (The losses continued to mount in the Texas Medical Center months after Allison paid her visit. Hospitals and units remained empty, losing millions of dollars a day, yet unable to resume operations due to damaged power gear, lost computers, and soggy communication switches.)

Wet flood-proofing

The main goal behind wet flood-proofing is not to keep water out, but to minimize the structural damage caused to a building by the pressure water exerts. Hydrostatic pressure should not be taken lightly. Rushing water, as in a flash flood, demonstrates this immense power by upsetting or destroying virtually everything in its path. The danger of hydrostatic pressure is also exhibited by contained, still water, which exerts about 23 kg/0.03 m^3 (50 lb./ft^3) of pressure on surrounding walls and structures. (For this reason, the walls of a wet flood-proofed building should be given the same structural evaluation as floodwalls, levees, floodgates, and barriers to ensure they will not collapse). The best solution is to provide several openings for water to exit as well as enter.

Wet flood-proofing should be considered for areas or buildings that can be sacrificed, or contain equipment that can be dried

Floodwalls such as low brick walls and landscaped earthen berms are permanent barriers that protect a facility or equipment, while levees are used mostly on large plains or along riverbanks to divert flowing water. Floodgates and barriers are often used to seal access openings in floodwalls and levees. Larger or outdoor areas such as parking garages, driveways, and loading docks—as well as outdoor utility sheds—can be sealed off with floodwalls with floodgates, providing access as needed. Entrances to facilities can be well protected with removable or permanently placed gates and barriers.

Gates can be used for openings ranging from 760-mm (30-in.) doorways to 12-m (40-ft) wide truck openings—sometimes wider. Openings intended for wheelchair access require a gate and sill arrangement that will not be damaged by heavy vehicles nor prevent wheelchair access. While configuring gates and barriers, designers should comply with ADA if the entrance is designated wheelchair accessible.

For above-grade openings or openings partially below the flood level, partial-height barriers are recommended. Such barriers are frequently constructed of lightweight aluminum for easy placement and removal. Windows, vents, and ducts can be sealed with permanently mounted shields that can be removed or fitted to permit air circulation. Openings in floors or roofs can be sealed with hatches.

Bulkhead doors can be used for below-grade openings, or openings that would be submerged in a flood. These doors are watertight to protect entrances to basements, tunnels, and galleries that house equipment, and can be designed to provide total protection under meters of standing water.

Decision time

The issue of flood-proofing is not to be left on the back burner, nor should you wait to see what someone else comes up with.

• Flood-proofing makes good business sense—protecting those things that money cannot replace—and is likely already incorporated into building codes (particularly in designated flood zones). Property improvement or sale may trigger their implementation.

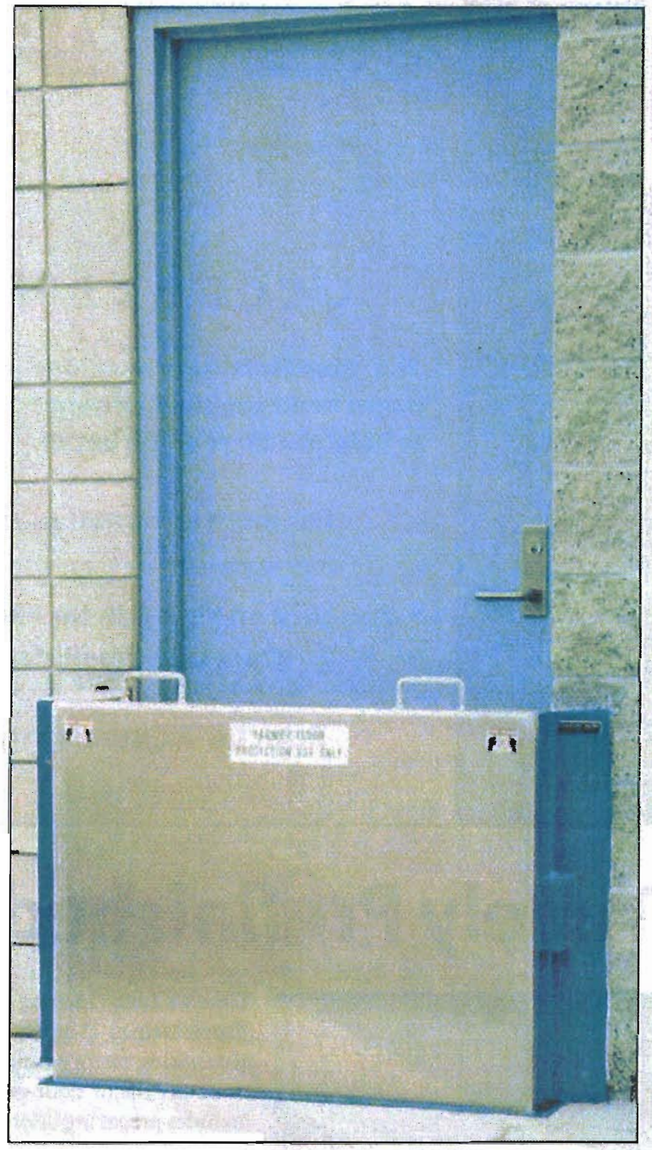
• As values rise, insurance will not cover your losses. Limits of $500,000 for property damage and contents to businesses seems hardly adequate.

• Mold damage and the associated clean-up costs—not to mention loss of use while clean-up drags on—are matters of disputes and lawsuits between victims and insurance providers.

• Flood insurance and damage relief from the federal government may soon no longer be available as freely and readily as in the past. Motions in congress, backed by FEMA, call for both limiting compensation to a single occurrence per location, and increasing insurance premium rates to commercial levels from current subsidized rates.

• Flood-proofing is actually quite affordable, particularly when measured against realized losses. As mentioned earlier, the estimated return at the Texas Medical Center would have been $100 for every $1 invested in flood-proofing.

If you need one last bit of an incentive, contact FEMA or your local state task force and ask about Public Law 106-390, *The Disaster Mitigation Act of 2000—The Robert T. Stafford Disaster Relief And Emergency Assistance Act*. This act outlines various relief and assistance measures available from all levels of government for both post-disaster as well as pre-disaster mitigation. Preventative measures under the act have been expanded to substantially increase federal and state participation, especially in mitigation efforts—in many cases covering 100 percent of the costs—to help prevent future losses. ♥



Partial height barriers are made of light aluminum and easily manipulated.

ADDITIONAL INFORMATION

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01610—Basic Product Requirements
02050—Basic Site Materials and Methods
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02800—Site Improvements and Amenities
02900—Planting
08050—Basic Materials and Methods
08390—Pressure Resistant Doors
General Data—Economic Issues
General Data—Environmental Issues
General Data—General Information
General Data—Infrastructure
General Data—Insurance

Key words

Division 1
Division 2
Division 8
Americans with Disabilities Act
The Disaster Mitigation Act of 2000
Federal Emergency Management Agency
Flood-proofing

Abstract

Although Allison is not the worst storm to hit the Houston, Texas, it is nonetheless blamed for the loss of 22 lives, not to mention all the equipment destroyed, merchandise lost, and damaged property that amounts to billions of dollars in replacement costs.

According to the author, while flooding is a communal issue requiring coordinated actions, much can be done to correct and protect individual properties. Specifically, he discusses ways of either avoiding flood-incurred losses altogether, or mitigating those losses through various flood-proofing options. He uses the Texas Medical Center in Houston to help illustrate his arguments for proper and improper flood-proofing techniques.