

# TEXAS FLOOD

Flood-Resistant Structures for Enhanced Resilience



## SPEAKERS



**Erik Verboon**

*Principal, Structures Group  
Walter P Moore*



**Colley Hodges, AIA, NCARB,  
LEED AP, WELL AP**

*Senior Associate, Director of  
Sustainability  
Kirksey Architecture*



**Rich Romero**

*Vice President  
Savannah Trims, Inc.*

Facade  
Technics



**TEXAS**

**FLOOD**

FLOOD-RESISTANT STRUCTURES FOR ENHANCED RESILIENCE



# FEMA

## **FEMA defines urban flooding as:**

“the inundation of property in a built environment, particularly in more densely populated areas, caused by rain falling on increased amounts of impervious surfaces and overwhelming the capacity of drainage systems. It excludes flooding in undeveloped or agricultural areas. It includes situations in which stormwater enters buildings through a) **windows, doors, or other openings;** b) water backup through pipes and drains; c) seepage through **walls and floors.**”





\$40b worldwide

\$8b usa

## Elements of a Floodplain

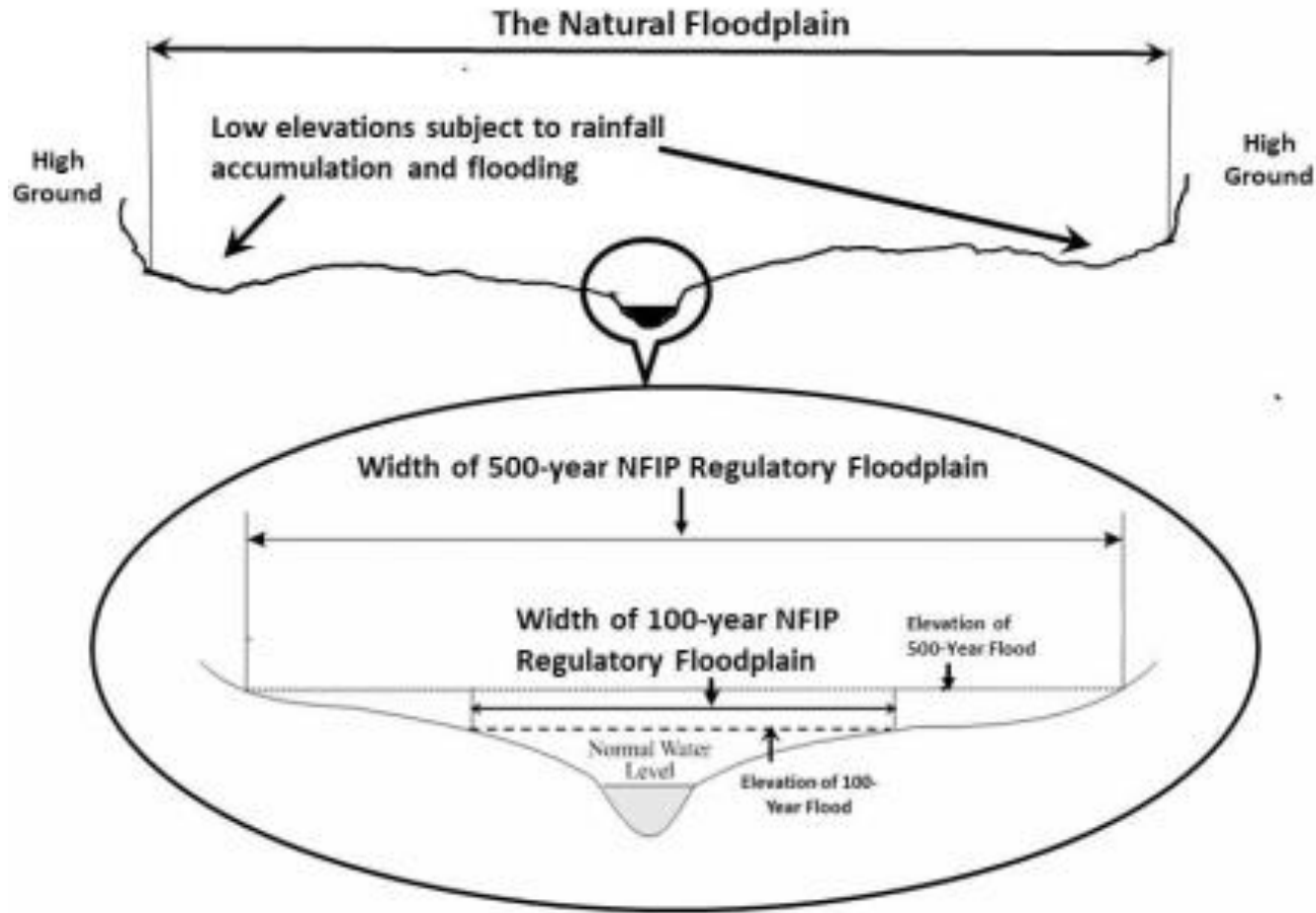


FIGURE 3. THE 100-YEAR FLOODPLAIN REPRESENTS AN AREA WHERE THERE IS A 1% ANNUAL CHANCE THAT A FLOOD WILL OCCUR, AND A 500-YEAR FLOOD IS WHERE THERE IS A 0.2% CHANCE EACH YEAR OF SUCH AN EVENT. SOURCE: CENTER FOR DISASTER RESILIENCE, UMD.



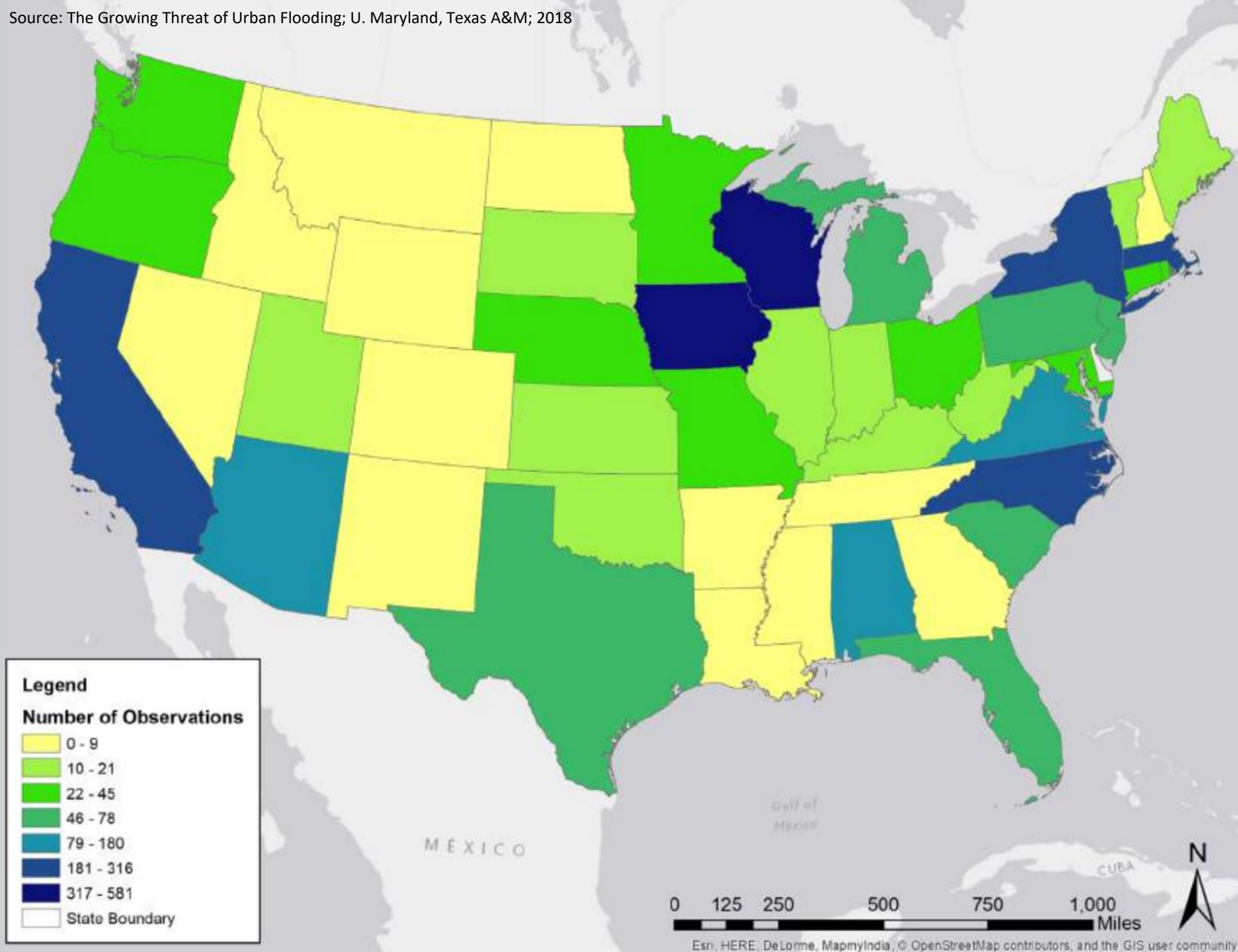
Ankeny, 2018



Ellicott City, 2018

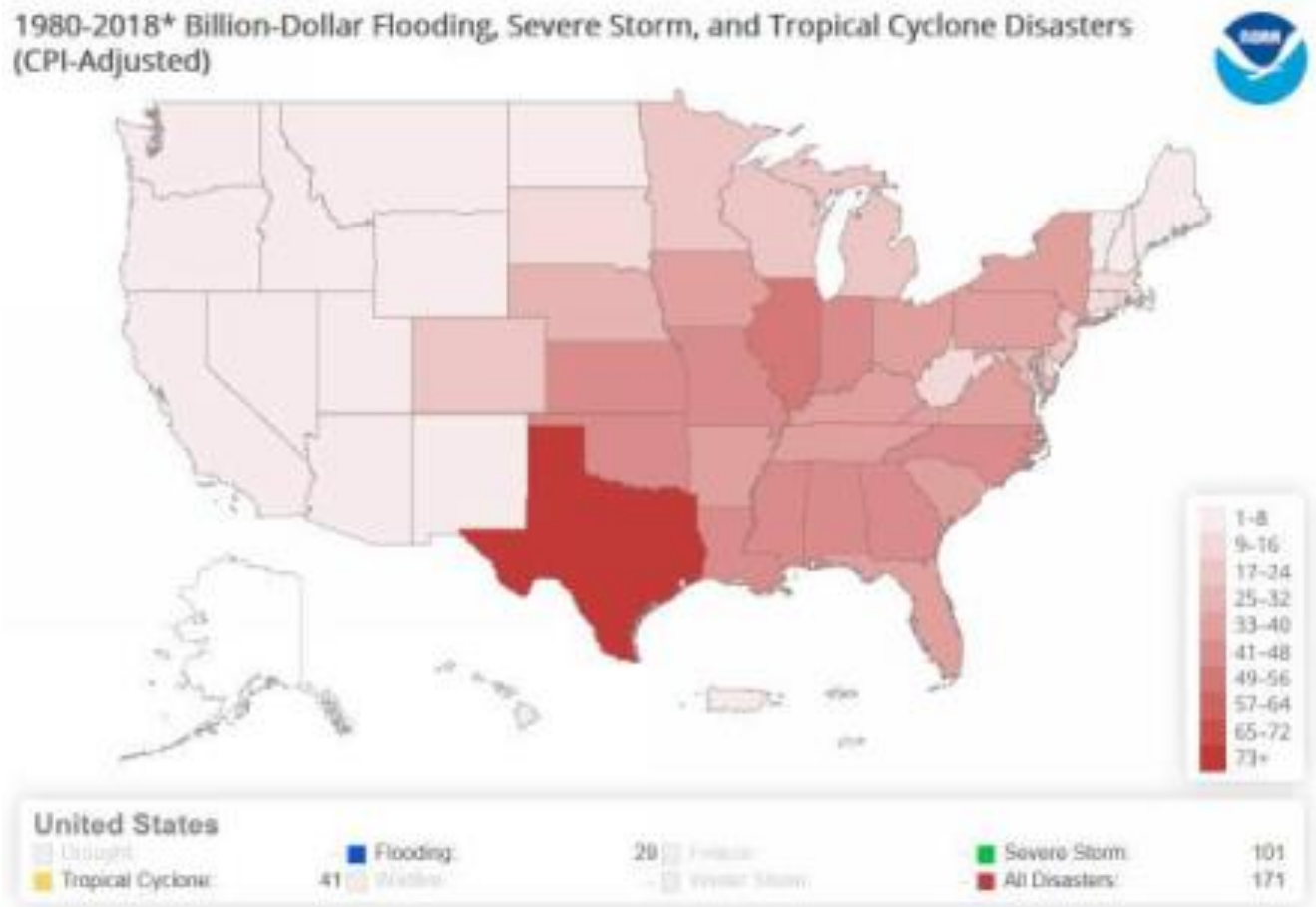
NUMBER OF URBAN FLOODING  
OBSERVATIONS BY STATE (1993-2017).  
SOURCE: NOAA; MAP BY CENTER FOR  
TEXAS BEACHES AND SHORES, TEXAS  
A&M (CTBS), 2018.

Source: The Growing Threat of Urban Flooding; U. Maryland, Texas A&M; 2018



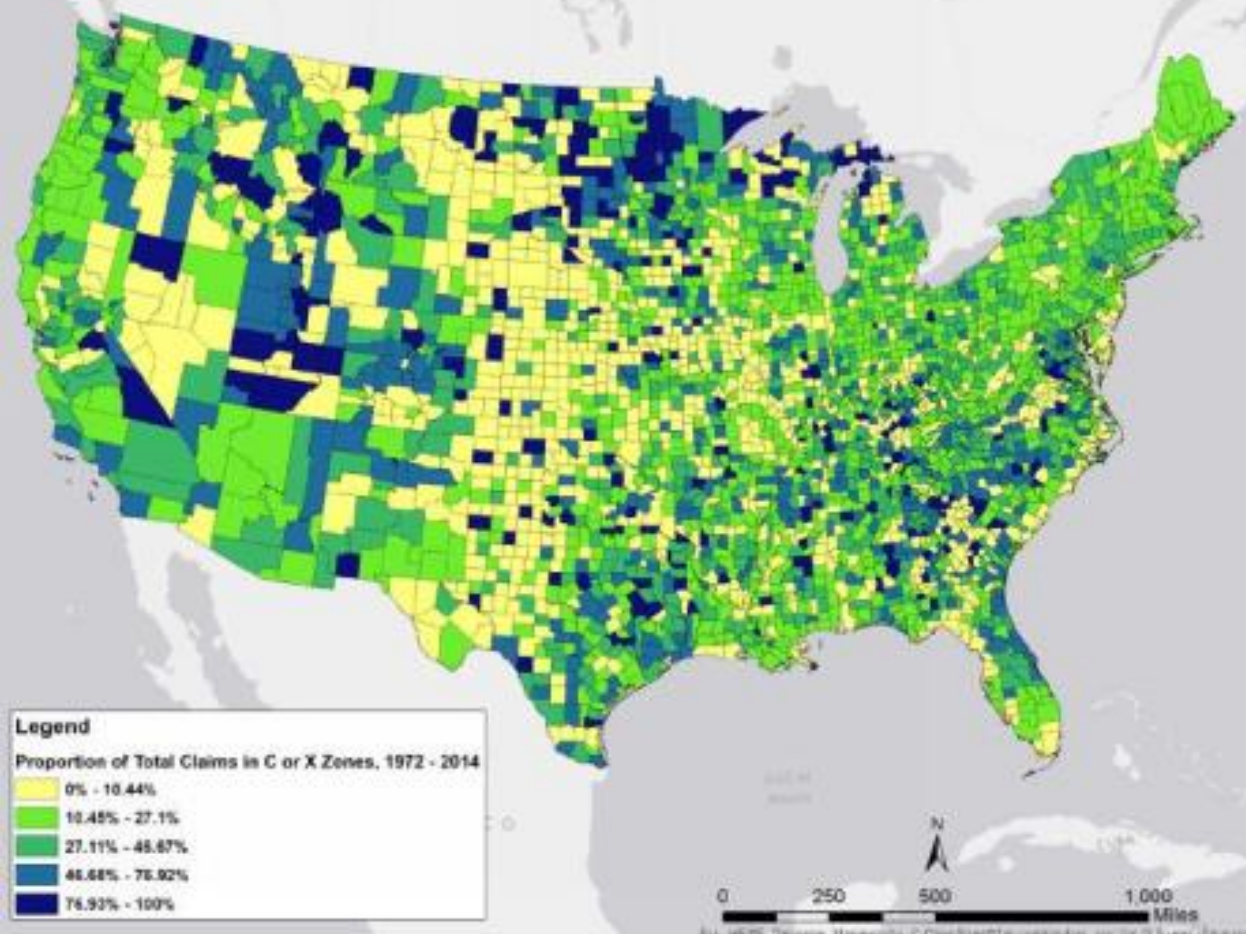
**30M** people (10% of population) live in combined 100 & 500 yr floodplains.

2/3 of which reside in **Texas** or **New York**.



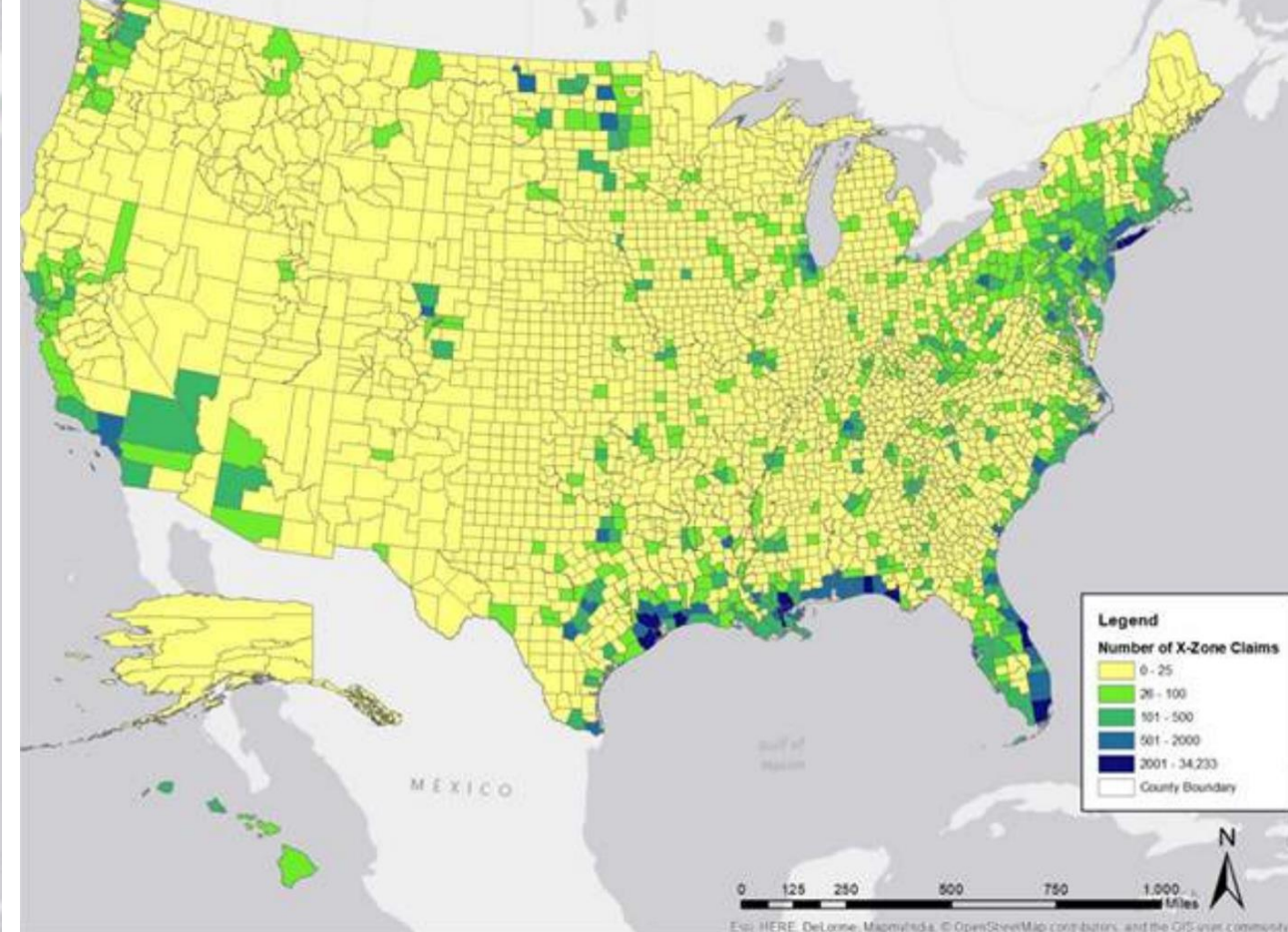
Source: NOAA

Source: The Growing Threat of Urban Flooding; U. Maryland, Texas A&M; 2018



NFIP CLAIMS PAYOUTS BY COUNTY, 1974-2014 FOR PROPERTIES OUTSIDE THE SFHA (100-YEAR FLOODPLAIN). SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

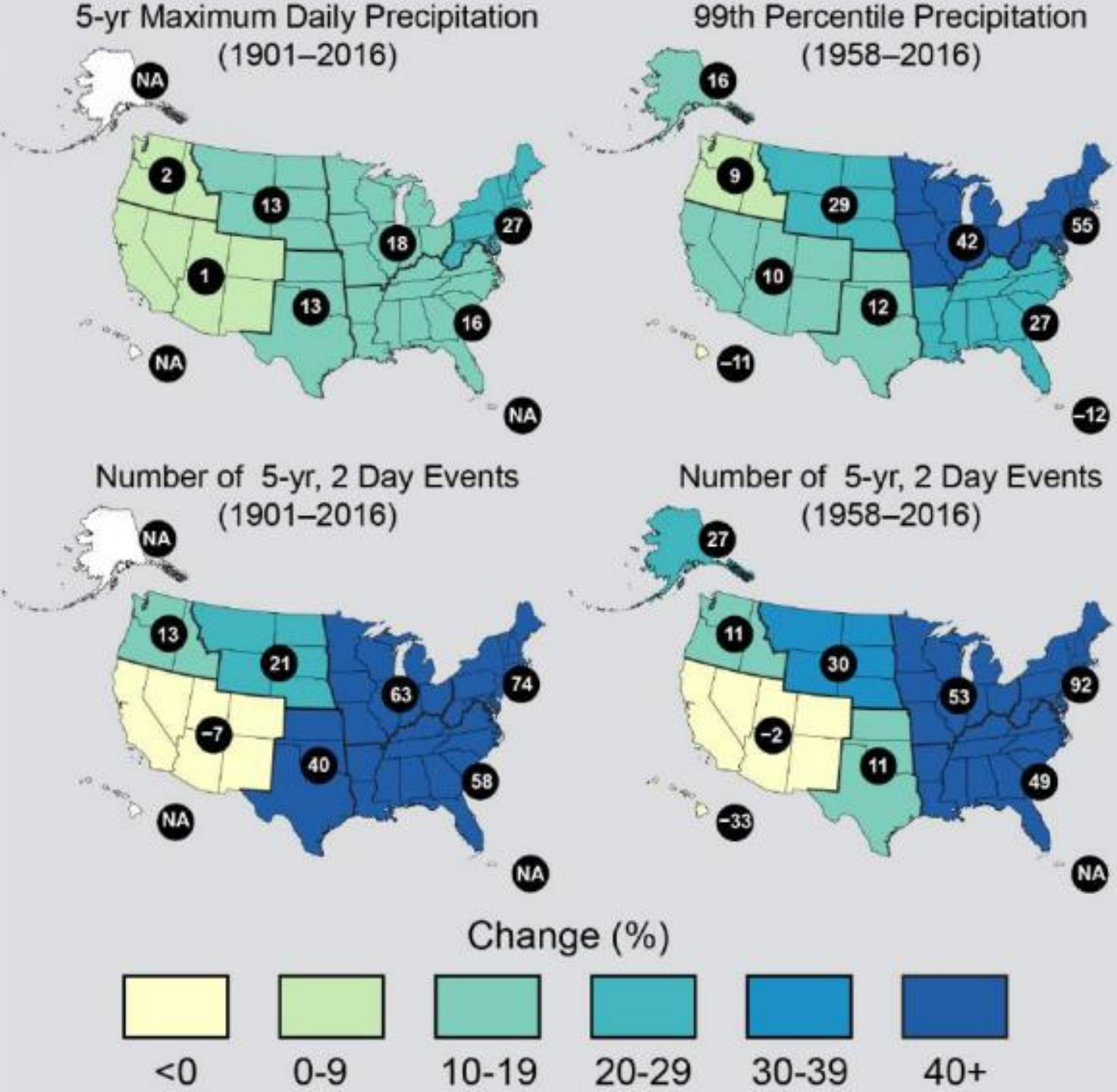
Source: The Growing Threat of Urban Flooding; U. Maryland, Texas A&M; 2018



PERCENTAGE OF TOTAL NFIP CLAIMS BY COUNTY (1972-2014) ATTRIBUTABLE TO PROPERTIES OUTSIDE THE SFHA. SOURCE: FEMA NFIP; MAP BY CENTER FOR TEXAS BEACHES AND SHORES, TEXAS A&M (CTBS), 2018.

**60%** of Houston properties damaged by Harvey outside of 100yr floor plain.

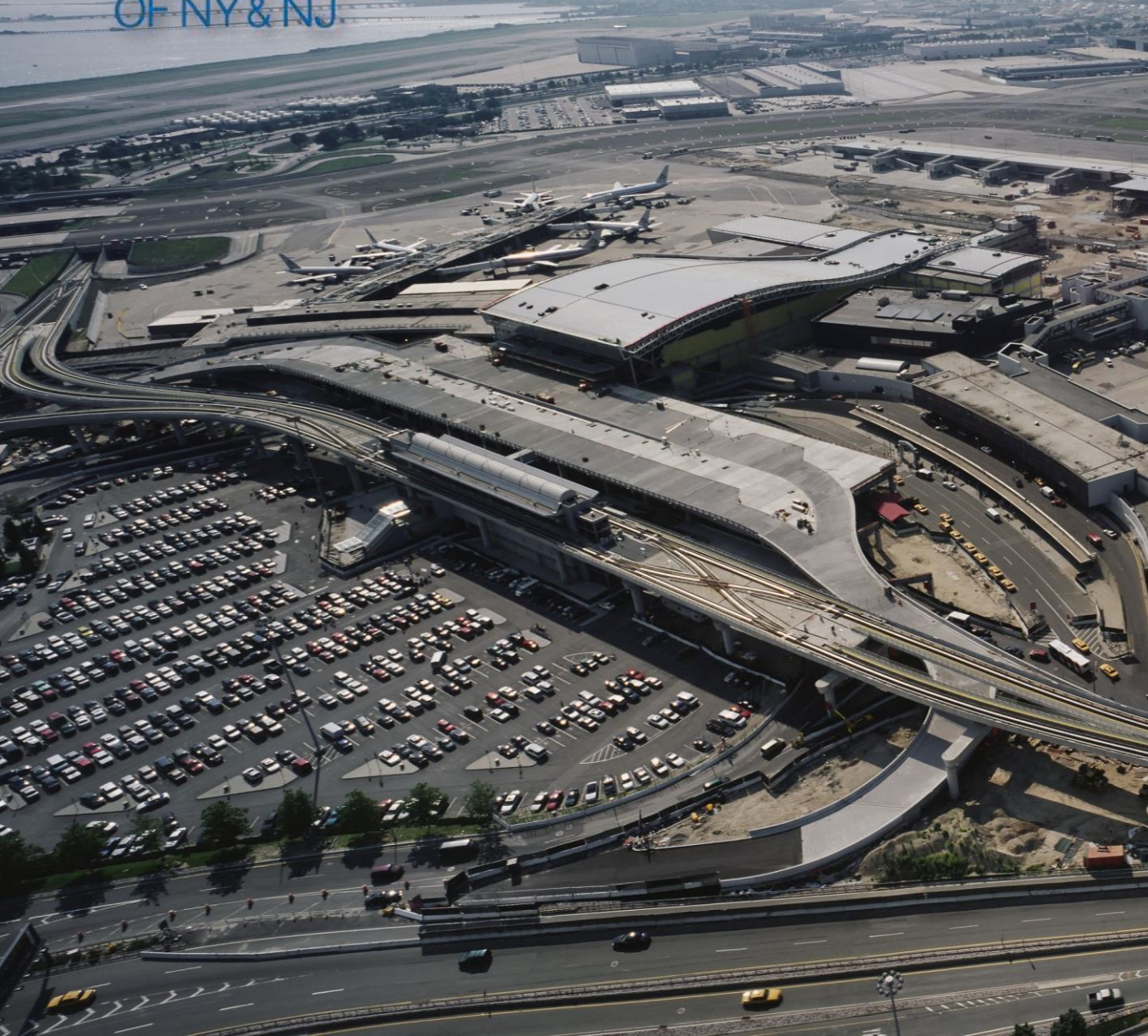
# And the rate is accelerating



Source: The Growing Threat of Urban Flooding; U. Maryland, Texas A&M; 2018



# THE PORT AUTHORITY OF NY & NJ



Projected Climate Change Hazard	Potential Impacts to Port Authority
<p><u>Sea Level Rise:</u></p> <ul style="list-style-type: none"><li>- Observed relative sea level rise of about 1.2 inches per decade (which includes factors such as land subsidence) in the greater New York City region has averaged twice the observed global rate.</li><li>- Sea level rise is very likely (&gt;90% probability of occurrence) to accelerate as the century progresses.</li></ul>	<ul style="list-style-type: none"><li>- Amplifies the depth and extent of storm surge, putting more areas at risk of <b>flooding</b> during coastal storm events.</li><li>- Increasing depth and extent of coastal inundation during extreme and regular high tides.</li><li>- Increased likelihood of backflow from drainage outfalls.</li><li>- Progressively greater risk of groundwater <b>flooding</b> in coastally connected areas.</li><li>- Corrosion of tracks and equipment from saltwater exposure.</li><li>- Diminishing air draft below bridge spans.</li></ul>
<p><u>Precipitation:</u></p> <ul style="list-style-type: none"><li>- The number of annual rainfall downpours is very likely (&gt;90% probability of occurrence) to increase.</li></ul>	<ul style="list-style-type: none"><li>- Greater volumes of rain in more concentrated downpours could overwhelm drainage systems and cause localized <b>flooding</b>.</li><li>- Disruption to movement of transit vehicles and freight both during and after significant precipitation events.</li><li>- Erosion and scour of foundations, pilings, footings, and shorelines from overland flow.</li><li>- Additional stress on drainage and pumping systems.</li></ul>

The Climate Resilience Guidelines supplement ASCE 24 and applicable local codes in two primary ways:

- **Adjustment of the BFE for Sea Level Rise:** The Guidelines augment the applicable FEMA BFE by adding the relative increase in future sea levels (based on the NPCC projections) over the project's expected service life<sup>8</sup>.
- **Consideration of future floodplain expansion:** Rising sea levels may also lead to expansion of the 100-year tidal floodplain over time, depending on local conditions. Therefore, the Guidelines apply to projects sited in or proximate to today's 0.2% annual chance ("500-year") floodplain or in the projected future tidal 100-year floodplain, in addition to the current FEMA 100-year floodplain.



**DOING OUR PART**



# Assessing Risk



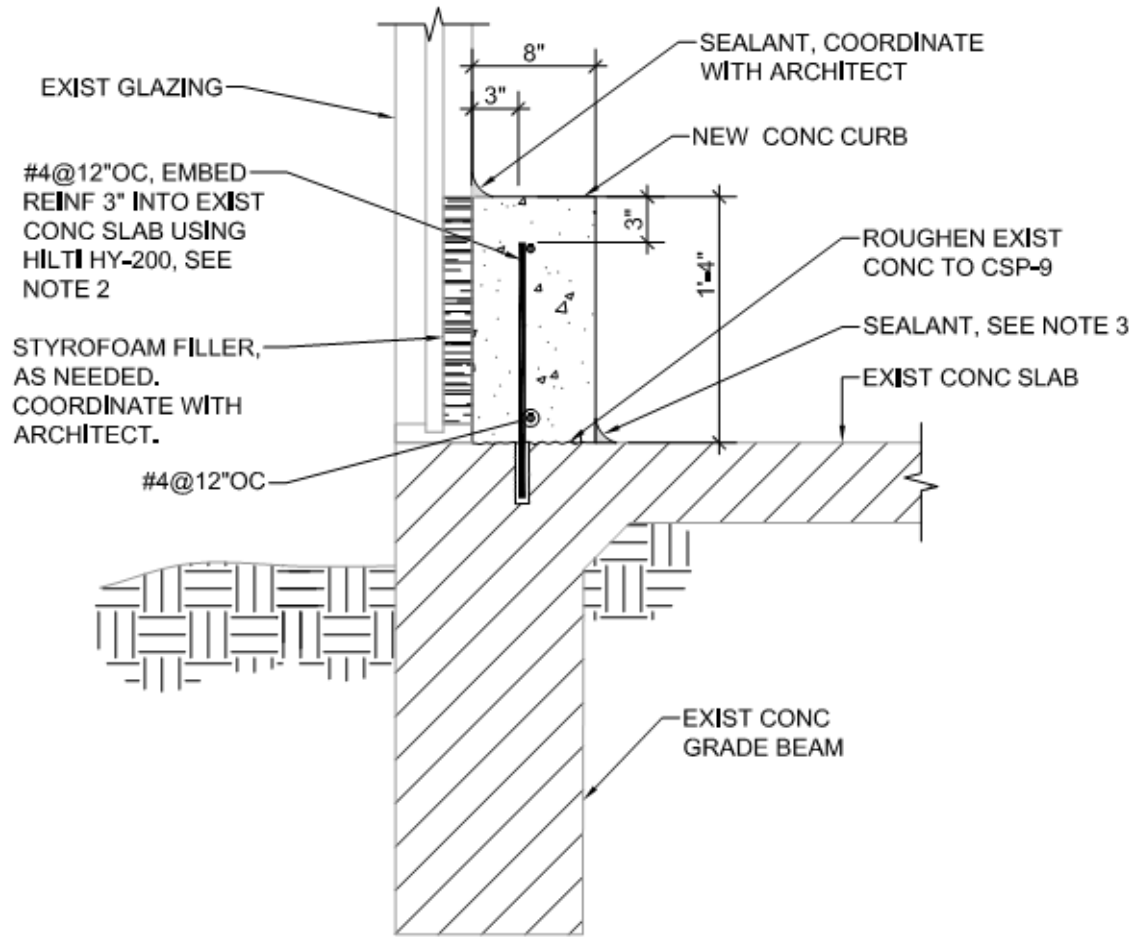


**VS**



 yesprep  
PUBLIC SCHOOLS

yes prep



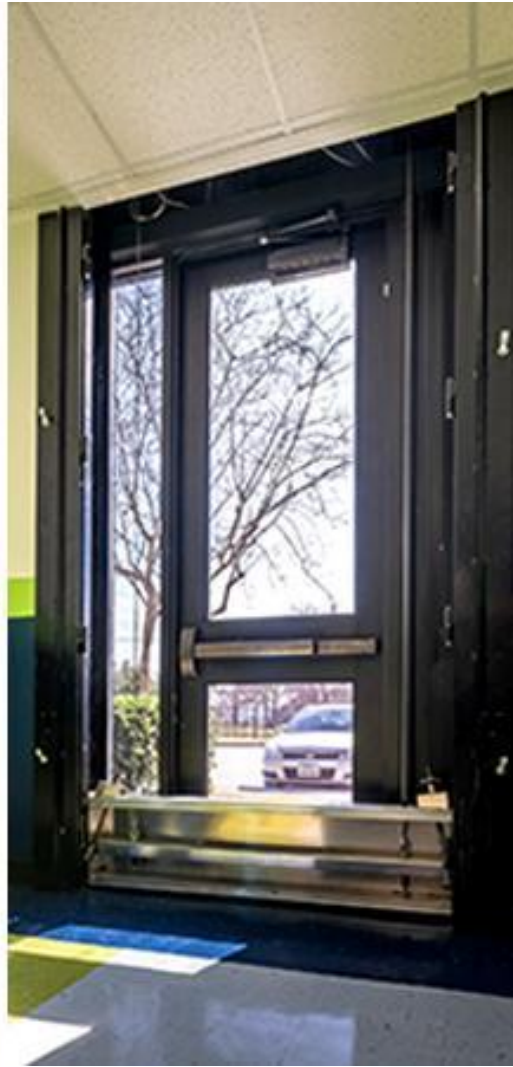
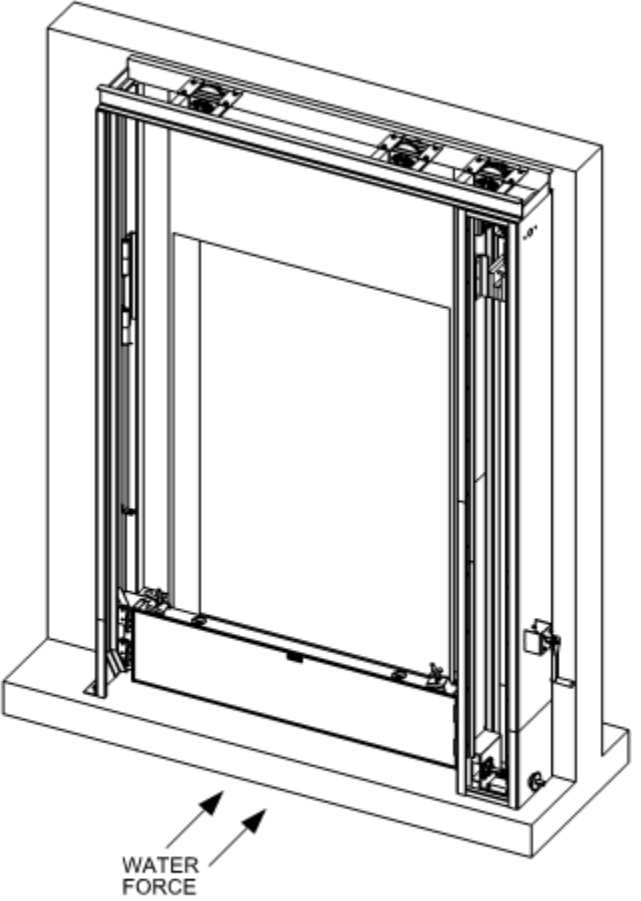
- NOTES:**
1. FIELD VERIFY ALL EXISTING CONDITIONS AND DIMENSIONS. IF THEY VARY FROM THOSE SHOWN CONTACT ENGINEER.
  2. CONTACT ENGINEER IF THICKNESS OF EXISTING SLAB IS LESS THAN 6".
  3. SEE ARCHITECTURAL DRAWINGS FOR ACCEPTABLE SEALANT MATERIALS.

1

## NEW CONCRETE CURB

NO SCALE

PS Doors





# 3000 Post Oak



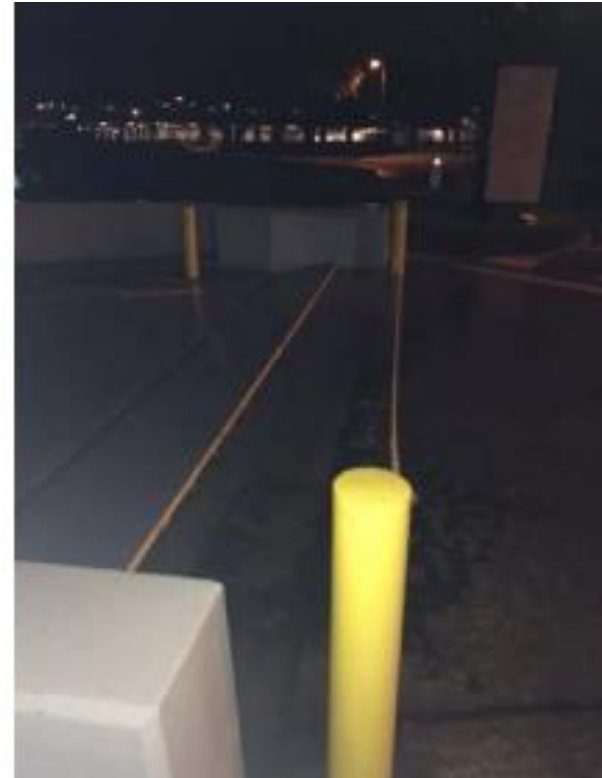
# Phase 1: Protect the Building

## Tax Day Flood 2016



## Phase 1: Protect the Building

## Hurricane Harvey



## Phase 2: Protect the Garage



**ALFRED HITCHCOCK'S THE 39 STEPS**  
A COMEDY THRILLER!  
Presented by **SOMMER THEATRES**  
EXTENDED TO SEPTEMBER 3

WORLD PREMIERE  
**DESCRIBE THE NIGHT**  
BY RALPH JOSEPH  
DIRECTED BY GIOVANNA SARDELLI  
SEPTEMBER 15 - OCTOBER 12

**ALLEY THEATRE**

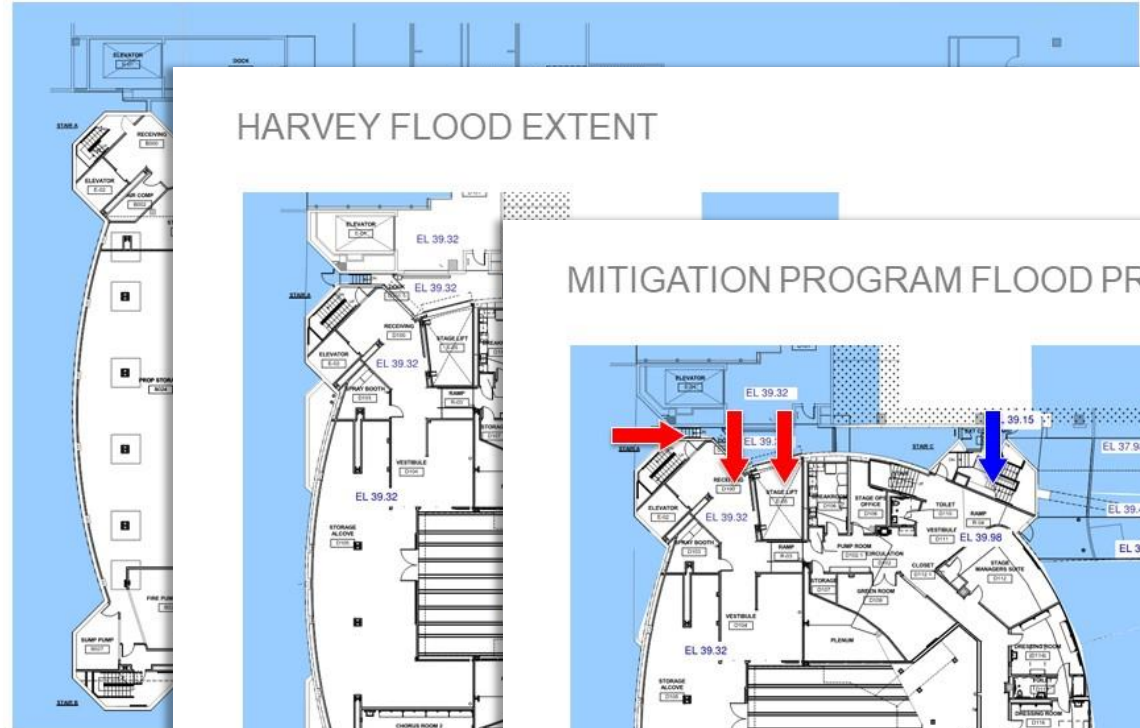


alleytheatre.org  
713.220.5700

# Alley Theatre

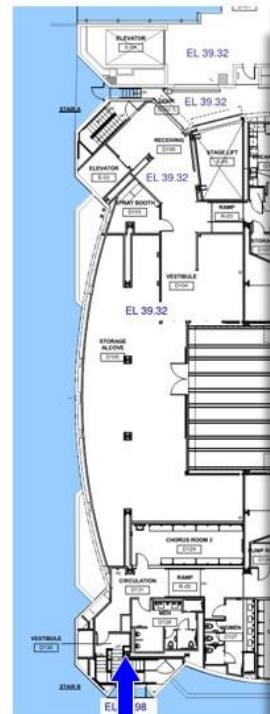


HARVEY FLOOD EXTENT



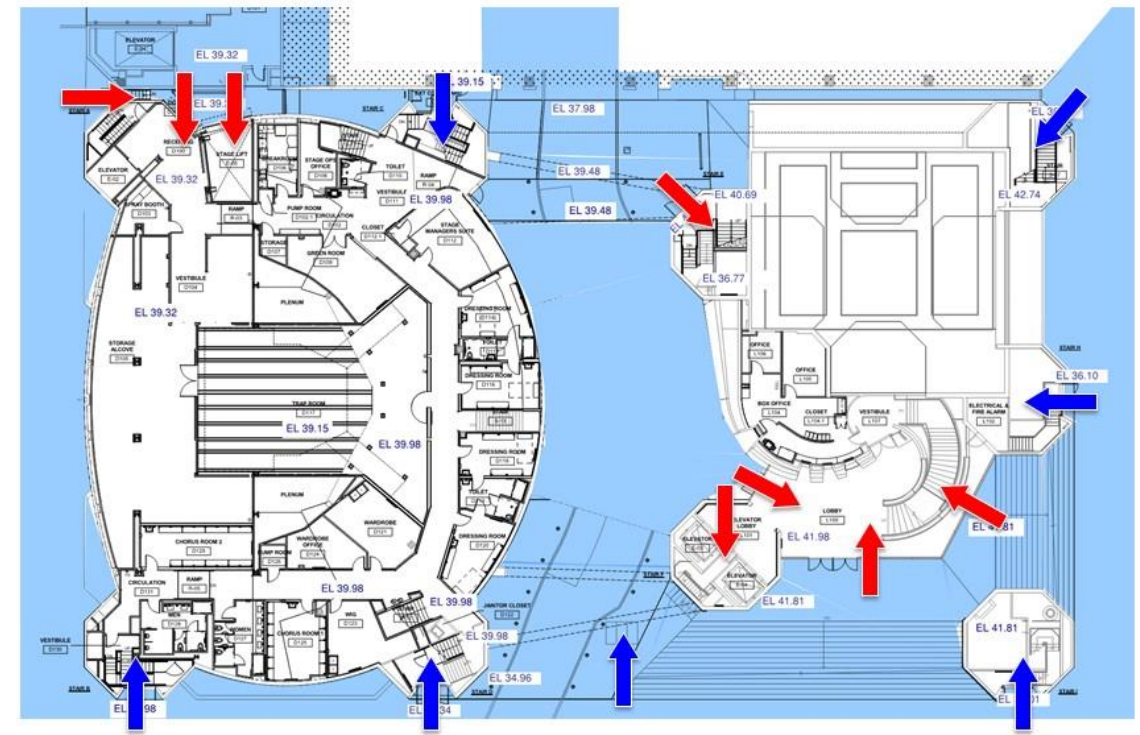
Harvey Flo

HARVEY FLOOD EXTENT



Harvey Flood Eve

MITIGATION PROGRAM FLOOD PROTECTION



500-year Flood Event

Ground Level

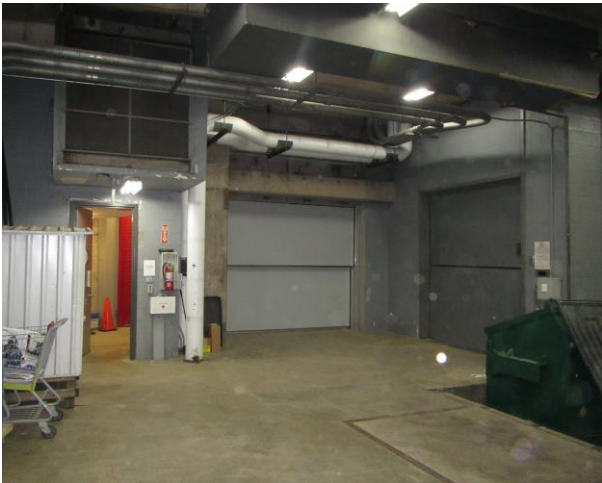
# Vulnerability Definition



**Flood Doors**



**Flood Gates**



**Vert.Lift Flood Barrier**



**Glazing Replacement**



**Hatch Vaults**

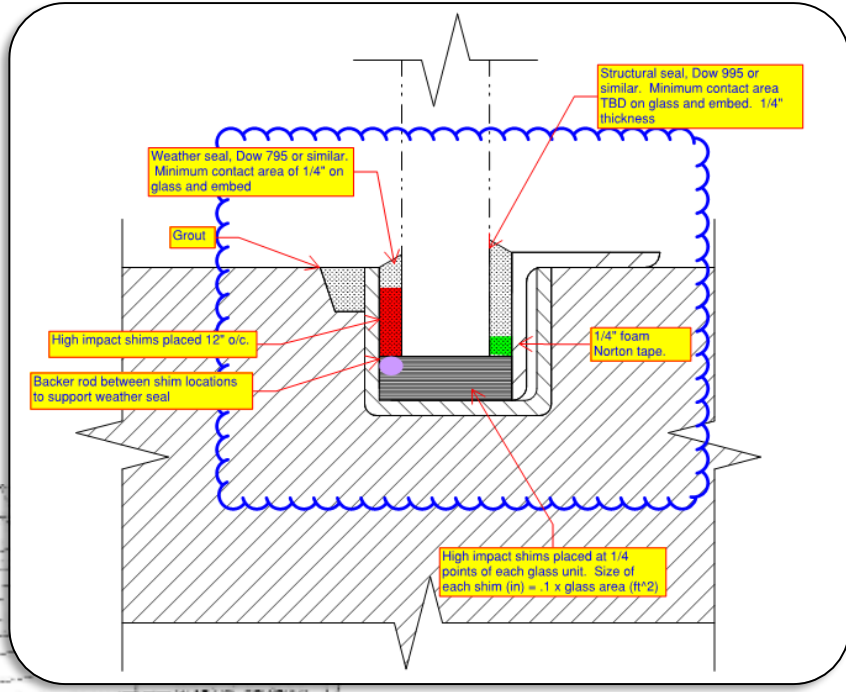


**Structural FRP Reinforcement**

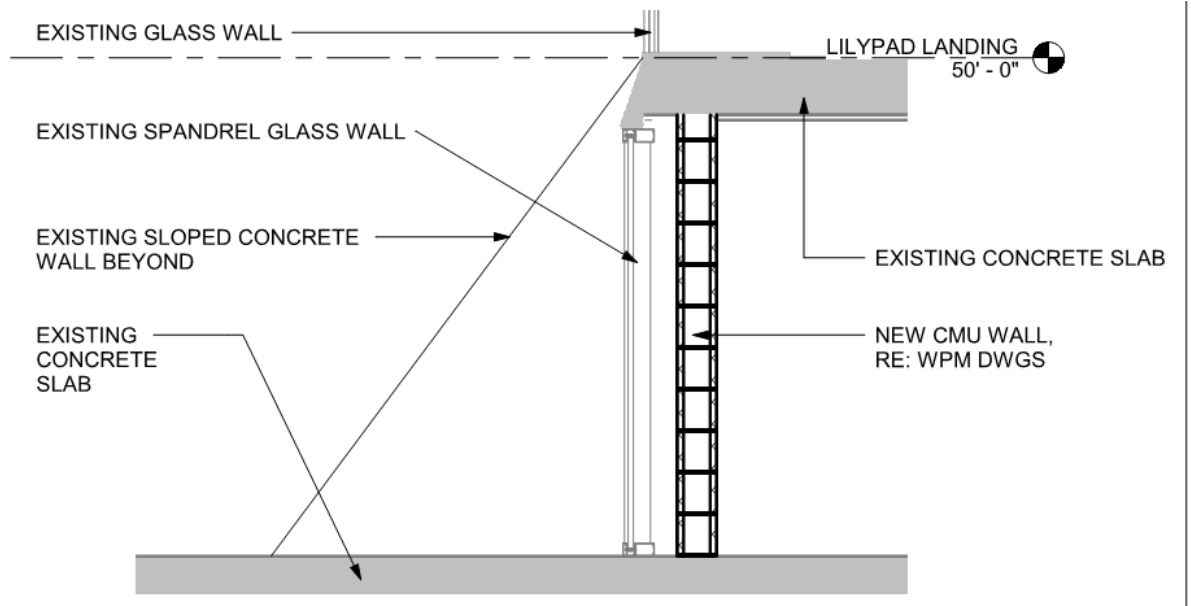
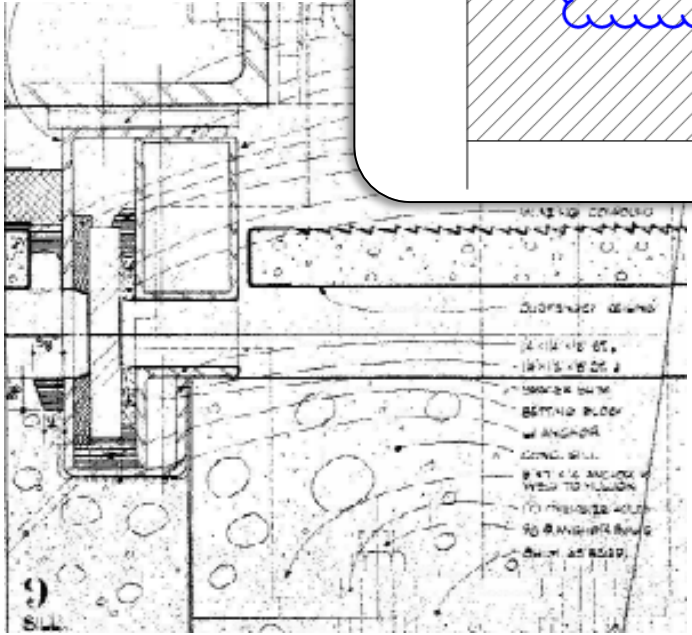


**Recessed Bottom Hinge Floor Barrier**

# Recommendations



**3 & 4-lite laminated glass.**



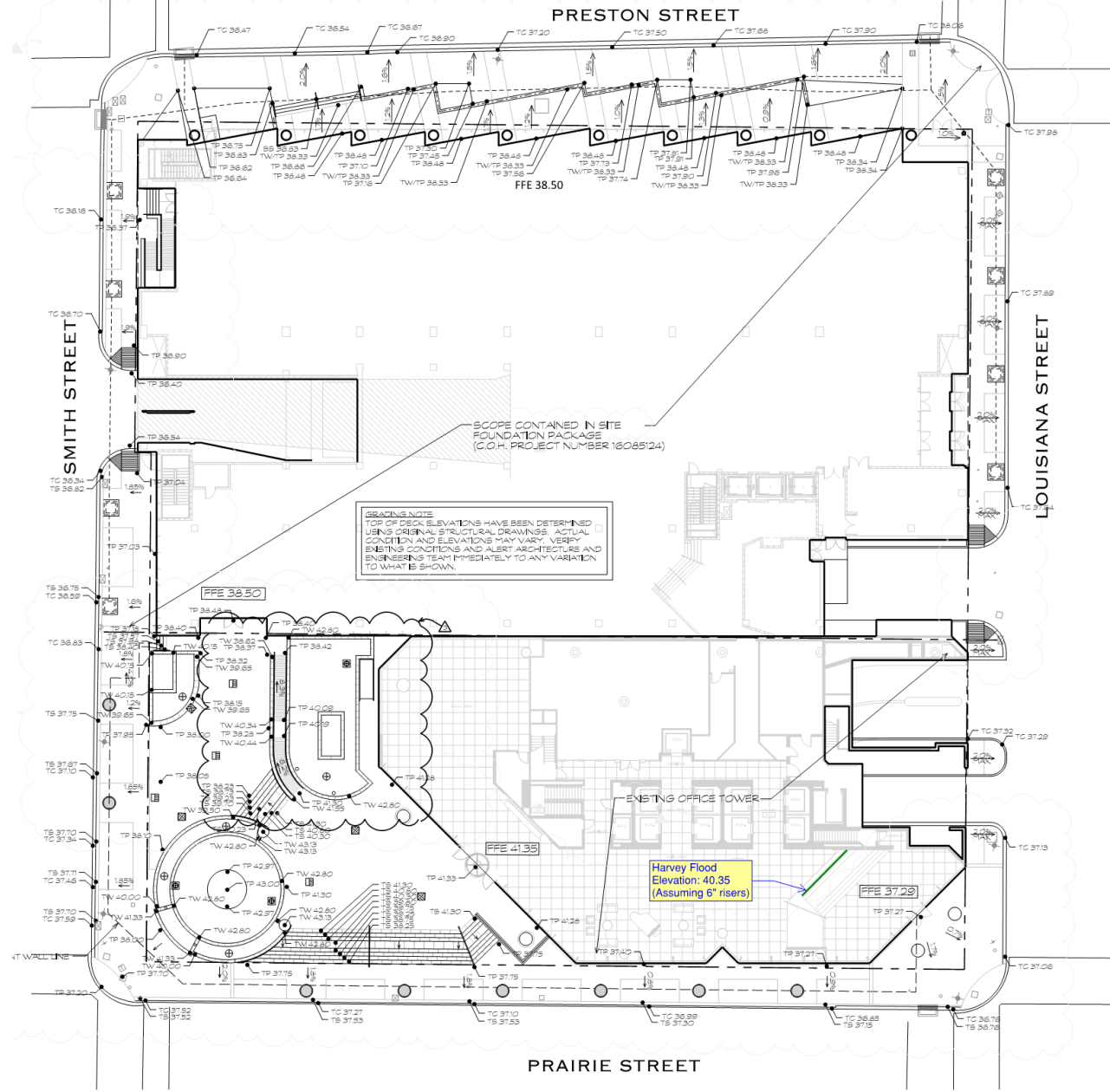
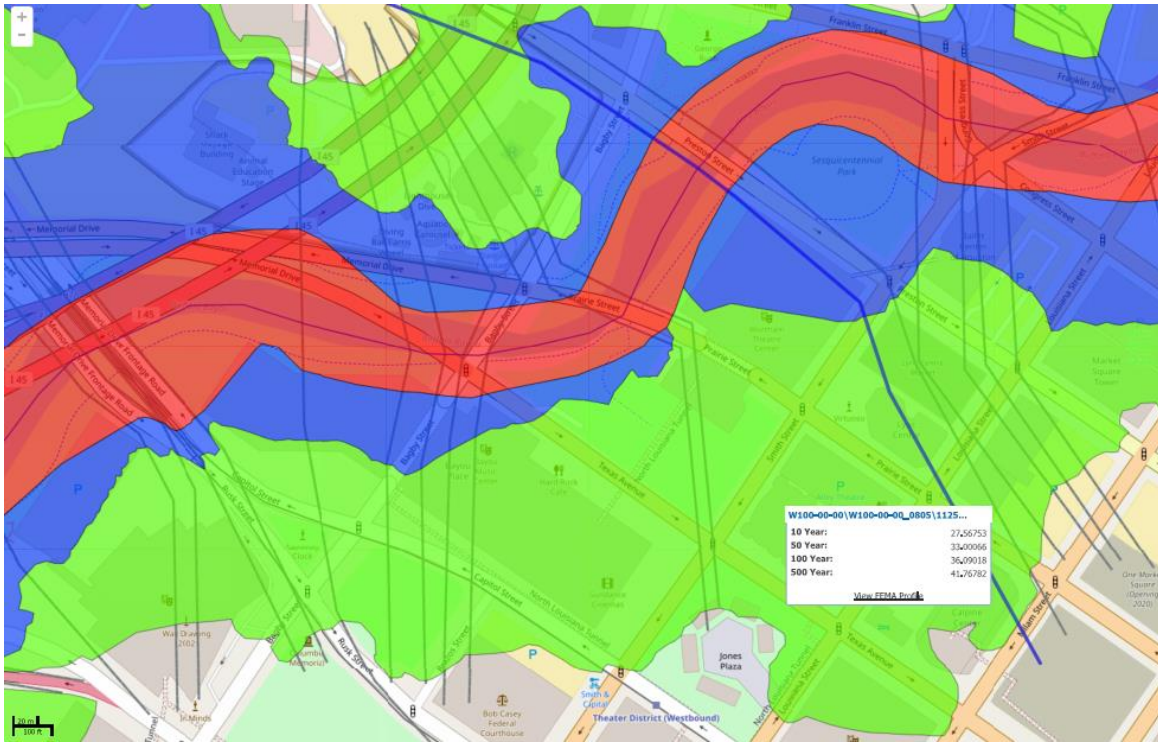
**Backup wall at spandrel glass.**

BOX OFFICE WINDOW 1/2" = 1'-0" 06

# Storefront

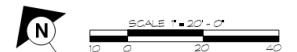


# Lyric Center



**Harvey Flood Elevation = 40.35'**

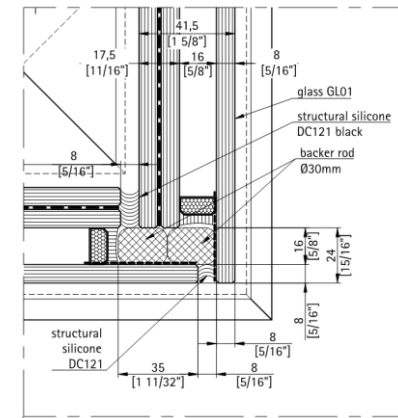
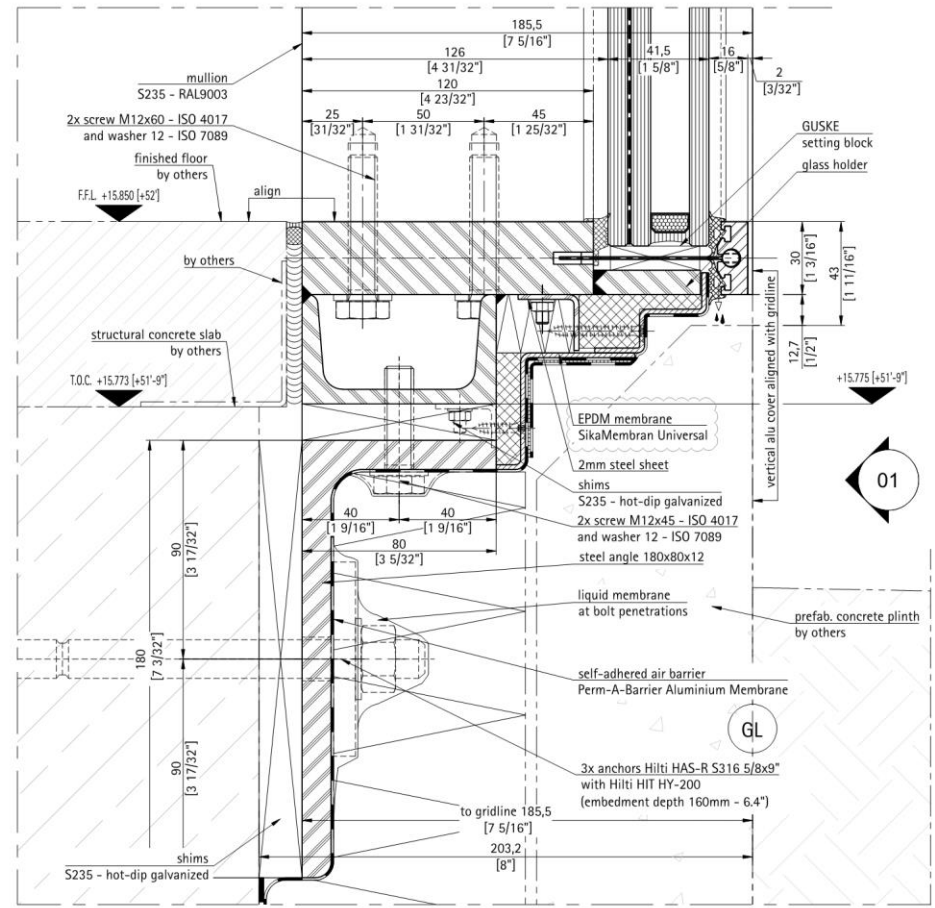
GARAGE & PLAZA - LEVEL 1  
SCALE: 1" = 20'-0"







# Menil Drawing Center





- 1. Most enclosures are design for wind loads, not water loads.**
- 2. Flood resistance is not just about walls and doors.**
- 3. Any system that has weeps are vulnerable**
- 4. Transparency requires BIG decisions**
- 5. Get full buy-in on strategies from all parties.**
- 6. Testing, Testing, Testing**

# **Takeaways**

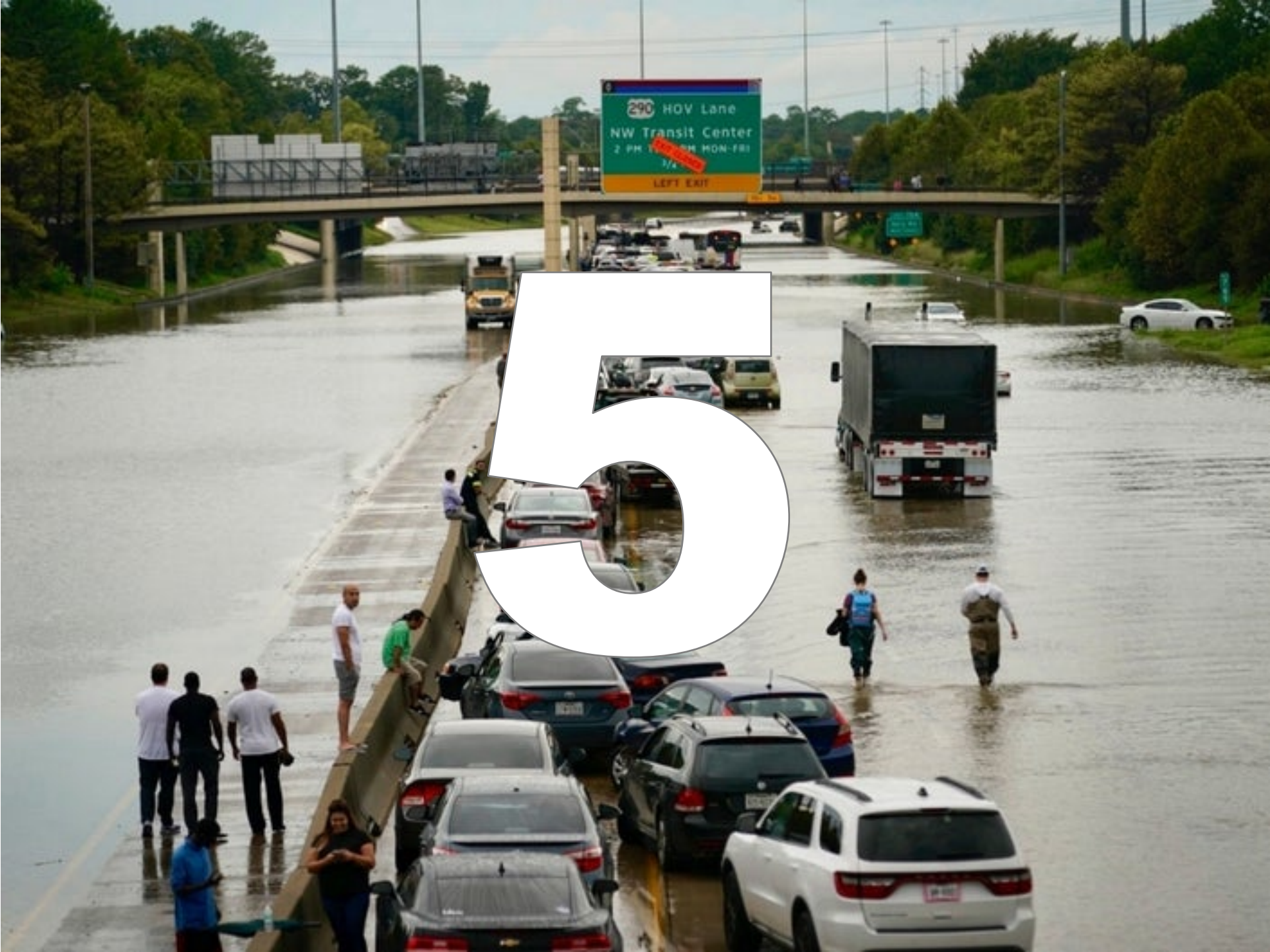


# Kirksey

ARCHITECTURE

48 YEARS | 160 EMPLOYEES | HOUSTON & AUSTIN, TX

















An aerial photograph of a residential neighborhood that has been severely flooded. The water is murky brown and covers most of the ground, including streets and yards. Numerous houses with dark roofs and light-colored walls are visible, some partially submerged. There are many green trees scattered throughout the area. In the foreground, several palm trees are visible. A large, white, stylized number '8' is overlaid in the center of the image, with a thin black outline. The number is positioned over a flooded street and a small structure, possibly a gazebo or a small building, which is partially submerged in the water.

8













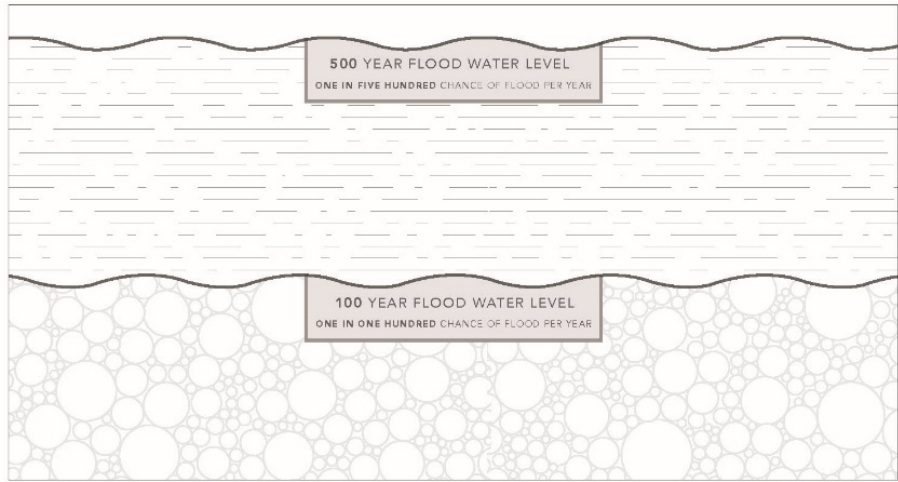




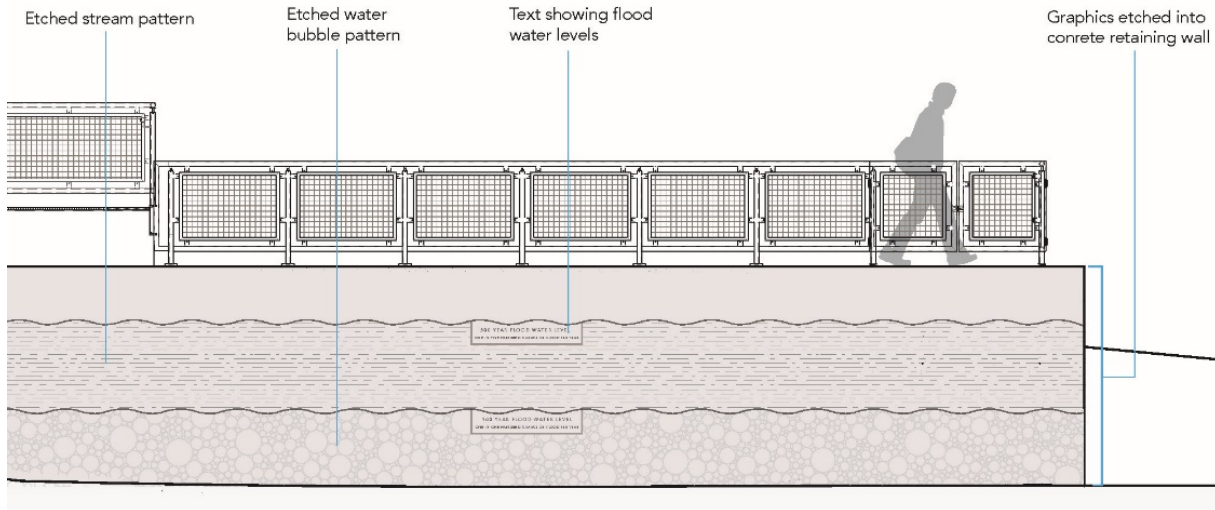


Slide courtesy of Anne Loes Nillesen

**PRIORITIZE  
THE  
PASSIVE**



Graphics Detail  
Scale 3/4" = 1'-0"



build high



use resilient or  
sacrificial materials



elevate mechanical &  
electrical equipment





buildings are  
operated by  
people

fewer  
moving parts,  
the better

**SITE MATTERS**



site = first line of defense





**MATERIALS MATTER**



embodied energy and carbon

# quality of space



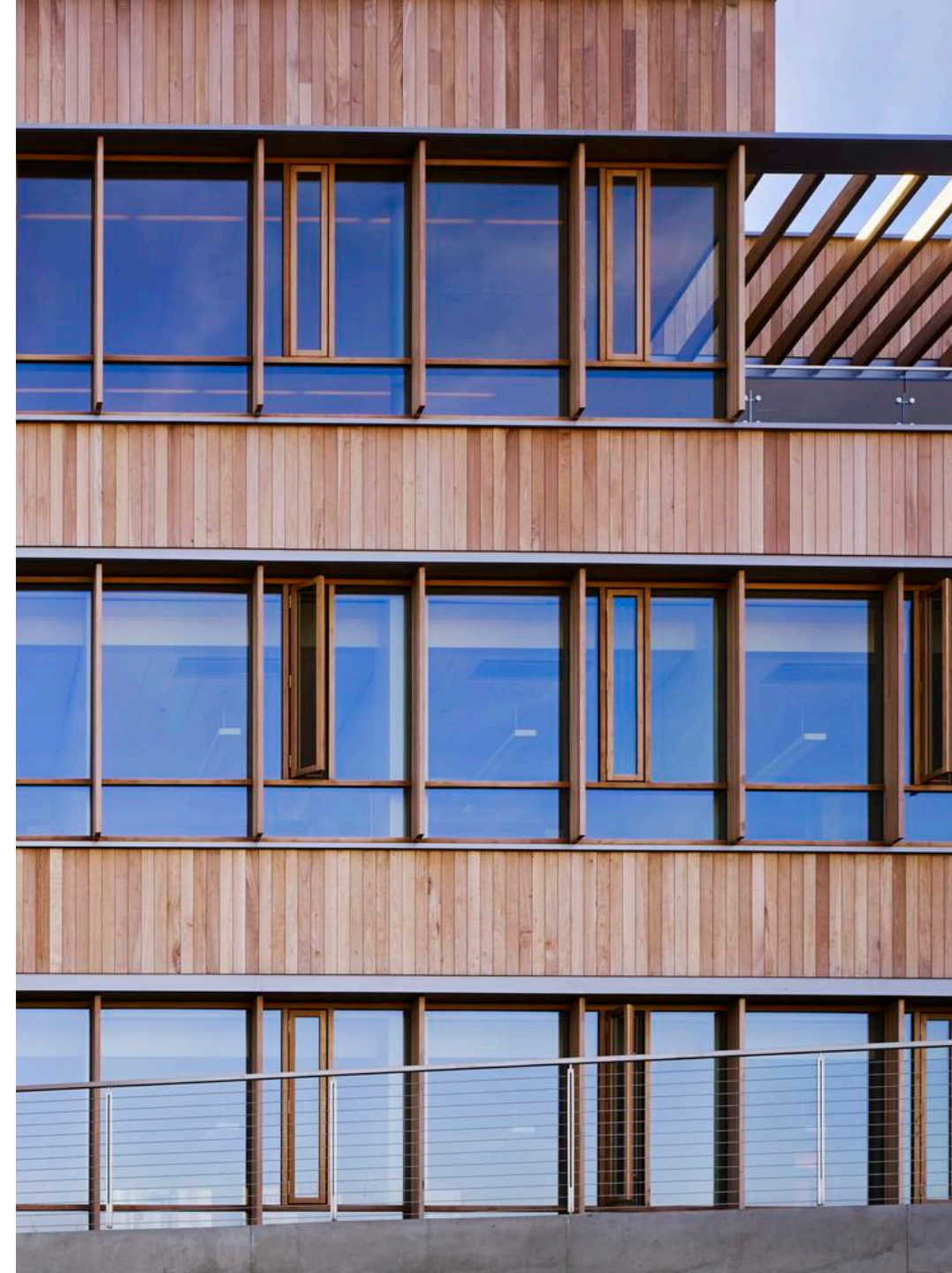
"You must give respect to get respect."

"Be the change that you wish  
to see in the world."  
- Gandhi

"You should always have hope."



passive survivability







**QUESTIONS**

# Architectural Considerations For Flood Protection



**Savannah Trims Inc**  
[\(561\) 656-2556](tel:(561)656-2556)  
[Savannahtrims.com](http://Savannahtrims.com)



# Why Flood Protection is Important

Being educated on flood control solutions can facilitate getting your Building Certificate of Occupancy and Permits and Protection of Property and increase the range your practice



# Flood Terminology

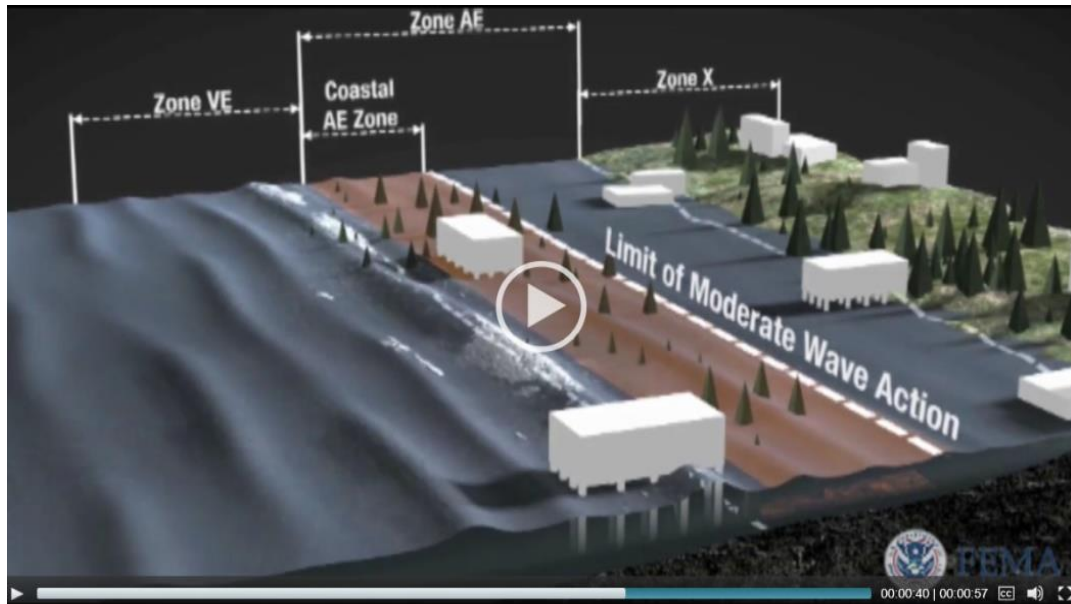
## Common Abbreviations

<b>BFE</b> – Base Flood Elevation	(Set by flood map)
<b>FF</b> – Finish Floor Elevation	(Set by Building Designer)
<b>FB</b> – Free Board Height	(Set by local code, minimum of 1 ft)
<b>DFE</b> – Design Flood Elevation	(BFE + FB)
<b>FPE</b> – Flood Protection Elevation	([BFE + FB] – FF) or (DFE – FF)

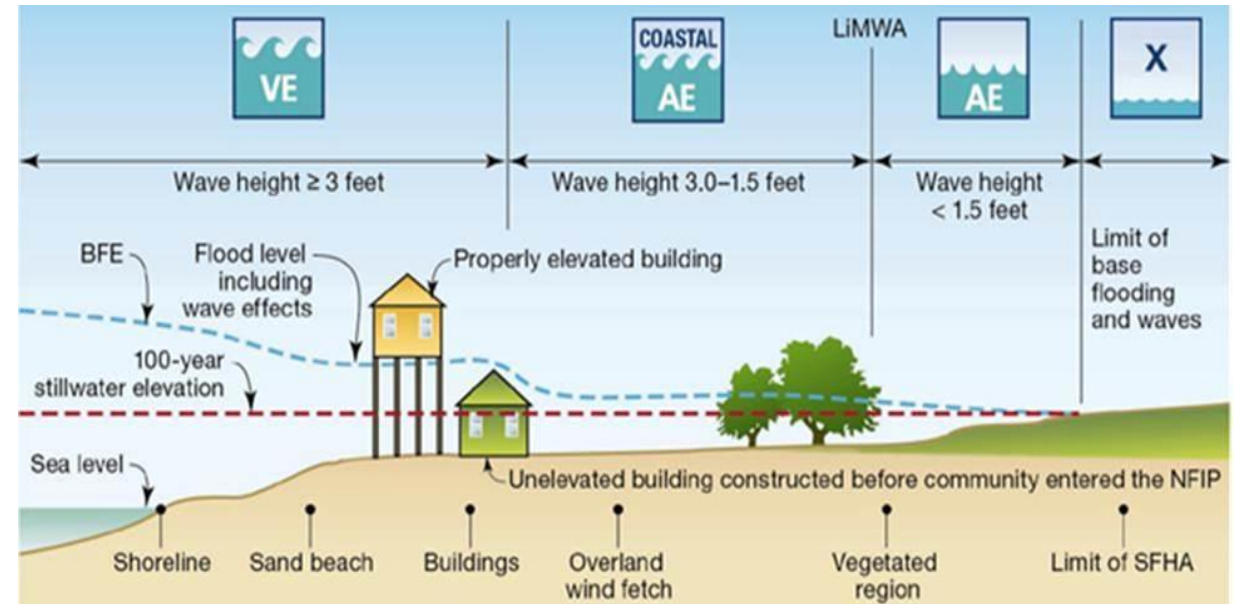
## Structural Considerations

- hydrostatic flood force
- buoyancy force
- hydrodynamic force
- debris impact force

<https://www.fema.gov/media-library/assets/videos/82399>

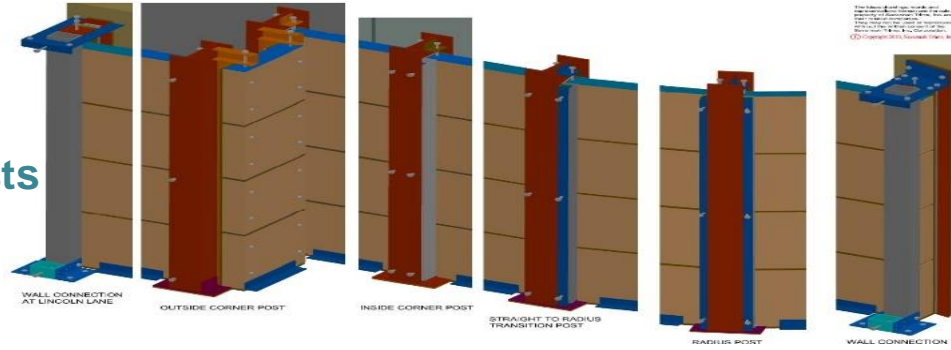


<https://www.fema.gov/media-library/assets/videos/83209>



# Removable Flood Barriers Types

Planks & Posts



## Considerations:

- Foundations/Footers
- Egress
- Mounting Points
- Smooth Level Impermeable Surfaces

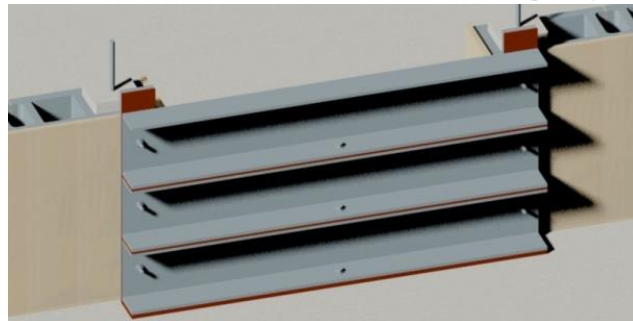
Side by Side Panels with Kickers



Side by Side Panels with Posts



Stacking Systems (Logs)



Engineered for Each Application



# Removable Protection Considerations

## Aluminum flood panels

- Rubber gaskets affect the seal at opening
- Success = Flat, paper smooth building surface + building contractor vigilance

All Removable Barriers cannot be installed onto brick cavity walls without careful design & detailing

## Face Brick Buildings

- Care must be taken not to crack brick
- Bricks must be bonded to structure (no-air space, or air space filled with structure)
- Bricks must be smooth faced
- Permanent plates may be needed



# Removable, Aluminum Flood Panels

## Overview

- Medium and high-water window/door opening protection
- Rubber gaskets at seal of opening perimeter
- Stored nearby
- Additional bracing with vertical posts or diagonal braces

## Advantages

- Lightweight
- Small tools for installation
- Kickers for water resistance
- Lowest price

## Disadvantages

- Takes time to deploy + install
- Storage space needed
- Inspection + maintenance
- Cannot be set on pavers
- Paper smooth surfaces for installation
- Parts can be lost overtime



# Stacking Systems

## Overview

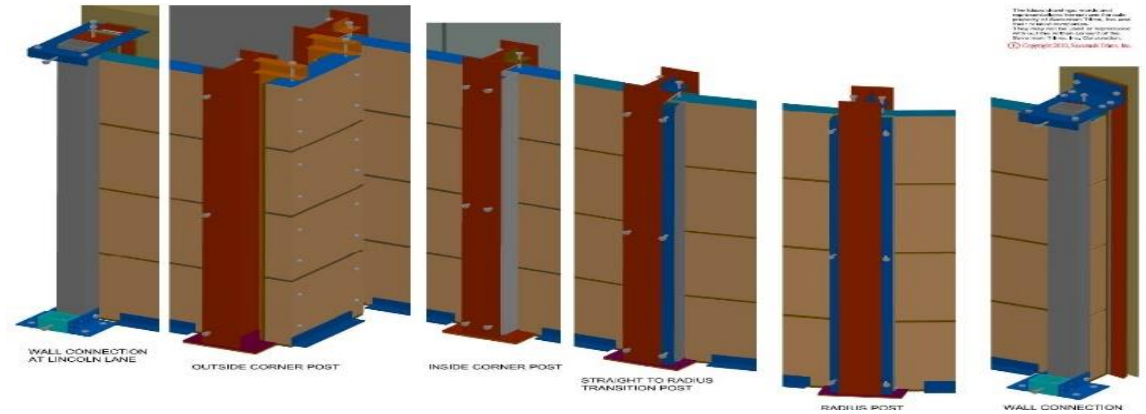
- Used on large open areas
- Small, lightweight components

## Advantages

- Lightest weight
- Easy storage + deployment
- Simple install
- Less time consuming deployment/installation

## Disadvantages

- More expensive than side by side
- Needs inspection and maintenance
- Cannot be set on pavers
- Paper smooth surfaces for installation





← Gran Paraiso Miami Beach

Apple Miami Beach FL →



Raleigh Police Equestrian Barn →

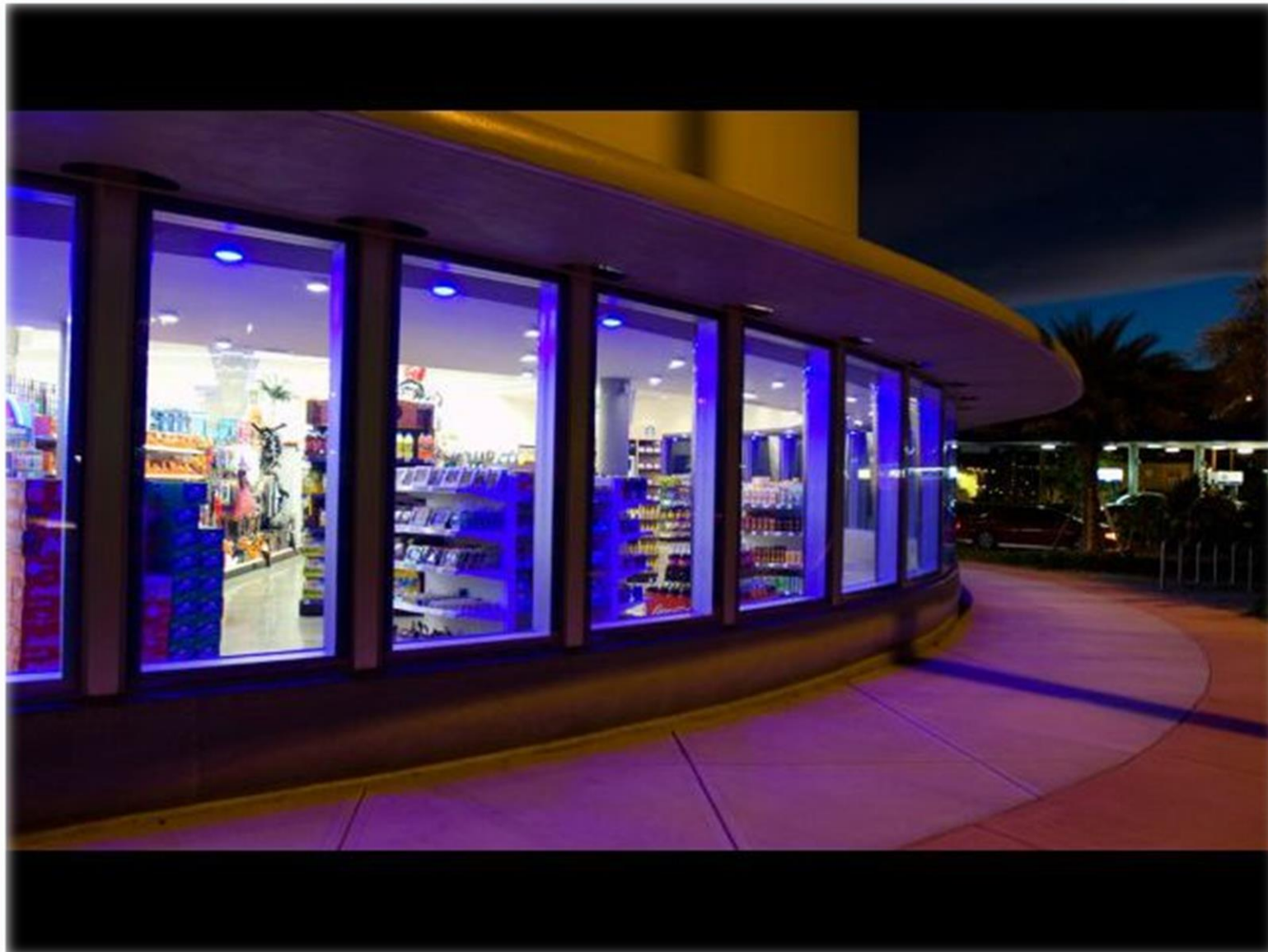


← NIKE Flagship Store Miami Beach

Quonset State Airport, Rhode Island →



# Flood Glass Systems



# In Place Glass Storefront Flood Protection

## A Passive Solution

Hybrid laminated glass product using site-specific engineering to confirm compliance

Door openings may still use the removable aluminum panels or Flood Resistant Doors may be used

## Considerations:

- Glass Thickness
- Glass Size
- Mullion Spacing / Size / Reinforcing
- Wetted Area
- Structural Supports (Header, Sill, Jambs)



← Installation of flood-rated glass  
this glass meets BFE of 54 inches/

# Flood Doors

Offer utility and great aesthetics

Frequently used when practical

Hybrid laminated technology



# Flood Door Types



**Hollow Metal**



**Aluminum Store Front**



**High Performance**

Connecticut Edison Electric NJ



**Sliding**



**Testing**



**Vault**

# Permanent In-Place Moving Panels + Gates

## Overview

- Large panels needing heavy construction and reinforcement are always ready to be swung closed and protect the openings
- Suited for high-water protection needs

## Advantages

- Excellent in front of entryways, driveways, warehouse/factory openings
- Simple usage and installation procedures
- Maintenance required

## Disadvantages

- Appearance
- Occupy space

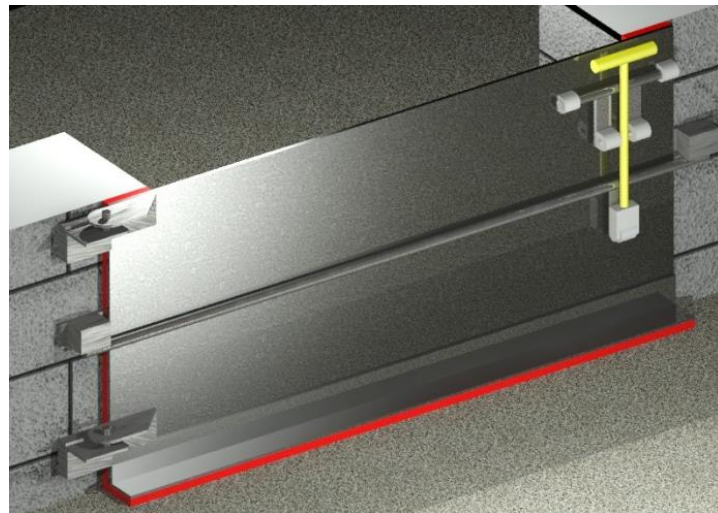


# Permanent In-Place Panels + Gates



## Sliding

Satala Power Plant  
Tsunami Hardening,  
American Samoa



## Hinged

Custom Chemicals  
Flood Gate,  
Greensborough,  
N.C.



## Lift-Out



## Drop-Down

# Automatic In-Ground Flood Barriers

**Excellent for large openings w/ patented deployment technique**

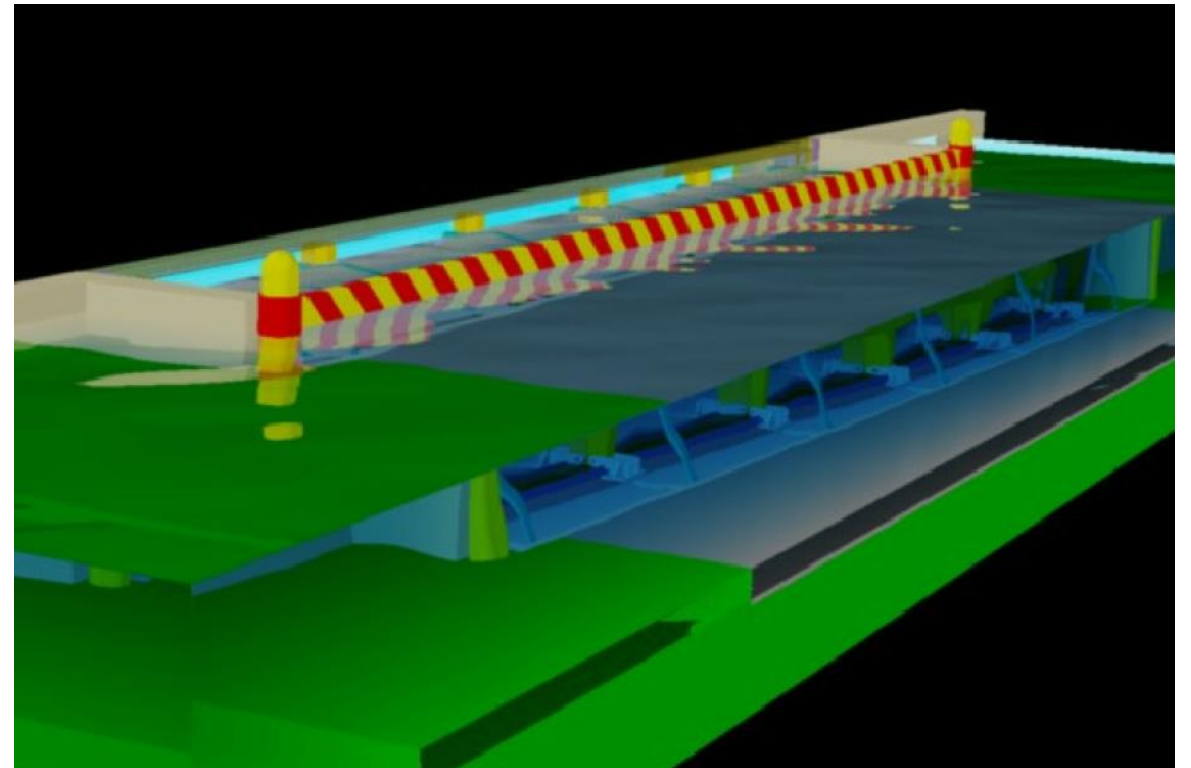
- Driveways
- Parking deck openings
- Roadways (Installed alongside berms or wall openings)

## Advantages

- Easily solves obvious problems
- No electrical requirements
- Self-operated

## Disadvantages

- Poor operation in icy conditions
- High initial expense



# Cost Factors

Most manufacturers evaluate applications and provide budget estimates

## **Most Expensive**

- In-ground automatic barriers
- In-place barriers

## **Least Expensive**

- Removable flood barriers (lower upfront cost)
- Glass store front barriers (passive)



# Flood Glass Vs. Flood Barriers

## Flood Barriers

- **Must Be Deployed** – possibility of no personnel, no time
- **Theft** – one missing part = system is not effective
- **Storage Required** – occupies valuable retail / etc. footage
- **Personnel** – training, certifications, yearly deployment, stoppages
- **Initial Cost** – footing labor & install + flood barrier + storefront
- **Long Term Cost** – maintenance storage, yearly training, deployment

## Flood Glass

**No: Install, Theft, Storage, Personnel**

### Initial Cost

- Higher initial cost of storefront
- Only glass within the DFE needs to be flood glass

### Long Term Cost

- **NONE**

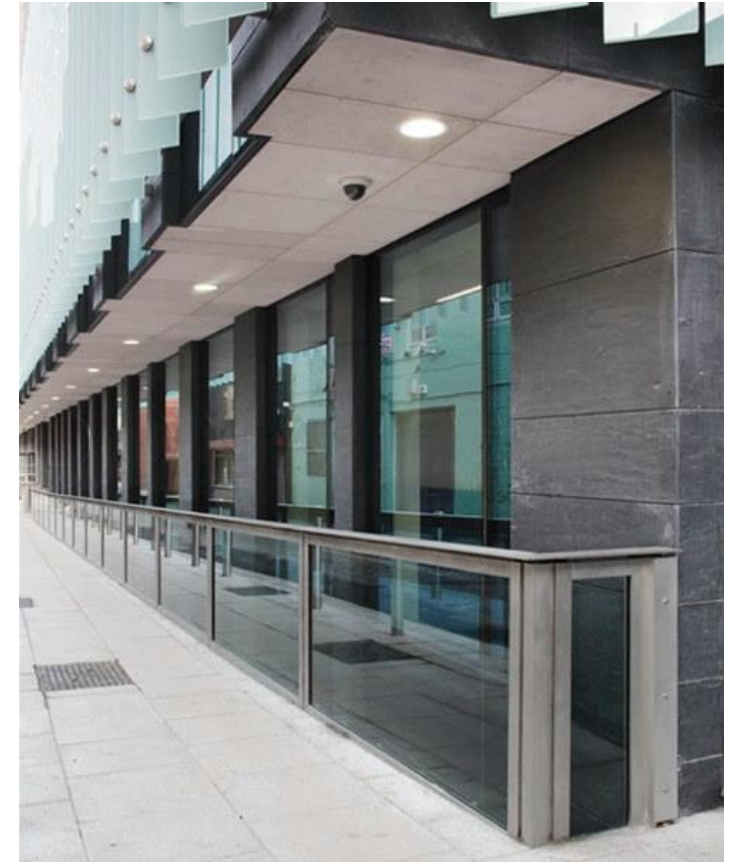
# Engineered Glass Railings for Flood Protection

Railing immediately after installation when the posts, set in concrete are curing

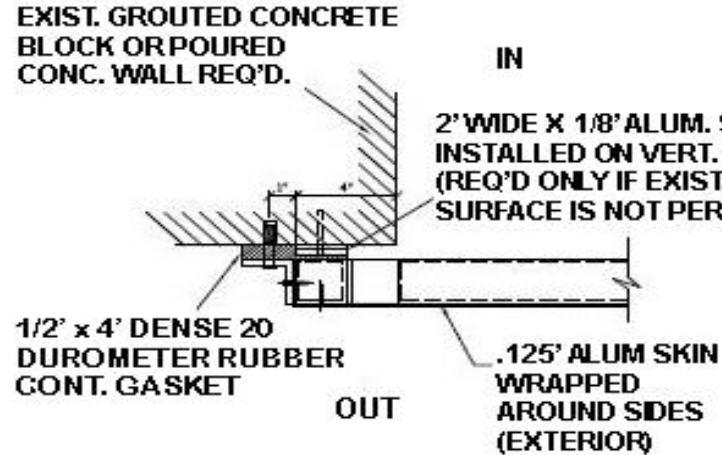


**Riggs  
Residence  
Dallas, TX**

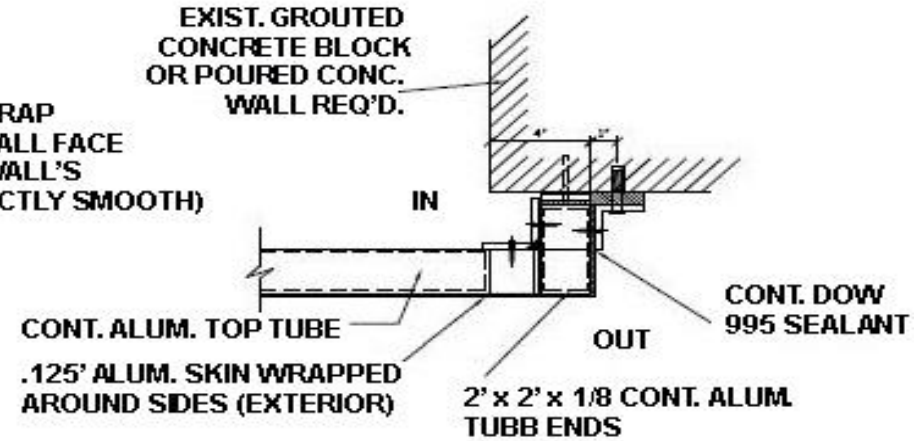
Urban application protecting a building and windows



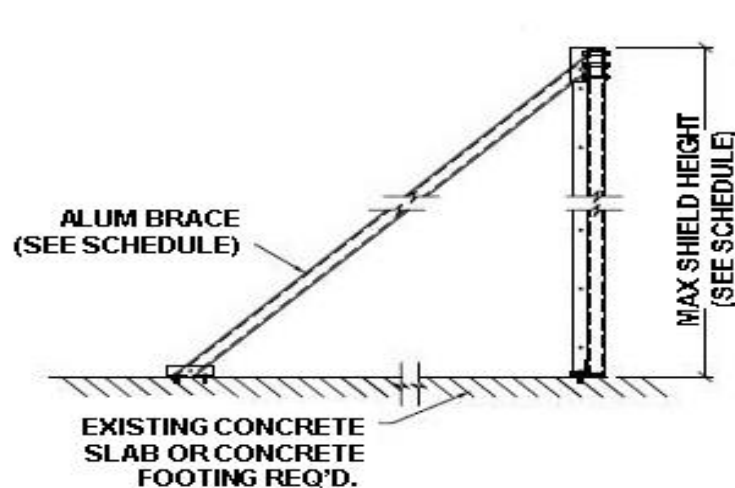
# Sample Flood Barrier Details



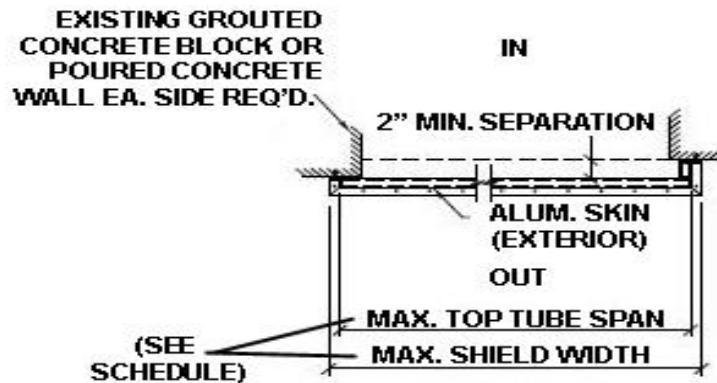
STANDARD JAMB DETAIL (NOT TO SCALE)



OFFSET JAMB DETAIL



TYPICAL BRACE WHEN REQUIRED (NOT TO SCALE)



PLAN VIEW

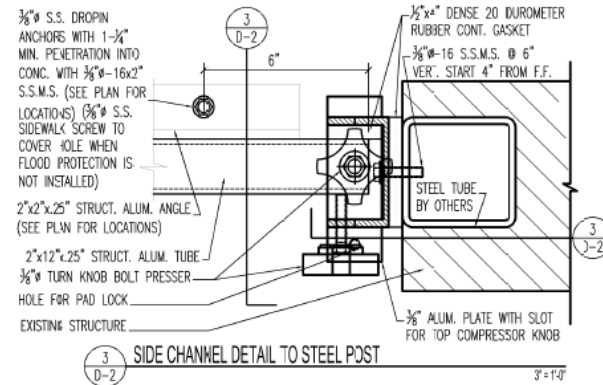
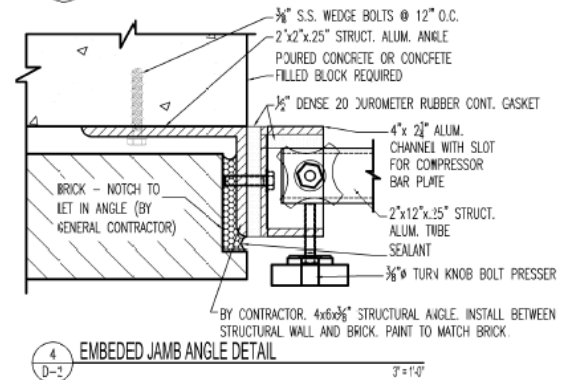
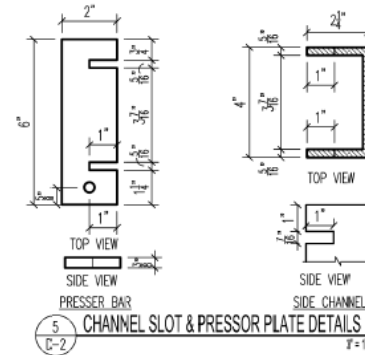
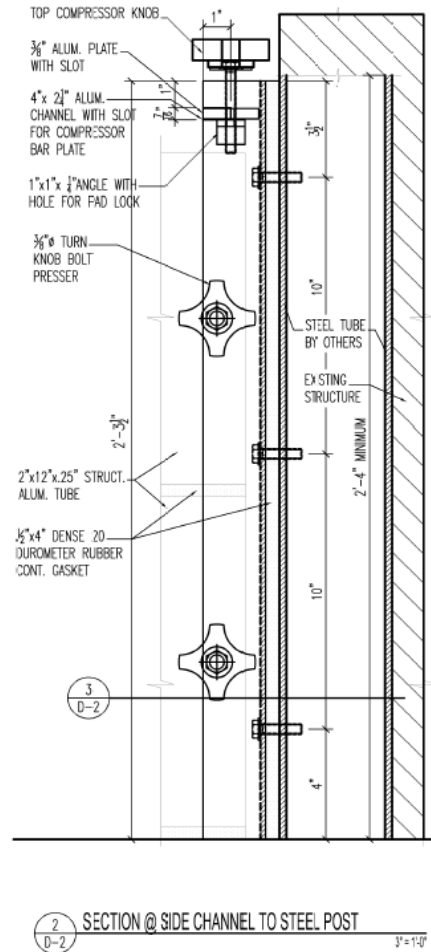
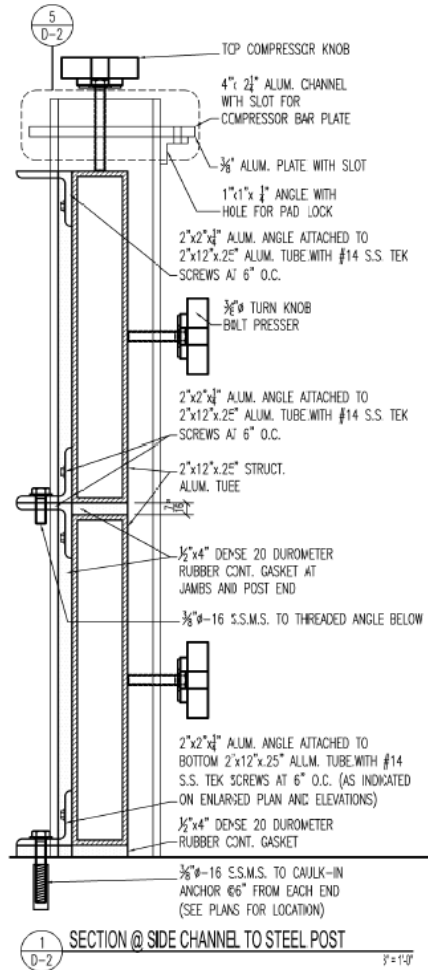
# Sample Flood Barrier Details

THIS DRAWING BEING SUBMITTED FOR REVIEW AND APPROVAL. REVIEWED AND APPROVED WITH NO CHANGES. REVIEWED AND APPROVED AS NOTED.

FABRICATION WILL NOT BEGIN UNTIL CONTRACTOR GUARANTEES ALL DIMENSIONS. "IN WRITING" TO DELAY DIMENSIONS WILL DELAY DELIVERY.

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SIGNED \_\_\_\_\_ DATE \_\_\_\_\_



# Sample Flood Barrier Details

CEI ENGINEERING SERVICES, INC. CA#30935  
 CONSTANTIN BORTES FL PE#77915  
 200 NE 12 AVENUE, SUITE 600  
 HALLANDALE BEACH, FL 33009  
 PHONE: 304-324-1612

ENGINEER'S SEAL

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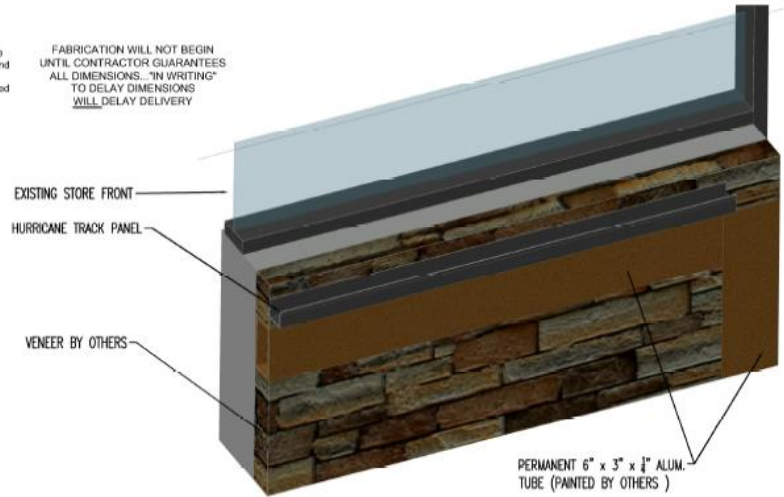
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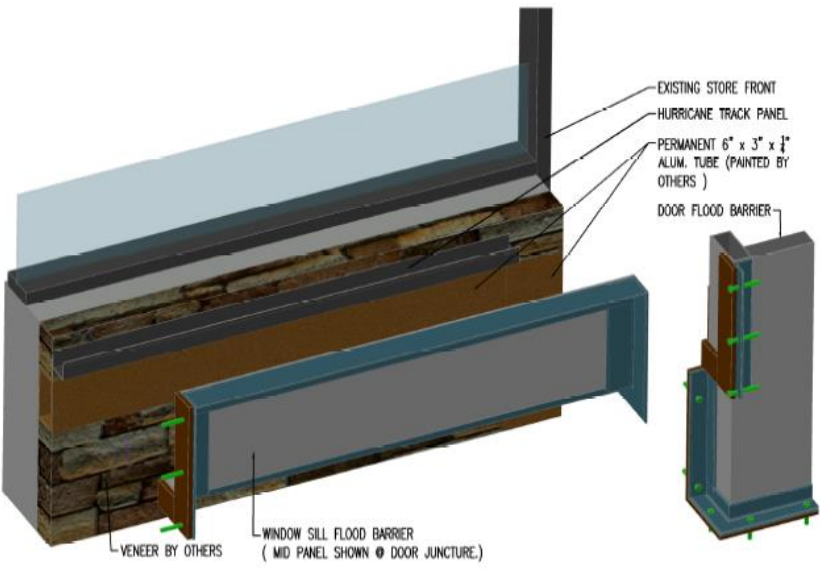
**FOR PRODUCTION**  
**11-20-2018**



WALL @ DOOR WITH PERMANENT EMBD TUBE ( BARRIER NOT INSTALLED )

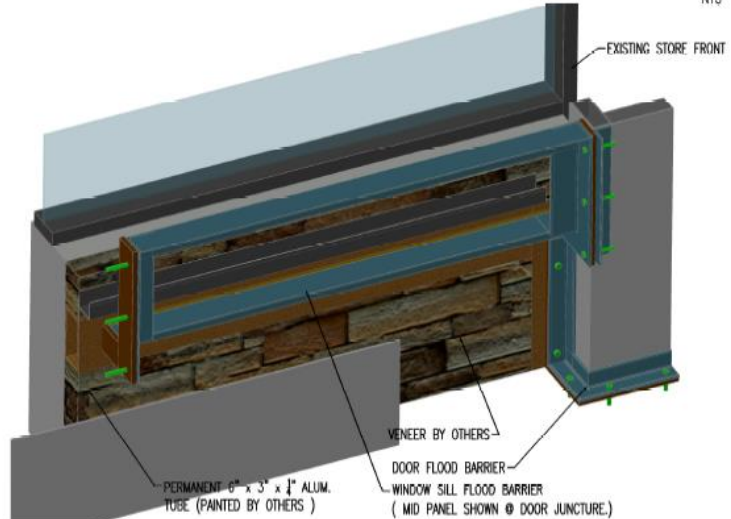
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## BARRIER ASSEMBLY AT CMU WALL WITH STONE VENEER FINISH



WALL @ DOOR WITH PERMANENT EMBD TUBE ( BARRIER NOT INSTALLED )

1/17/20



WALL @ DOOR ( BARRIER INSTALLED )

1/17/20

# Sample Flood Barrier Details

CE ENGINEERING SERVICES, INC. CA#200320  
 CONSTANTIN BORTES, FL PE#77915  
 200 NE 12 AVENUE, UNIT 60,  
 HALLANDALE BEACH, FL 33009  
 PHONE: 954-354-1612

ENGINEER'S SEAL

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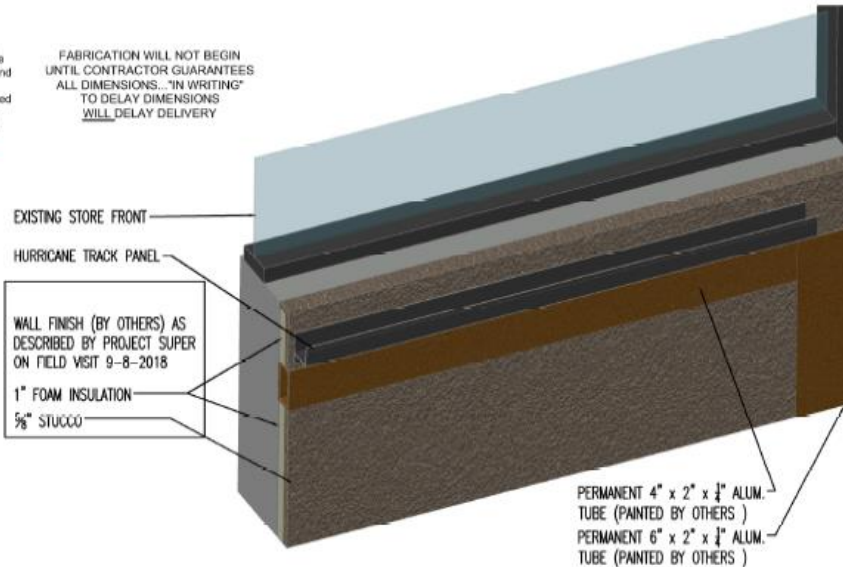
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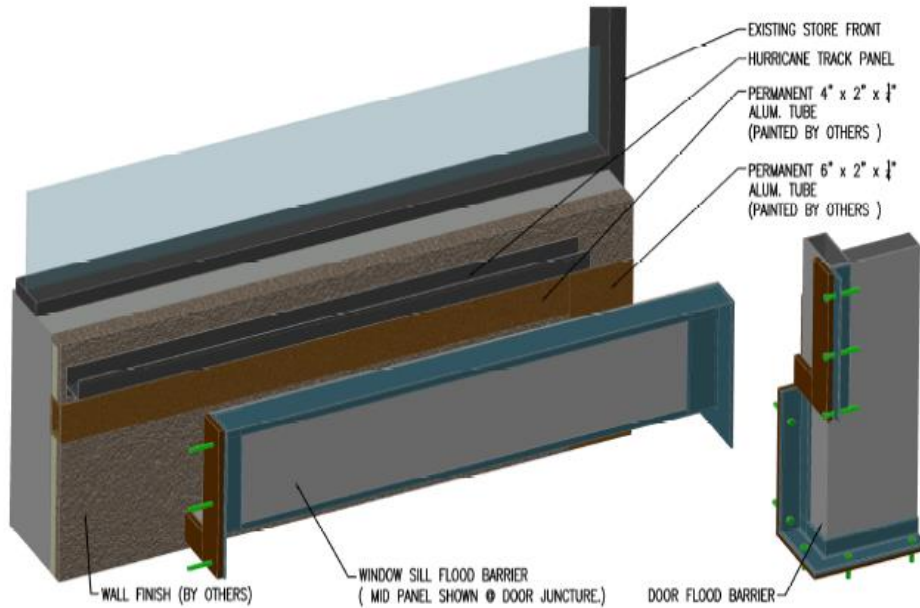
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BARRIER ASSEMBLY AT CMU WALL WITH FOAM AND STUCCO FINISH

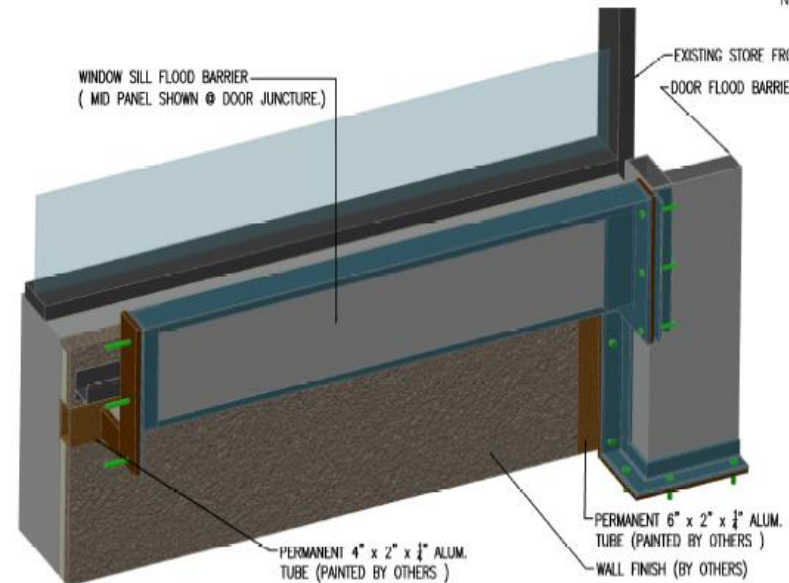
WALL @ DOOR WITH PERMANENT EMBD TUBE ( BARRIER NOT INSTALLED )

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WALL @ DOOR WITH PERMANENT EMBD TUBE ( BARRIER NOT INSTALLED )

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WALL @ DOOR ( BARRIER INSTALLED )

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# Questions?



# TEXAS FLOOD

Flood-Resistant Structures for Enhanced Resilience



## SPEAKERS



**Erik Verboon**

*Principal, Structures Group  
Walter P Moore*



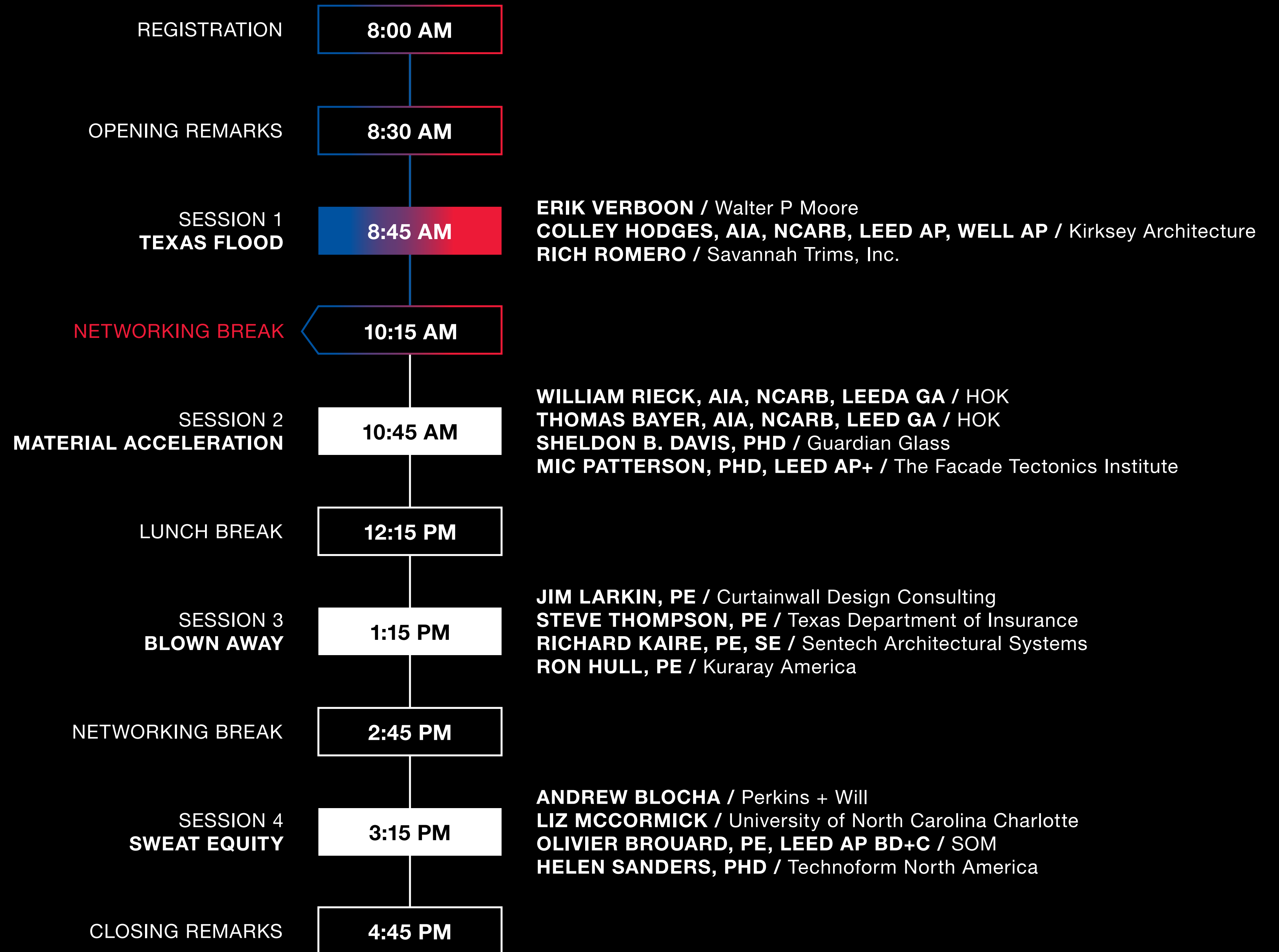
**Colley Hodges, AIA, NCARB,  
LEED AP, WELL AP**

*Senior Associate, Director of  
Sustainability  
Kirksey Architecture*



**Rich Romero**

*Vice President  
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