ASCE 7-22 Supplement Overview of proposed revisions to Chapter 5 Flood Load

Flood Load Subcommittee

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Question/comments to dan.cox@oregonstate.edu

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Who is impacted by Flood Hazards?

Table 1: Population Living in the Floodplain, 2011-2015

	Total	Share of U.S. Population
100-year floodplain	15,000,304	5%
Combined floodplain	30,239,796	10%
U.S.	316,515,021	100%

Sources: American Community Survey, U.S. Federal Emergency Management Agency, NYU Furman Center

❖ Approximately 10% of the US population lives within 500-year floodplain

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Who is impacted by Flood Hazards?

Coastal shoreline counties bordering the ocean or contain FEMA coastal **high hazard area**, 2011

Establishments:	3,736,206
Employment:	5.7 Million
Wages:	$2.8 Trillion
GDP:	$6.6 Trillion

❖ High economic value in US coastal high hazard area

Source: stateofthecoast.noaa.gov

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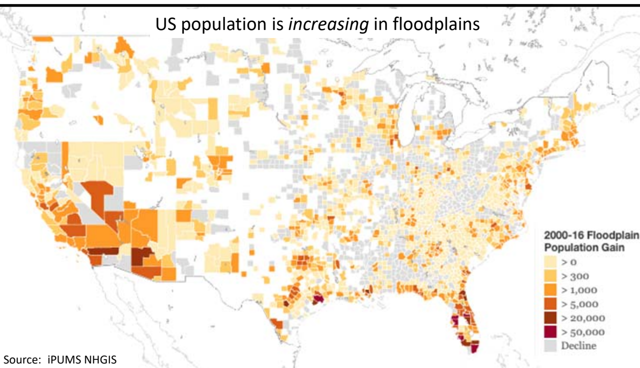
US population is *increasing* in floodplains



Source: iPUMS NHGIS

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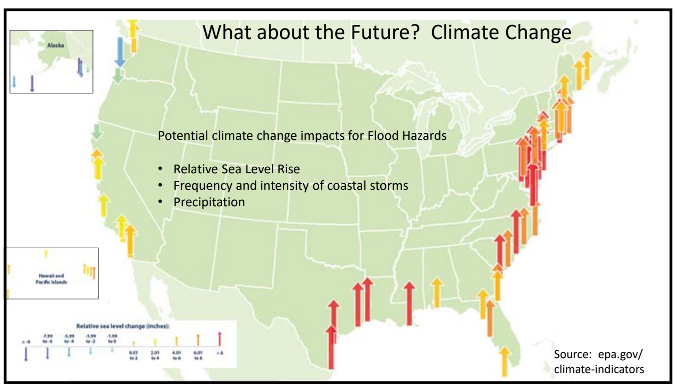
What about the Future? Climate Change



Potential climate change impacts for Flood Hazards

- Relative Sea Level Rise
- Frequency and intensity of coastal storms
- Precipitation

Source: epa.gov/ climate-indicators

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Examples of local flood requirements more restrictive than ASCE 7 or ASCE 24

- Boston, Massachusetts – Boston Zoning Code Coastal Flood Resilience Overlay District
  - o Adopts a regulatory flood map (fully independent from FEMA FIRMs) based on a 100-yr coastal flood with 3.4 ft of relative sea level rise.
- Newburyport, Massachusetts – Wetlands Protection Regulations
  - o Requires projects in FEMA SFHAs to incorporate 40 in. of sea level rise in the project design and construction
- Houston, Texas – Code of Ordinances
  - o Defines the "Minimum Flood Protection Elevation" as the 500-yr flood elevation plus 2 ft of freeboard
  - o Extends the regulated flood zone into shaded X Zones (500-yr floodplain)
- Vashon and Maury Islands, Washington – King County Zoning Code Sea Level Rise Risk Area
  - o Enlarges coastal high hazard areas by extending landward to all areas below the FEMA BFE + 3 ft
  - o Defines the "Sea Level Rise Protection Elevation" as the FEMA BFE + 3 ft

❖ Enlarging the floodplain area

❖ Increasing to 500-year flood, including sea level rise

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Existing
(ASCE 7-22)

5.1 General
5.2 Definitions
5.3 Design Requirements
- 5.3.1 Design Loads
- 5.3.2 Erosion and Scour
- 5.3.3 Loads on Breakaway Walls

5.4 Loads During Flooding
- 5.4.1 Load Basis
- 5.4.2 Hydrostatic Loads
- 5.4.3 Hydrodynamic Loads
- 5.4.4 Wave Loads
  - 5.4.4.1 Breaking Wave Loads on Vertical Piles or Columns
  - 5.4.4.2 Breaking Wave Loads on Vertical Walls
  - 5.4.4.3 Breaking Wave Loads on Non-Vertical Walls
  - 5.4.4.4 Breaking Wave Loads from Obliquely Incident Waves
  - 5.4.4.5 Impact Loads

5.5 Consensus Standards and Other Affiliated Criteria

Proposed
(ASCE 7-22 Supplement)

5.1 **General**
5.2 **Definitions** and Symbols
- 5.2.1 Definitions
- 5.2.2 Symbols

5.3 Design Requirements
- 5.3.1 Flood Hazard Area
- 5.3.2 Design Loads
- 5.3.3 Design Stillwater Flood Depth
  - 5.3.3.1 Stillwater Elevation Determination When Data Not Available Beyond the 100-year Flood
- 5.3.4 Effects of Relative Sea Level Change
- 5.3.5 Erosion
- 5.3.6 Flood Velocity
  - 5.3.6.1 Flood Velocity in Coastal Areas
  - 5.3.6.2 Flood Velocity in Riverine Areas
- 5.3.7 Wave Effects
  - 5.3.7.1 Wave Height
  - 5.3.7.2 Wave Period and Wavelength
- 5.3.8 Scour
  - 5.3.8.1 Scour at Walls
    - 5.3.8.1.1. Scour at Walls Due to Nonbreaking Waves
    - 5.3.8.1.2. Scour at Walls Due to Breaking Waves
  - 5.3.8.2 Scour at Vertical Piles and Columns
- 5.3.9 Debris
  - 5.3.9.1 Debris Impact
    - 5.3.9.1.1. Debris Impact Objects
    - 5.3.9.1.2. Site Hazard Assessment for Localized Marine Debris. Shipping Containers, Ships, Small Vessels, and Barges
    - 5.3.9.1.3. Extraordinary Debris Impact Loading
  - 5.3.9.2 Debris Damming
- 5.3.10 Loads on Breakaway Walls
- 5.3.11 Site-Specific Studies
- 5.3.12 Performance Based Design

5.4 Loads During Flooding
- 5.4.1 Load Basis
- 5.4.2 Hydrostatic Loads
  - 5.4.2.1 Vertical Hydrostatic Force
  - 5.4.2.2 Lateral Hydrostatic Force
  - 5.4.2.3 Seepage
- 5.4.3 Hydrodynamic Loads
- 5.4.4 Wave Loads
  - 5.4.4.1 Wave Loads on Vertical Piles or Columns
    - 5.4.4.1.1. Non-breaking Wave Loads on Vertical Piles or Columns
    - 5.4.4.1.2. Breaking Wave Loads on Vertical Piles or Columns
  - 5.4.4.2 Lateral Wave Loads on Walls
    - 5.4.4.2.1. Lateral Non-Breaking Wave Loads on Non-elevated Vertical Walls
    - 5.4.4.2.2. Lateral Breaking Wave Loads on Non-elevated Vertical Walls
    - 5.4.4.2.3. Lateral Breaking Wave Loads on Non-Vertical Walls
    - 5.4.4.2.4. Lateral Breaking Wave Loads from Obliquely Incident Waves
    - 5.4.4.2.5. Lateral Wave Loads on Walls of Elevated Walls
  - 5.4.4.3 Wave Uplift Forces on Elevated Structures and Non-Elevated Structures with Overhangs
- 5.4.5 Debris Impact Loads
  - 5.4.5.1 Debris Impact Load Determination
    - 5.4.5.1.1. Simplified Debris Impact Load for Passenger Vehicles or Small Vessels
    - 5.4.5.1.2. Elastic Debris Impact Loads
    - 5.4.5.1.3. Alternate Methods of Debris Impact Analysis
  - 5.4.5.2 Debris Types and Properties
  - 5.4.5.3 Extraordinary Debris Impact
  - 5.4.5.4 Debris Impact Load Redistribution

5.5 Flood Load Cases
- 5.5.1 Stability for Global Uplift
- 5.5.2 Stability for Global Sliding

5.6 **Consensus Standards and Other Affiliated Criteria**

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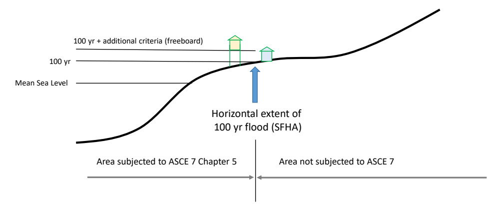
What would Chapter 5 revisions accomplish?

- Increase the flood hazard area from 100-year to 500-year for all RC II, III, and IV structures

Existing problem: "Waterfall effect"



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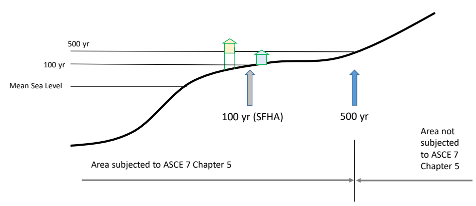
- Increase the flood hazard area from 100-year to 500-year for all RC II, III, and IV structures

Eliminate waterfall for most structures



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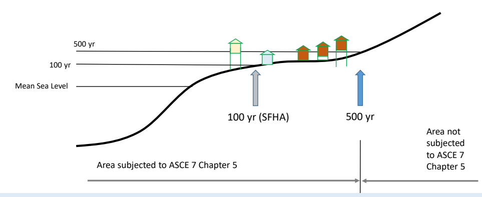

Note: ASCE 7 Chapter 5 does not prescribe elevation requirements for structures. ASCE 24 does that.

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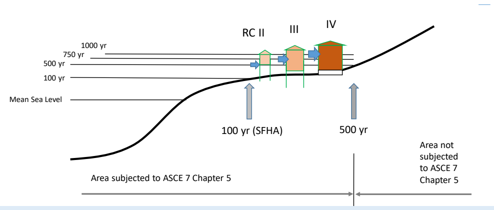
What would Chapter 5 revisions accomplish?

- Incorporate a risk-based approach where flood hazard is tied to structure risk category
  RC I 100-year RC II 500-year RC III 750-year RC IV 1000-year



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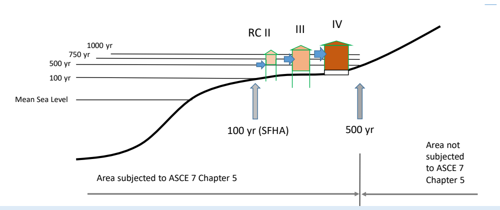

Design flood hazard increases and therefore loads may increase with risk category of structure.

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What would Chapter 5 revisions accomplish?

Revisions provide requirements and guidance for Hazards, Loads, Load Cases, Reliability Analysis

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What would Chapter 5 revisions accomplish?

Revisions provide requirements and guidance for Hazards, Loads, Load Cases, Reliability Analysis

- Hazard
  - Flood depth,
  - Flood velocity,
  - Wave conditions,
  - Scour depth,
  - Debris hazards

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Revisions provide requirements and guidance for Hazards, Loads, Load Cases, Reliability Analysis

- Hazard
  - Flood depth,
  - Flood velocity,
  - Wave conditions,
  - Scour depth,
  - Debris hazards
- Load
  - Hydrostatic,
  - Hydrodynamic,
  - Wave forces,
  - Debris impact

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  - Flood depth,
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- Load Cases
  - Combinations of loads
  - Stability check

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Revisions provide requirements and guidance for Hazards, Loads, Load Cases, Reliability Analysis

- Hazard
  - Flood depth,
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  - Hydrostatic,
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- Load Cases
  - Combinations of loads
  - Stability check
- Reliability Analysis
  - Consistency with Chapter 2

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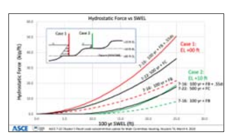
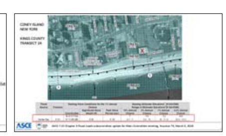
Example calculations by FLSC to compare *existing* standard and *proposed* changes

FLSC presentation to 7-22 Main Committee on 3/2020 in Houston, TX



- ✓ Example comparisons for different use cases
- ✓ Documented changes in load for
  - hydrostatic
  - hydrodynamic



- ✓ Two site-specific locations on Long Island, NY
- ✓ Documented changes in load for
  - hydrostatic,
  - hydrodynamic
  - breaking wave
  - debris impact

- ✓ Three site-specific location in Manhattan, NY
- ✓ Documented changed in load for
  - hydrostatic,
  - hydrodynamic
  - debris impact

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Ongoing work by FLSC

Prepare manuscripts for peer-review
- ✓ Summary of changes with examples
- ✓ MRI coefficients/Reliability analysis
- ✓ Received ‘ok’ from *JSE* editor

- Development of ASCE Guidance Document
- Coordinate with changes at FEMA
- Coordinate with ongoing efforts at NOAA for climate change

- ✓ Contribute to ASCE 7 reliability analysis document led by LCSC
- ✓ Contribute to SEI CSAD Climate Change Initiative
- ✓ Contribute to revision of ASCE 24 for IBC 2027
- ✓ Consider additional Chapter 5 revisions for ASCE 7-28 cycle

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Hazard
- o Flood depth,
- o Flood velocity,
- o Wave conditions,
- o Scour depth,
- o Debris hazards

Load
- o Hydrostatic,
- o Hydrodynamic,
- o Wave forces,
- o Debris impact

Load Cases
- o Combinations of loads
- o Stability check

Reliability Analysis
- o Consistency with Chapter 2

Flood hazard area

5.3 DESIGN REQUIREMENTS

5.3.1 Flood Hazard Area.

For Risk Category II, III, and IV structures, the Flood Hazard Area shall be the 500-year floodplain designated as the Special Flood Hazard Area and the Shaded X-Zone. For Risk Category I structures, the Flood Hazard Area shall be the 100-year floodplain designated as the Special Flood Hazard Area.

Intention to extend the design requirements out to the 500-year floodplain for RC II, III, and IV structures

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Hazard
- o Flood depth,
- o Flood velocity,
- o Wave conditions,
- o Scour depth,
- o Debris hazards

Load
- o Hydrostatic,
- o Hydrodynamic,
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- o Debris impact

Load Cases
- o Combinations of loads
- o Stability check

Reliability Analysis
- o Consistency with Chapter 2

Flood hazard area

5.3.3 Design Stillwater Flood Depth.

The design stillwater flood depth, d_f, in ft (m) shall be determined in accordance with Equation 5.3-1:

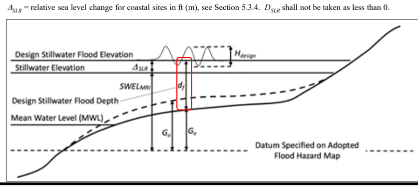
$$d_f = (SWEL_{MRI} - G_e) + \Delta_{SLR} \qquad (5.3\text{-}1)$$

where

$SWEL_{MRI}$ = stillwater elevation corresponding to the risk category and MRI defined in Table 5.3-1 provided by a flood hazard study adopted by the Authority Having Jurisdiction in ft (m). Where the stillwater elevation for a given MRI is not provided in the flood hazard study, the 100-year stillwater elevation shall be scaled to the required MRI per Section 5.3.3.1.

G_e = elevation of grade at the building or other structure inclusive of effects of erosion in ft (m), per Section 5.3.5.

Δ_{SLR} = relative sea level change for coastal sites in ft (m), see Section 5.3.4. D_{SLR} shall not be taken as less than 0.



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Hazard
- o Flood depth,
- o Flood velocity,
- o Wave conditions,
- o Scour depth,
- o Debris hazards

Load
- o Hydrostatic,
- o Hydrodynamic,
- o Wave forces,
- o Debris impact

Load Cases
- o Combinations of loads
- o Stability check

Reliability Analysis
- o Consistency with Chapter 2

Flood hazard area

5.3.3.1 Stillwater Elevation Determination When MRI Data Not Available.

Where MRI data is not available, $SWEL_{MRI}$ shall be determined according to Equation 5.3-2

$$SWEL_{MRI} = C_{MRI}\,(SWEL_{100} - Z_{datum}) + Z_{datum} \qquad (5.3\text{-}2)$$

where

$SWEL_{100}$ = stillwater elevation for the 100-year MRI provided by a flood hazard study adopted by the Authority Having Jurisdiction in ft (m).

C_{MRI} = flood scale factor associated with the MRI from Table 5.3-1 for different locations.

Z_{datum} = elevation of mean water level based on local datum, in ft (m). For riverine sites, Z_{datum} shall be taken as the annual high-water level. Z_{datum} shall be permitted to be taken as zero for coastal sites. Values for $SWEL_{100}$, $SWEL_{MRI}$, and G_e shall all reference the same local datum.

Risk Category	MRI (year)	Annual Exceedance Probability (AEP)	C_{MRI} Gulf of Mexico Coastal Sites[1]	C_{MRI} All Other Coastal Sites[1]	C_{MRI} Great Lakes Sites[2]	C_{MRI} Riverine Sites
I	100	1.00%	1.00	1.00	1.00	1.00
II	500	0.20%	1.35	1.25	1.15	1.35
III	750	0.13%	1.45	1.35	1.20	1.45
IV	1,000	0.10%	1.50	1.40	1.25	1.50

Intention is to use modern flood information as it becomes available.

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Hazard
- o Flood depth,
- o Flood velocity,
- o Wave conditions,
- o Scour depth,
- o Debris hazards

Load
- o Hydrostatic,
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- o Debris impact

Load Cases
- o Combinations of loads
- o Stability check

Reliability Analysis
- o Consistency with Chapter 2

Requirement to consider Sea Level Rise based on historic rates

5.3.4 Effects of Relative Sea Level Change.

The effects of relative sea level change shall be included in the calculation of flood conditions and flood loads for sites whose flooding comes from coastal sources. A project lifecycle of not less than 50 years shall be used for this quantification. The minimum rate of relative sea level change shall be the historically recorded sea level change rate for the site over a 50-year period. The increase in relative sea level during the project lifecycle of the structure shall be added to the design stillwater flood elevation as required by Section 5.3.3.

Historic rate does not include climate projections

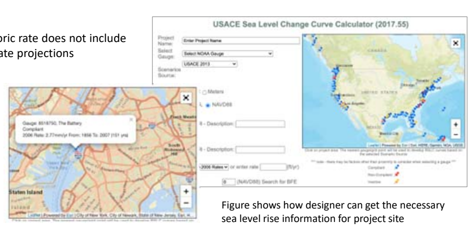

Figure shows how designer can get the necessary sea level rise information for project site

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Hazard
- o Flood depth,
- o Flood velocity,
- o Wave conditions,
- o Scour depth,
- o Debris hazards

Load
- o Hydrostatic,
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- o Debris impact

Load Cases
- o Combinations of loads
- o Stability check

Reliability Analysis
- o Consistency with Chapter 2

Commentary language to bridge between existing practice and proposed changes

In ASCE 7-22 Supplement 3, loads in Chapter 5 are based on the stillwater elevation. In prior editions, flood loads also were based on stillwater elevation, but the Chapter referenced a DFE in some load calculations. ASCE 7-22 Supplement 3 drops the reference to the DFE.

If needed for comparison purposes, the ASCE 7-22 Supplement 3 coastal DFE can be determined in accordance with Equation C5.3-1:

$$DFE = d_f + G_e + 0.7H_{design} \qquad (C5.3\text{-}1)$$

DFE = existing terminology
d_f = proposed terminology

where

H_{design} = design wave height in ft (m) as calculated in Section 5.3.7.1.

G_e = elevation of grade at the building or other structure inclusive of effects of erosion in ft (m), per Section 5.3.5.

d_f = design stillwater flood depth, in ft (m), per section 5.3.3

The ASCE 7-22 Supplement 3 riverine DFE is the same as the Design Stillwater Flood Elevation. The DFE calculated above is not the same DFE that is used for NFIP, ASCE 24, or other model building code purposes. Each DFE should be calculated separately per the applicable Standard for its intended purpose.

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Load
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Load Cases
- o Combinations of loads
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Reliability Analysis
- o Consistency with Chapter 2

Revised method to estimate velocity

- Based on USACE hurricane simulations
- Reduction factor, C = 0.5
- Cap on maximum velocity, Vmax depends on MRI

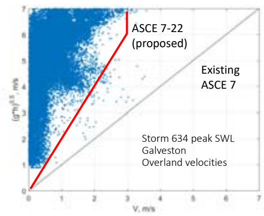

Figure compares existing ASCE 7 method to estimate velocity (black) with new method (red).
Data points are computer simulation by USACE for scenario hurricane impacting Galveston, TX.

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Hazard
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- o Flood velocity,
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Load
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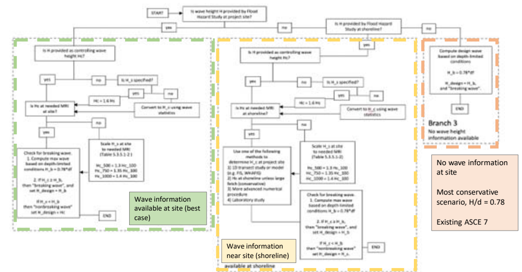
- o Debris impact

Load Cases
- o Combinations of loads
- o Stability check

Reliability Analysis
- o Consistency with Chapter 2

New methods gives designers ability to refine wave height at project site



Intention is to allow designers to improve wave height estimates if this is important to design

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Load
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Load Cases
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Reliability Analysis
- o Consistency with Chapter 2

Commentary for designers to understand how sheltering affects wave height

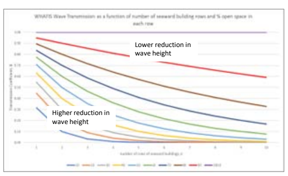

Figure shows how wave heights are decreased from shoreline depending on number of rows from shoreline and building density.

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Reliability Analysis
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Scour Depth

5.3.8.1.1 Scour Due to Nonbreaking Waves.

The maximum scour depth S_m in ft (m) at walls for nonbreaking waves shall be calculated by Eq. (5.3-11)

$$S_m = \frac{0.25 H_{design}}{\left[\sinh\left(\frac{2\pi d_f}{L}\right)\right]^{1.35}} \quad (5.3\text{-}11)$$

where

d_f = design stillwater flood depth as defined in Section 5.3.3

H_{design} = design wave height as defined in Section 5.3.7

L = wavelength in ft (m) as defined in Section 5.3.7

S_m need not be taken greater than S_m as calculated in Section 5.3.8.1.2.

5.3.8.1.2 Scour Due to Breaking Waves.

The maximum scour depth, S_m, in ft (m) at walls for breaking waves shall be calculated by Eq. (5.3-12)

$$S_m = H_{design} \quad (5.3\text{-}12)$$

where

H_{design} = breaking wave height H_b in ft (m) as defined in Section 5.3.7.

5.3.8.2 Scour at Vertical Piles and Columns.

The scour depth, S_m, at the base of a single vertical pile or column inundated at the time of flooding shall be calculated by Eq. (5.3-13). Tightly spaced piles shall be considered to act as a wall per Section 5.3.8.1.

$$S_m = 2.0\,D \quad (5.3\text{-}13)$$

where

D = pile or column diameter, in ft (m) for circular sections, or for a square pile or column, 1.4 times the width of the pile or column in ft (m)

Scour at embedded piles (i.e., buried under pile caps) need only be considered if piles are determined to be exposed, based on scour of walls and pile caps above the piles.

Scour requirement remains the same.

Intention is to provide designers with explicit equations not provided in existing Chapter 5

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Hazard
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- o Flood velocity,
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Load
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Load Cases
- o Combinations of loads
- o Stability check

Reliability Analysis
- o Consistency with Chapter 2

Debris Hazard Considerations

- Bring forward items from Commentary
- Make consistent with Chapter 6 Tsunami
- Limit the 'sphere of influence' overland

Debris Type	Applicable Risk Categories	Threshold Depth (ft)[1]	Impact on Columns, piles, bearing walls and transfer beams	Impact on non-load bearing elements[2]
Wood Poles	RC III/IV	3 ft (0.91 m)	Yes	Yes
Passenger Vehicles	RC II/III/IV	3 ft (0.91 m)	Yes	Yes
Small Vessels	RC II/III/IV	3 ft (0.91 m)	Yes[3]	Yes[3]
Shipping Containers	RC III/IV	3 ft (0.91 m)	Yes[3]	n/a
Ships/barges	RC III/IV	6 ft (1.8 m)	Yes[3]	n/a
Extraordinary Debris	RC IV	12 ft (3.7 m)	Yes[3]	n/a

Table indicates what debris types must be considered based on structure RC

Figure shows how debris hazard is considered based on debris source, open water, and urban environments

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- o Flood velocity,
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Load Cases
- o Combinations of loads
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Reliability Analysis
- o Consistency with Chapter 2

Other improvements in first section

- Loads on Breakaway Walls – in existing standard
  - ✓ Added requirement to resist the lateral earth pressure requirement of Chapter 3
- Site-specific studies
  - ✓ allowed for velocity and wave hazards but not depth
  - ✓ reductions comparable to other chapters

Table 5.3-6 Maximum Allowable Reductions for Site-specific Studies

Hazard	Allowable Reduction with Peer Review	Allowable Reduction without Peer Review
Velocity, V	30%	20%
Wave height, H	30%	20%

- PBD allowable per Section 1.3.1.3. PBD statement in Chapter 5 allows for flood-specific guidance in commentary

Table C5.3-4 Matrix of Expected Performance and Hazard Levels for Flood

Hazard Level vs Performance	Operational	Repairable	Significant Damage	Unsafe to Occupy
Routine	RC IV, RC III	RC II		
Design	RC IV	RC III, RC II		
Extreme		RC IV	RC III	RC II

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Hazard
- o Flood depth,
- o Flood velocity,
- o Wave conditions,
- o Scour depth,
- o Debris hazards

Load
- o Hydrostatic,
- o Hydrodynamic,
- o Wave forces,
- o Debris impact

Load Cases
- o Combinations of loads
- o Stability check

Reliability Analysis
- o Consistency with Chapter 2

Include basic equations for hydrostatic loads. Define buoyancy and discuss in commentary.

Include basic equations for moving water.

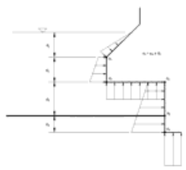

Figure shows typical pressure distribution

Structural Element Section	C_d
Round column or equilateral polygon with six sides or more	1.2
Rectangular column of at least 2:1 aspect ratio with longer face oriented parallel to flow	1.6
Free-standing wall submerged in flow	1.6
Square, or rectangular column with longer face oriented perpendicular to flow	1.6
Triangular column pointing away from flow	2.0
Wall or flat plate, normal to flow	2.0
Diamond-shape column, pointed into the flow (based on face width, not projected width)	2.5
Rectangular beam, normal to flow	2.0
I, L, and Channel shapes	2.0

Table lists drag coefficients for typical cross sections used in design

Intention is to provide designers with explicit equations not provided in existing Chapter 5

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Hazard
- o Flood depth,
- o Flood velocity,
- o Wave conditions,
- o Scour depth,
- o Debris hazards

Load
- o Hydrostatic,
- o Hydrodynamic,
- o Wave forces,
- o Debris impact

Load Cases
- o Combinations of loads
- o Stability check

Reliability Analysis
- o Consistency with Chapter 2

Wave Forces
- Added provisions for nonbreaking waves based on accepted engineering practice
- Include wave loads on elevated structures

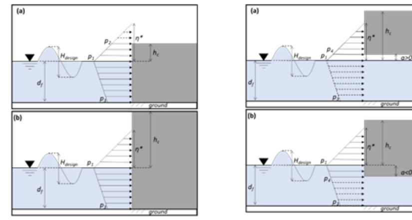

Figure shows definition sketch for non-elevated structures for use with Goda Equations

Figure shows definition sketch for elevated structures for use with Goda Equations

Intention is to provide designers with explicit equations commonly used in engineering practice not found in existing Chapter 5

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Hazard
- o Flood depth,
- o Flood velocity,
- o Wave conditions,
- o Scour depth,
- o Debris hazards

Load
- o Hydrostatic,
- o Hydrodynamic,
- o Wave forces,
- o Debris impact

Load Cases
- o Combinations of loads
- o Stability check

Reliability Analysis
- o Consistency with Chapter 2

Debris Impact

- Debris impact loads required per 5.3.9 with several exceptions
- Some guidance from 7-22 commentary moved to provisions
- Three procedures to calculate debris impact
- Specification of debris types and properties

Table 5.4-4 Minimum Debris Properties

Debris Type	Minimum debris weight (W_{debris})	Minimum elastic debris stiffness (k_e)
Wood Log/Pole	1,000 lb (4.448 kN)	4,200,000 lb/ft (61,300 kN/m)
Passenger Vehicle	2,400 lb (12.455 kN)	72,000 lb/ft (1,051 kN/m)
Small Vessels	2,500 lb (11.121 kN)	360,000 lb/ft (5,254 kN/m)
20 ft Shipping Container	5,000 lb (22.241 kN)	2,940,000 lb/ft (42,900 kN/m)
40 ft Shipping Container	8,400 lb (37.365 kN)	2,040,000 lb/ft (29,800 kN/m)
Ships/Barges	Established based on local conditions	

Table lists minimum debris properties used for design

- Extraordinary Debris Impact for RC IV structures
- Debris impact load redistribution – related to progressive collapse
- Improved consistency of debris impact with Chapter 6 Tsunami

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Hazard
- o Flood depth,
- o Flood velocity,
- o Wave conditions,
- o Scour depth,
- o Debris hazards

Load
- o Hydrostatic,
- o Hydrodynamic,
- o Wave forces,
- o Debris impact

Load Cases
- o Combinations of loads
- o Stability check

Reliability Analysis
- o Consistency with Chapter 2

Combination of Loads

5.5 FLOOD LOAD CASES

The flood load (F_a) used in the Chapter 2 load combinations shall include the following flood load cases in the applicable directions:

For coastal flooding:

1. Combination of hydrostatic loads including buoyancy (5.4.2), hydrodynamic loads (5.4.3) and debris impact loads (5.4.5)
2. Combination of hydrostatic loads including buoyancy (5.4.2), hydrodynamic loads (5.4.3) and wave loads (5.4.4)

For riverine flooding:

1. Combination of hydrostatic loads including buoyancy (5.4.2), hydrodynamic loads (5.4.3) and debris impact loads (5.4.5)

5.5.1 Stability for Uplift.
5.5.2 Stability for Sliding.

Clear requirement on how individual loads must be combined

Overall flood load F_a is used in Chapter 2.

Stability checks are often done in practice, but existing standard does not include this.

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Hazard
- o Flood depth,
- o Flood velocity,
- o Wave conditions,
- o Scour depth,
- o Debris hazards

Load
- o Hydrostatic,
- o Hydrodynamic,
- o Wave forces,
- o Debris impact

Load Cases
- o Combinations of loads
- o Stability check

Reliability Analysis
- o Consistency with Chapter 2

Reliability Analysis

- Reliability Analysis conducted for RC I, II, III, IV structures
  - ✓ Chapter 1 Commentary modified
  - ✓ Factor 2.0 changed to 1.0, consistent for RC I-IV

2.3.2 Load Combinations Including Flood Load.
When a structure is located in a flood ~~zone~~ hazard area (Section 5.3.1), the following load combinations shall be considered in addition to the basic combinations in Section 2.3.1:

~~In V-Zones or Coastal A-Zones:~~
~~4b. 1.2D + 1.0W + 2.0Fa + L + 0.5(Lr or S or R)~~
~~5b. 0.9D + 1.0W + 2.0Fa~~
~~In noncoastal A-Zones:~~
~~4b. 1.2D + 0.5W + 1.0Fa + L + 0.5(Lr or S or R)~~
~~5b. 0.9D + 0.5W + 1.0Fa~~

4b. $1.2D + 1.0W + 1.0F_a + 1.0L + 0.5(L_r \text{ or } S \text{ or } R)$
5b. $0.9D + 0.5W + 1.0F_a$

Existing standard has “2.0” factor of uncertainty.

With proposed modifications, target reliability achieved for RC I – IV.

Intention is to shows target reliability is achieved for MRI-based flood level

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Summary

Complete revision to Chapter 5
- Increase the flood hazard area from 100-year to 500-year for all RC II, III, and IV structures
- Incorporate a risk-based approach where flood hazard is tied to structure risk category
  RC I 100-year RC II 500-year RC III 750-year RC IV 1000-year
- Hazards: Flood depth, velocity, wave, scour and debris hazards
- Loads: Provides hydrostatic, hydrodynamic, wave, and debris impact loads
- Load cases: Combination of flood loads and stability checks, consistency w/ Chapter 2

and as a subcommittee
- Understand how proposed changes would affect engineering design and impact related standards
- Document analytical work and case studies for future cycles and for engineering practice

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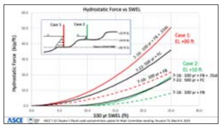
Appendix A

Example calculations by FLSC to compare *existing* standard and *proposed* changes

FLSC presentation to 7-22 Main Committee on 3/2020 in Houston, TX



- ✓ Example comparisons for different use cases
- ✓ Documented changes in load for
  - hydrostatic
  - hydrodynamic

- ✓ Two site-specific locations on Long Island, NY
- ✓ Documented changes in load for
  - hydrostatic,
  - hydrodynamic
  - breaking wave
  - debris impact

- ✓ Three site-specific location in Manhattan, NY
- ✓ Documented changed in load for
  - hydrostatic,
  - hydrodynamic
  - debris impact

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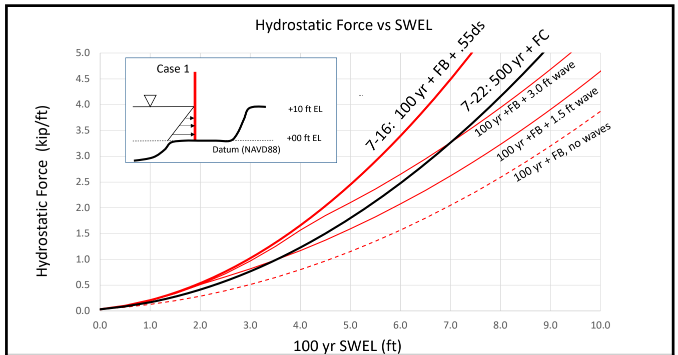

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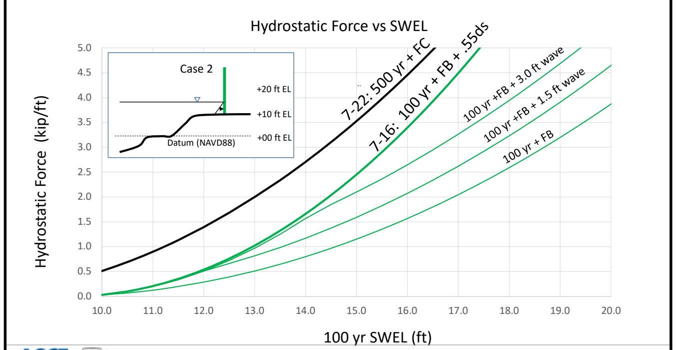

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Hydrodynamic Force on a Square Column

The hydrodynamic drag force, exerted by moving water on structural components shall be determined by

$$F_{drag} = (1/2)\,\rho\, C_d\, V^2 A \qquad (5.4\text{-}4)$$

where

ρ = the water density

C_d = the drag coefficient (2.0 for square column)

A = the projected area in the flow direction exposed to the moving water.

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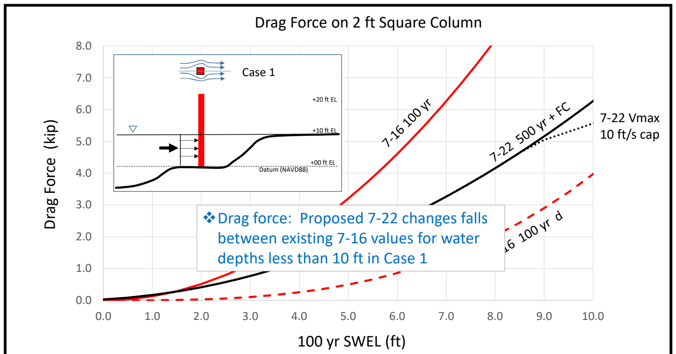

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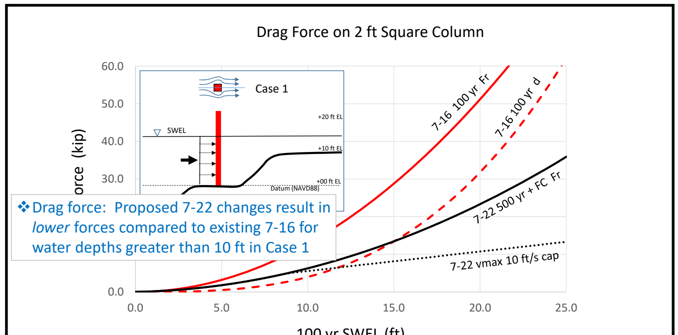

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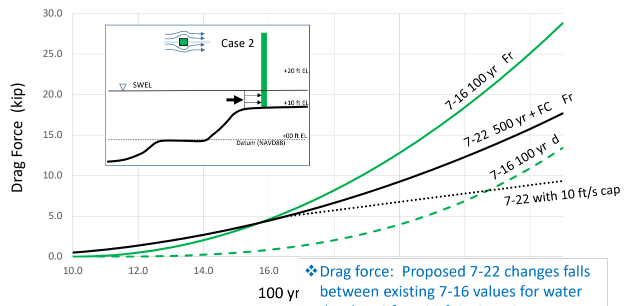
Drag Force on 2 ft Square Column



❖ Drag force: Proposed 7-22 changes falls between existing 7-16 values for water depths 16 ft to 22 ft in Case 2

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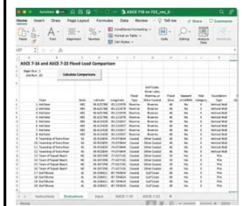
Example calculations by CDM Smith to compare *existing* standard and *proposed* changes



- ✓ Use of proposed standard by design professionals familiar with ASCE 7-16, ASCE 24, FEMA requirements and so on
- ✓ Not involved in FLSC committee work
- ✓ Sites selected
  - Riverine: Hollister MO
  - Coastal (Atlantic): Toms River, NJ
  - Coastal (Atlantic): Topsail Beach, NC
  - Coastal (Gulf): Gulf Shores, AL
- ✓ RC II structures with variations in
  - Foundation types – vertical wall & pile supported
  - Building elevation above grade
  - First floor elevation requirements
- ✓ Calculations and comparisons of loads for
  - Hydrostatic
  - Hydrodynamic
  - Wave breaking
  - Debris impact

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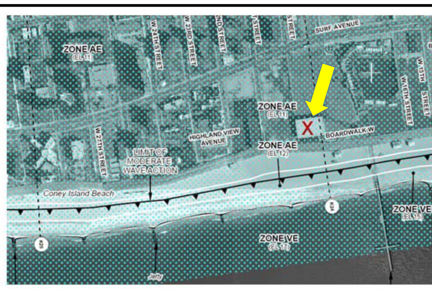
CONEY ISLAND
NEW YORK

KINGS COUNTY
TRANSECT 24



Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations[1] (ft NAVD88) Range of Stillwater Elevations[2] (ft NAVD88)			
		Coordinates	Significant Wave Height (ft)	Peak Wave Period (sec)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Raritan Bay	K-24	N 40.571304 W 73.985245	8.36	11.20	7 6.7 - 7	9.9 9.4 - 10	11.2 10 - 11.4	14.6 12.8 - 14.9

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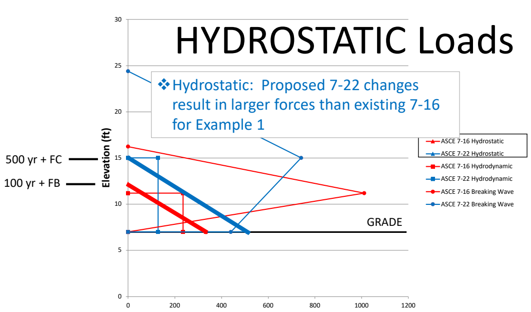
HYDROSTATIC Loads



❖ Hydrostatic: Proposed 7-22 changes result in larger forces than existing 7-16 for Example 1

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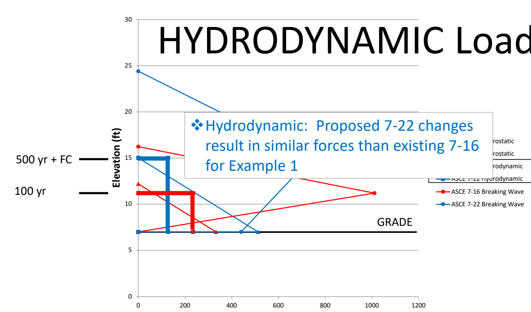
HYDRODYNAMIC Loads



❖ Hydrodynamic: Proposed 7-22 changes result in similar forces than existing 7-16 for Example 1

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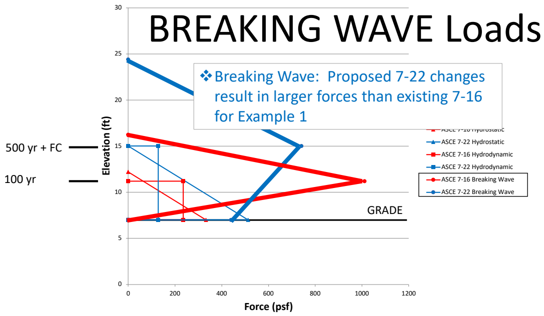
BREAKING WAVE Loads



- Breaking Wave: Proposed 7-22 changes result in larger forces than existing 7-16 for Example 1

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7-16 vs 7-22 Comparison Summary

	Units	ASCE 7-16	Notes	ASCE 7-22	Notes	Factor ASCE 7-22 / ASCE 7-16
Stillwater Depth	ft	5.2		8.0		
Velocity	ft/s	11.6		8.0		
Hydrostatic Load	lb/ft	865		2057		2.38
Hydrodynamic Load	lb/ft	988	Not applicable BFE = Stillwater?	1028		1.04
Breaking Wave Load Pile	lb	601		2190		3.64
Nonbreaking Wave Load Pile	lb			876		
Breaking Wave Load Wall	lb/ft	5321	Not applicable BFE = Stillwater? Subtracted Hydrostatic Load for Comparison	9420		1.77
Nonbreaking Wave Load Wall	lb/ft			5594		
Impact Load - 1000#, commentary method	lb	5446		12751		2.34
Impact Load - 1000# FEMA 55	lb	4187				3.05
Impact Load - Vessel 2800# FEMA 55	lb	11722		20160		1.72

ASCE 7-22 Chapter 5 Flood Loads subcommittee update for Main Committee webinar. August 13, 2020

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7-16 vs 7-22 Comparison Summary

	Units	ASCE 7-16	Notes	ASCE 7-22	Notes	Factor ASCE 7-22 / ASCE 7-16
Stillwater Depth	ft	5.2		8.0		
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Hydrostatic Load	lb/ft	865		2057		2.38
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Breaking Wave Load Pile	lb	601		2190		3.64
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Breaking Wave Load Wall	lb/ft	5321	Not applicable BFE = Stillwater? Subtracted Hydrostatic Load for Comparison	9420		1.77
Nonbreaking Wave Load Wall	lb/ft			5594		
Impact Load - 1000#, commentary method	lb	5446		12751		2.34
Impact Load - 1000# FEMA 55	lb	4187				3.05
Impact Load - Vessel 2800# FEMA 55	lb	11722		20160		1.72

Environmental variables (input)
- Depth *increases* from 7-16 to 7-22 by factor 1.5
- Velocity *decreases* from 7-16 to 7-22 by factor 0.69

ASCE 7-22 Chapter 5 Flood Loads subcommittee update for Main Committee webinar. August 13, 2020

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7-16 vs 7-22 Comparison Summary

	Units	ASCE 7-16	Notes	ASCE 7-22	Notes	Factor ASCE 7-22 / ASCE 7-16
Stillwater Depth	ft	5.2		8.0		
Velocity	ft/s	11.6		8.0		
Hydrostatic Load	lb/ft	865		2057		2.38
Hydrodynamic Load	lb/ft	988	Not applicable BFE = Stillwater?	1028		1.04
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Nonbreaking Wave Load Wall	lb/ft			5594		
Impact Load - 1000#, commentary method	lb	5446		12751		2.34
Impact Load - 1000# FEMA 55	lb	4187				3.05
Impact Load - Vessel 2800# FEMA 55	lb	11722		20160		1.72

Hydrostatic and Hydrodynamic Loads (output)
- Hydrostatic *increases* by factor 2.4
- Hydrodynamic *stays the same* with factor 1.04

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7-16 vs 7-22 Comparison Summary

	Units	ASCE 7-16	Notes	ASCE 7-22	Notes	Factor ASCE 7-22 / ASCE 7-16
Stillwater Depth	ft	5.2		8.0		
Velocity	ft/s	11.6		8.0		
Hydrostatic Load	lb/ft	865		2057		2.38
Hydrodynamic Load	lb/ft	988	Not applicable BFE = Stillwater?	1028		1.04
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Nonbreaking Wave Load Wall	lb/ft			5594		
Impact Load - 1000#, commentary method	lb	5446		12751		2.34
Impact Load - 1000# FEMA 55	lb	4187				3.05
Impact Load - Vessel 2800# FEMA 55	lb	11722		20160		1.72

Wave Loads on Piles
- For breaking waves, *increases* by factor 3.6
- For non-breaking waves, *increases* by factor 1.45

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7-16 vs 7-22 Comparison Summary

	Units	ASCE 7-16	Notes	ASCE 7-22	Notes	Factor ASCE 7-22 / ASCE 7-16
Stillwater Depth	ft	5.2		8.0		
Velocity	ft/s	11.6		8.0		
Hydrostatic Load	lb/ft	865		2057		2.38
Hydrodynamic Load	lb/ft	988	Not applicable BFE = Stillwater?	1028		1.04
Breaking Wave Load Pile	lb	601		2190		3.64
Nonbreaking Wave Load Pile	lb			876		
Breaking Wave Load Wall	lb/ft	5321	Not applicable BFE = Stillwater? Subtracted Hydrostatic Load for Comparison	9420		1.77
Nonbreaking Wave Load Wall	lb/ft			5594		
Impact Load - 1000#, commentary method	lb	5446		12751		2.34
Impact Load - 1000# FEMA 55	lb	4187				3.05
Impact Load - Vessel 2800# FEMA 55	lb	11722		20160		1.72

Wave Loads on Walls
- For breaking waves, *increases* by factor 1.77
- For non-breaking waves, *increases* by factor 1.05

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7-16 vs 7-22 Comparison Summary

	Units	ASCE 7-16	Notes	ASCE 7-22	Notes	Factor ASCE 7-22 / ASCE 7-16
Stillwater Depth	ft	5.2		8.0		
Velocity	ft/s	11.6		8.0		
Hydrostatic Load	lb/ft	865		2057		2.38
Hydrodynamic Load	lb/ft	988	Not applicable BFE = Stillwater?	1028		1.04
Breaking Wave Load Pile	lb	601		2190		3.64
Nonbreaking Wave Load Pile	lb			876		
Breaking Wave Load Wall	lb/ft	5321	Not applicable BFE = Stillwater? Subtracted Hydrostatic Load for Comparison	9420		1.77
Nonbreaking Wave Load Wall	lb/ft			5594		
Impact Load - 1000#, commentary method	lb	5446		12751		2.34
Impact Load - 1000# FEMA 55	lb	4187				3.05
Impact Load - Vessel 2800# FEMA 55	lb	11722		20160		1.72

Debris Impact Loads
- 1000 lb log, using 7-16 commentary, 7-22 *increases* by factor 2.34
- 1000 lb log, using FEMA P55 CCM, 7-22 *increases* by factor 3.05
- 2800 lb vessel, using FEMA P55 CCM, 7-22 *increases* by factor 1.72

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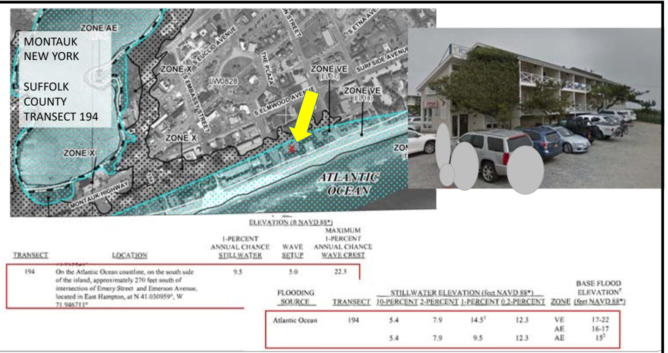

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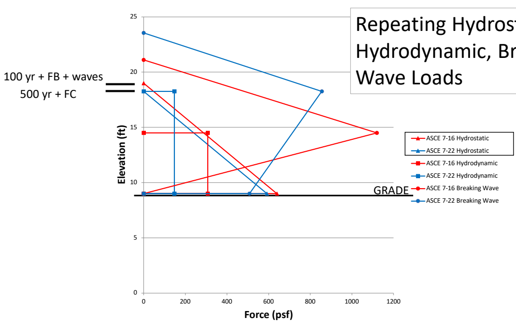

Repeating Hydrostatic, Hydrodynamic, Breaking Wave Loads

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7-16 vs 7-22 Comparison Summary

	Units	ASCE 7-16	Notes	ASCE 7-22	Notes	Factor ASCE 7-22 / ASCE 7-16
Stillwater Depth	ft	7.5		9.3		
Velocity	ft/s	13.3		8.6		
Hydrostatic Load	lb/ft	3200		2739		0.86
Hydrodynamic Load	lb/ft	1694		1369		0.81
Breaking Wave Load Pile	lb	1031		2916		2.83
Nonbreaking Wave Load Pile	lb			1166		
Breaking Wave Load Wall	lb/ft	7409	Subtracted Hydrostatic Load for Comparison	12546		1.69
Nonbreaking Wave Load Wall	lb/ft			7450		
Impact Load - 1000#,	lb	6232	commentary method	13698		2.20
Impact Load - 1000#	lb	4791	FEMA 55			2.86
Impact Load - Vessel 2800#	lb	13414	FEMA 55	21658		1.61

Environmental variables (input)
- Depth *increases* from 7-16 to 7-22 by factor 1.24
- Velocity *decreases* from 7-16 to 7-22 by factor 0.65

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7-16 vs 7-22 Comparison Summary

	Units	ASCE 7-16	Notes	ASCE 7-22	Notes	Factor ASCE 7-22 / ASCE 7-16
Stillwater Depth	ft	7.5		9.3		
Velocity	ft/s	13.3		8.6		
Hydrostatic Load	lb/ft	3200		2739		0.86
Hydrodynamic Load	lb/ft	1694		1369		0.81
Breaking Wave Load Pile	lb	1031		2916		2.83
Nonbreaking Wave Load Pile	lb			1166		
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Nonbreaking Wave Load Wall	lb/ft			7450		
Impact Load - 1000#,	lb	6232	commentary method	13698		2.20
Impact Load - 1000#	lb	4791	FEMA 55			2.86
Impact Load - Vessel 2800#	lb	13414	FEMA 55	21658		1.61

Hydrostatic and Hydrodynamic Loads (output)
- Hydrostatic *decreases* by factor 0.86
- Hydrodynamic *decrease* by factor 0.81

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7-16 vs 7-22 Comparison Summary

	Units	ASCE 7-16	Notes	ASCE 7-22	Notes	Factor ASCE 7-22 / ASCE 7-16
Stillwater Depth	ft	7.5		9.3		
Velocity	ft/s	13.3		8.6		
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Impact Load - 1000#	lb	4791	FEMA 55			2.86
Impact Load - Vessel 2800#	lb	13414	FEMA 55	21658		1.61

Wave Loads on Piles
- For breaking waves, *increases* by factor 2.83
- For non-breaking waves, *increases* by factor 1.13

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7-16 vs 7-22 Comparison Summary

	Units	ASCE 7-16	Notes	ASCE 7-22	Notes	Factor ASCE 7-22 / ASCE 7-16
Stillwater Depth	ft	7.5		9.3		
Velocity	ft/s	13.3		8.6		
Hydrostatic Load	lb/ft	3200		2739		0.86
Hydrodynamic Load	lb/ft	1694		1369		0.81
Breaking Wave Load Pile	lb	1031		2916		2.83
Nonbreaking Wave Load Pile	lb			1166		
Breaking Wave Load Wall	lb/ft	7409	Subtracted Hydrostatic Load for Comparison	12546		1.69
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Impact Load - 1000#,	lb	6232	commentary method	13698		2.20
Impact Load - 1000#	lb	4791	FEMA 55			2.86
Impact Load - Vessel 2800#	lb	13414	FEMA 55	21658		1.61

Wave Loads on Walls
- For breaking waves, *increases* by factor 1.69
- For non-breaking waves, *stays about the same* by factor 1.01

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7-16 vs 7-22 Comparison Summary

	Units	ASCE 7-16	Notes	ASCE 7-22	Notes	Factor ASCE 7-22 / ASCE 7-16
Stillwater Depth	ft	7.5		9.3		
Velocity	ft/s	13.3		8.6		
Hydrostatic Load	lb/ft	3200		2739		0.86
Hydrodynamic Load	lb/ft	1694		1369		0.81
Breaking Wave Load Pile	lb	1031		2916		2.83
Nonbreaking Wave Load Pile	lb			1166		
Breaking Wave Load Wall	lb/ft	7409	Subtracted Hydrostatic Load for Comparison	12546		1.69
Nonbreaking Wave Load Wall	lb/ft			7450		
Impact Load - 1000#,	lb	6232	commentary method	13698		2.20
Impact Load - 1000#	lb	4791	FEMA 55			2.86
Impact Load - Vessel 2800#	lb	13414	FEMA 55	21658		1.61

Debris Impact Loads
- 1000 lb log, using 7-16 commentary, 7-22 *increases* by factor 2.20
- 1000 lb log, using FEMA P55 CCM, 7-22 *increases* by factor 2.86
- 2800 lb vessel, using FEMA P55 CCM, 7-22 *increases* by factor 1.61

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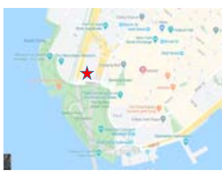
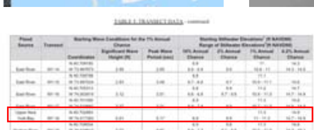
Example 3: Battery Place, New York, NY





Data:
Non-Coastal A-Zone – Zone AE
BFE +11-feet NAVD 88
1% (100-yr) SWEL +11.3-feet NAVD 88
0.2% (500-yr) SWEL +14.9-feet NAVD 88
Grade +6-feet NAVD 88

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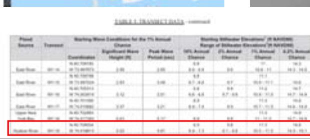
Example 4: 55 Battery Place, New York, NY



Data:
Zone X

1% (100-yr) SWEL +11.3-feet NAVD 88
0.2% (500-yr) SWEL +14.8-feet NAVD 88
Grade +11-feet NAVD 88

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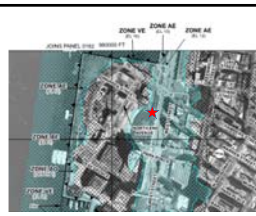
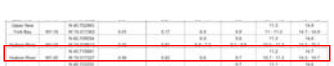
Example 5: West & Warren Sts, New York, NY





Data:
Non-Coastal A-Zone – Zone AE
BFE +11-feet NAVD 88
1% (100-yr) SWEL +11.2-feet NAVD 88
0.2% (500-yr) SWEL +14.7-feet NAVD 88
Grade +9-feet NAVD 88

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