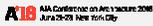


FEMA P-348: Protecting Building Utility Systems From Flood Damage

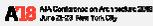


Course Number TH201
Thursday, June 21, 2018, 7:30 AM – 9:00 AM
Learning Units 1.50



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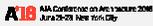
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Questions related to specific products and services may be addressed at the conclusion of this presentation.



Speakers List

- Session Organizer & Seminar Presenter: Dan Bass, Architect, Building Science Branch, FEMA
- Session Presenter: John Squerciati, PE, CFM, Senior Associate, Dewberry

Course / Learning Objectives

- Analyze building utility systems for potential flood risk.
- Understand methods for protecting new and existing large residential and nonresidential building systems subject to riverine and coastal flooding.
- Build skills to communicate general approaches and specific flood mitigation measures for various building systems.
- Learn to develop a comprehensive flood protection plan for building systems.

Workshop Outline – Part 1

- Introduction – NFIP, Flood Hazards and Loads
- Achieving Compliance – New Construction, Substantial Improvement
- Non-Conforming Existing Buildings, No Substantial Improvement
- Elevation, Relocation and Component Protection
- Other Mitigation Options – Partial Protection Measures
- Review Activity 1.1

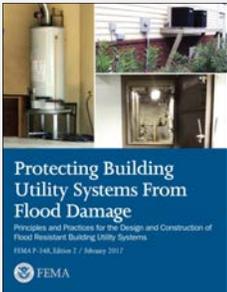
Workshop Outline – Part 2

- Residential and Non-Residential Buildings
- Heating, Ventilation and Air Conditioning (HVAC)
- Electrical Systems
- Plumbing Systems
- Fuel Systems and Tanks
- Conveyances – Elevators, Lifts and Escalators
- Review Activities 2.1 through 2.5

FEMA P-348 Overview

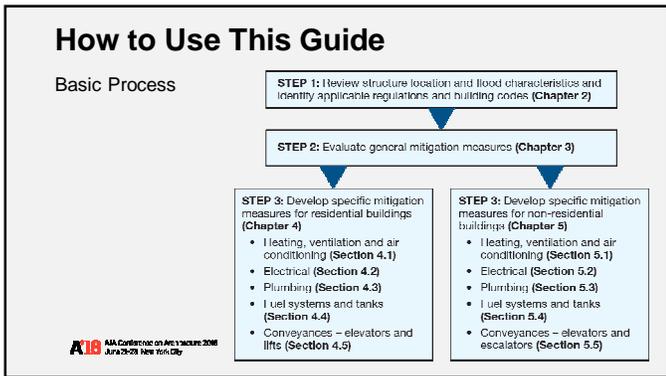
Five Chapters:

- 1) Introduction - Building Systems and Flood Hazards
- 2) Regulatory Framework
- 3) Compliance and Mitigation Measures
- 4) Mitigation for Residential Buildings
- 5) Mitigation for Non-Residential Buildings



Introduction





National Flood Insurance Program (NFIP) – Key Terms

Flood Insurance Rate Map (FIRM) - Features

- Identifies Special Flood Hazard Areas (SFHAs)
- Riverine and coastal flood elevations (BFEs)

Pre-FIRM vs. Post-FIRM Construction

Figure 1-2. Conceptual FIRM showing riverine and coastal flood zones.

Figure 1-3. Conceptual FIRM showing riverine and coastal flood zones.

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Key NFIP Terms (continued)

Substantial Improvement (SI)

- Any repair, rehabilitation, addition or other improvement of a structure
- Cost \geq 50% of structure market value before “start of construction” of improvement
- Includes repairs to address Substantial Damage

Substantial Damage (SD)

- Damage of any origin
- Repair cost \geq 50% of market value of structure before damage occurred, regardless of actual work performed

Both SI and SD structures must comply with NFIP regulations

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FEMA P-348 Term: Flood Protection Level

New Construction, SI/SD

- Flood protection level = Required flood elevation
- Required flood elevation = BFE + Freeboard or Design Flood Elevation (DFE)

Code/Regulatory Compliance not required

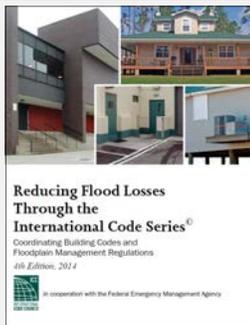
- Flood protection level = Level selected to provide desired protection

Flood Hazard Characteristics and Flood Loads

- NFIP, code requirement for SFHA buildings:
 - Resist flotation, collapse, and lateral movement
- Flood characteristics - flood loads on buildings:
 - Hydrostatic Loads
 - Hydrodynamic Loads
 - Wave Loads
 - Other – Debris, Erosion and Scour, Contaminants

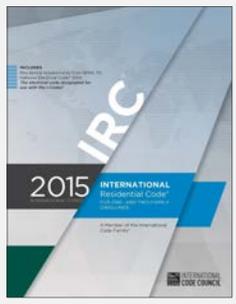
Building Codes

- Codes address flood, wind, seismic, snow
- Two most widely adopted model codes:
 - International Code Council, Inc. (ICC)
 - National Fire Protection Association (NFPA)
- ICC – IRC and IBC
- NFPA – NEC, Life Safety, Fire Codes



International Residential Code® (IRC)

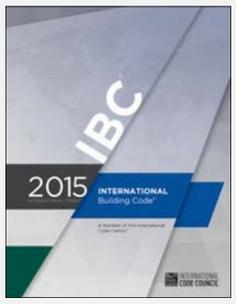
- Prescriptive Code: Specifies construction requirements - *How?*
- Most dwellings don't need PE or RA
- 2015 IRC (Section R322.1.6) requirement:
 - *Locate Building systems/Equipment at BFE + 1 foot*



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International Building Code® (IBC)

- Performance Code: Focus on outcomes - *What?*
- IBC references ASCE 24 for SFHAs
- IBC building system references:
 - *International Mechanical Code® (IMC)*
 - *International Fuel Gas Code® (IFGC)*
 - *International Plumbing Code® (IPC)*



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Referenced Flood Design Requirements

American Society of Civil Engineers (ASCE) Standards

- ASCE 7, *Minimum Design Loads for Buildings and Other Structures*
- ASCE 24, *Flood Resistant Design and Construction*
 - Minimum design and construction requirements in SHFAs
 - IBC and IRC require ASCE 24 compliance



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Summary: I-Code and ASCE 24 Standard References

Code/Standard	HVAC	Electrical	Plumbing	Fuel Systems & Tanks	Conveyances
2015 IBC	1612.4, ASCE 24	1612.4, ASCE 24	1612.4, ASCE 24	1612.4, ASCE 24	1612.4, ASCE 24, 3001.2
ASCE 24-14	7.1; 7.4	7.1; 7.2	7.1; 7.3	7.1; 9.7	7.1; 7.5
2015 IRC	R322.1.6; M1301.1.1; M1401.5; M1601.4.10; M1701.2; M2001.4; M2201.6	R322.1.6	R322.1.6; P2601.3; P2602.2; P2705.1; P3001.3; P3101.5	R322.1.6; G2404.7; R322.1.8; R322.2.4; R322.3.7	R322.1.6
2015 IMC, IPC, IFGC	IMC: 301.16; 401.4; 501.3.1; 602.4; 603.13; 1206.9.1; 1210.8.6; 1305.2.1		IPC: 309.1; 309.2; 309.3	IFGC: 301.11	
2015 UMC, UPC	UMC: 305.2; 603.9; 607.2		UPC: 301.4		

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Flood Design Guidance

FEMA Building Science Publications

- Promote Best Practices
- Non-mandatory (generally)
- Include:
 - FEMA P-55, *Coastal Construction Manual*
 - FEMA P-259, *Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures*
 - FEMA P-936, *Floodproofing Non-Residential Buildings*



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Residential Utility Designs

International Residential Code (IRC):

- Covers detached 1- and 2- family dwellings, townhouses < 3 stories
- Provisions apply A Zone construction
- V Zone construction requirement:
 - Prepared and sealed by registered design professional



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Non-Residential Utility Designs

FEMA P-348 Guidance:

- For non-residential and mixed use occupancies
- “May” apply to:
 - Residential occupancies outside IRC scope
 - Non-residential portions of mixed use buildings
- “Component protection” for non-residential Zone A buildings only
- Taller/larger residential building systems similar to non-residential



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Utility System Protection Methods

Flood mitigation for mechanical, electrical and plumbing (MEP) components - same as buildings:

- **Elevation:** Elevate vulnerable components “in place”
- **Relocation:** Move vulnerable components to higher level/floor
- **Component Protection (Dry floodproofing):** Install flood-resistant barriers to protect components; **not an option for new or SI residential buildings**
- **Other Measures (Wet floodproofing):** Partial measures to reduce flood damage/service losses
- *Part 2 covers specific application of methods*



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Elevation and Relocation – Best Practices

- Building above required flood protection level
- Elevate/relocate equipment to same height:
- Advantages
 - Protects equipment from higher flood risk
 - Eligible for lower NFIP insurance premiums.



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Elevation – Interior Equipment

Elevate indoor utility equipment on pedestals/frames



Relocation

- Relocation to higher floor most effective
- Reduces flood exposure for SI, equipment/system upgrades
- Components above DFE facilitate flood recovery, building re-occupation



Component Protection

Measures that protect systems, equipment, or components located below flood protection level

- Use in regulated floodplains outside coastal areas
- **New construction/SI - applicable to non-residential structures only**
- Measures/techniques:
 - Flood barriers
 - Dry floodproofing

Flood Barriers

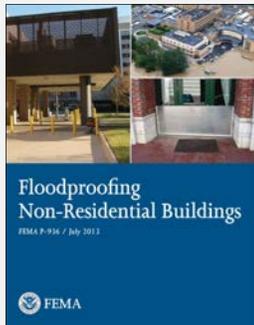
Key Design Considerations

- Wall height
- Adequate clearance for utilities
- Equipment access
- Utility connections to building
- Managing rainfall accumulation (drainage)



Dry Floodproofing

- Design and construction of "watertight" protective structures
- Structural components must resist flood loads below design protection level
- Design challenges and necessary protective measures can be costly
- Key reference: FEMA P-936, *Floodproofing Non-Residential Buildings* (2013)



Note: Dry Floodproofing Residual Risks

Greater dry floodproofing residual risks make it less effective than elevation:

- **Active Mitigation:** Requires human intervention to be effective
- **Overtopping:** Floods exceeding design height will inundate protected areas
- **Seepage:** Floods eventually fill protected areas and damage equipment unless operational sump pumps in place
- **Structural Failure:** If components cannot resist additional flood forces, components and structure will fail

Opportunities for More Resilient Building Utility Systems

- Replacement can reduce flood risk
- SI must meet NFIP new construction requirements
- Elevation or relocation can achieve compliance
- Non-residential systems can use "dry flood-proofing"



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Partial Protection Methods

Applicable Scenarios

Partial Protection allowed where full compliance is not required (existing buildings, not SI/SD or outside SFHA)

Examples:

- Full mitigation too costly or not feasible
- Large basement utility systems cannot be moved

Partial Protection Measures

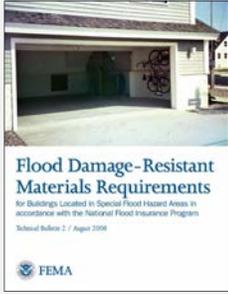
- Use of **flood damage-resistant materials**
- Design systems to facilitate **components replacement**
- Install **quick-connect mechanisms** to facilitate restoration of service
- Measures that allow **portions** of systems to be damaged without losing **functional loss** of the entire system

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Flood Damage-Resistant Materials (FDRMs)

- FDRMs provide partial protection below BFE
- FDRMs for utility components:
 - Uninsulated, stainless steel ductwork
 - Plumbing piping
 - Corrosion-resistant coatings and finishes



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Quick-Connect Mechanisms

- Quick-connect mechanisms (flanged connections) disconnect equipment components prior to flooding
 - Useful if large, heavy equipment cannot be elevated, relocated, or floodproofed
 - Allows connection of temporary equipment until damaged equipment can be repaired/ replaced
 - Does not eliminate damage, but facilitates service restoration and building function



Review Activity 1.1

- 1) What is the Substantial Improvement (SI) or Substantial Damage (SD) regulatory threshold percentage?
- 2) What utility systems must be built to flood resistance standards based on the local floodplain management ordinance and building code?
- 3) List the major types of utility protection measures in flood hazard areas?
- 4) List resources or tools should a designer or local official use to assure code compliance?
- 5) What are some key design considerations for protecting utility components sited below the flood protection level?

Residential Buildings

- Includes all dwellings within scope of the International Residential Code (IRC)
- Specific focus on detached 1- and 2-family dwellings and townhouses up to 3 stories high
- May also apply to larger residential buildings, but...
 - Such buildings often have utility systems similar to commercial (Chapter 5)



Non-Residential Buildings

- Includes non-residential structures and critical facilities
- Some guidance applicable to large residential buildings (systems similar to non-residential)
- Chapter 4 contains guidance for other residential buildings



Primary and Secondary Components

- **Primary components**
 - MEP components that **must** function for system operation
 - Primary component damage = building-wide system service loss
- **Secondary components**
 - MEP components that may be damaged or destroyed without complete loss of system operation
 - Secondary component damage results:
 - System function at reduced service levels, or
 - Service interruptions to portion of building

Summary of Utility System Mitigation Measures – Residential Buildings

System Components	NFIP Compliant for New Construction or SI	System Repairs for Existing and Non-SI Construction
General recommendations	<ul style="list-style-type: none"> • Minimize number of system components installed below flood protection level. • When placed below flood protection level, install components that resist flood forces and prevent floodwater entry or accumulation. 	<ul style="list-style-type: none"> • Install system components as high as possible • When placed below flood protection level, install components that can be readily restored or replaced and are functionally isolated from the rest of the system. Consider component protection as interim mitigation.
Primary and Secondary components	<ul style="list-style-type: none"> • Install at or above flood protection level unless components are submersible or can resist flood forces and prevent floodwater entry or accumulation. • Dry floodproofing not allowed. 	<ul style="list-style-type: none"> • Install all components – particularly primary components - as high as practical. • When placed below flood protection level, install components to reduce impacts from flood damage.

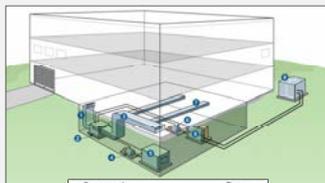
Summary of Utility System Mitigation Measures – Non-Residential Buildings

System Components	NFIP Compliant for New Construction or SI	System Repairs for Existing and Non-SI Construction
Primary components	<ul style="list-style-type: none"> Minimize number of system components installed below flood protection level. When placed below flood protection level, install components that resist flood forces and prevent floodwater entry or accumulation. 	<ul style="list-style-type: none"> Install system components as high as possible. When placed below flood protection level, install components that can be readily restored or replaced and can be functionally isolated from the rest of the system.
Secondary components	<ul style="list-style-type: none"> Install all components at or above flood protection level unless: <ul style="list-style-type: none"> Components are flood resistant and can resist flood forces and prevent floodwater entry or accumulation. OR Components are protected by dry floodproofing. 	<ul style="list-style-type: none"> Install all components particularly primary components as high as possible. When placed below flood protection level: <ul style="list-style-type: none"> Protect with dry floodproofing. OR Install components to reduce impacts from flood damage.

Non-Residential HVAC Systems

Example: Hydronic HVAC Systems

- Use water as thermal transfer medium
- Contain chillers, boilers, AHUs, and water pumps
- Smaller building HVAC may use heated air systems (furnaces, DX units, heat pumps)



Component	Type
1 Return trunkline duct	Primary
2 AHU	Primary
3 Supply trunkline duct	Primary
4 Hot water pump	Primary
5 Boiler	Primary
6 Chilled water pump	Primary
7 Lateral supply ducts and registers (typical)	Secondary
8 Chiller	Primary
9 Cooling tower	Primary

Flood Risks to HVAC Components

- HVAC components usually not flood-resistant; most damaged or destroyed when exposed to floodwater
- Flood damage risk to HVAC components depends on component elevation/location within building
 - Rooftop equipment = lowest flood risk
 - Lowest floor/below grade equipment = most vulnerable to flood damage



Residential HVAC Mitigation - Summary

- **Elevation: Most effective overall approach**
- Floodproofing options limited

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Non-Residential HVAC Mitigation

Primary Components: Chillers, Pumps, AHUs

Elevation - Most common approach for mitigating HVAC components

In-place elevation: Elevate on supports/frames without moving to higher floor

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Non-Residential HVAC Mitigation (continued)

Primary Components: Chillers, Pumps, AHUs (continued)

- **Reconfiguration:** Replace vertical AHUs with horizontal or in-line units
- **Relocation:** Elevating to higher floors effective, but more complex than in-place elevation
- Consider dry floodproofing as last option for in-place protection

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Non-Residential HVAC Mitigation (continued)

Secondary Components: Ductwork & Piping

- **Elevation:** Preferred risk reduction method
- Dry floodproofing: Allowed, but less desirable due to residual risks

Ductwork:

- Elevation at or above required flood elevation = most practical protection method
- In existing non-SI buildings, place ducts as high as possible
- Carefully inspect submerged ductwork; Discard and replace all duct insulation exposed to floodwater

Piping:

- Elevate piping components (vents, valves) to minimize corrosion risk
- Use flood damage-resistant piping insulation

Non-Residential HVAC Mitigation (continued)

Existing Construction

No readily available flood-resistant HVAC components meet NFIP criteria (i.e., prevent water entry and accumulation, resist flood forces)
Approaches to consider for minimizing damage, facilitating repairs and recovery:

- Create **transition points** between HVAC system sections above and below flood protection level (i.e., piping unions in chilled- and hot-water systems)
- Install **isolation devices/valves** at or above required flood protection level that feed portions of HVAC piping exposed to floodwater
 - Allows isolation of damaged equipment from undamaged sections
 - May allow function of undamaged sections during repairs

Review Activity 2.1

What's wrong with these pictures?



Review Activity 2.1 (continued)

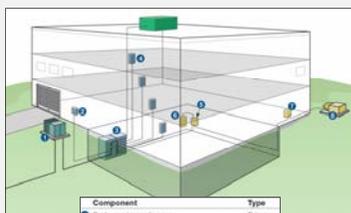
What's wrong with this picture?



Electrical Systems – Non-Residential

Main Components:

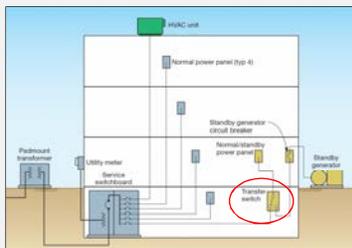
- 1) Utility Transformer
- 2) Utility Meter
- 3) Main Electrical Service
- 4) Feeders that supply
 - Electrical panels
 - HVAC equipment
- 1) thru 8) Components of standby/emergency power system



Component	Type
1 Padmount transformer	Primary
2 Electric meter	Primary
3 Service switchboard	Primary
4 Normal power panels	Primary
5 Transfer switch	Primary
6 Normal/standby power panel	Primary
7 Generator circuit breaker	Primary
8 Standby generator	Primary

Electrical Systems – Non-Residential (continued)

- Automatic transfer switch (ATS) senses loss of normal power, and signals generator to start if power interrupted
- Larger buildings typically contain more branch circuit panel boards and ATSS



Flood Risks to Electrical Systems

- Floodwater can damage nearly all electrical system components unless designed for submerged applications
- Electrical system component damages can:
 - Create fire and electrocution hazards during floods
 - Disrupt operation of power-dependent building services
 - Delay post-flood reoccupation of buildings

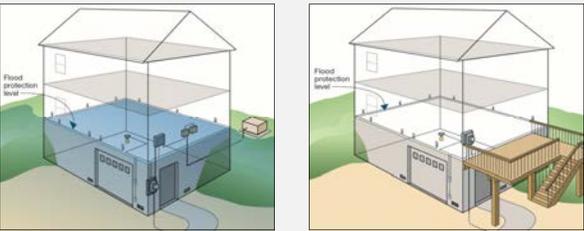


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Residential Electrical Mitigation - Summary

- Elevation: Preferred approach**



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Non-Residential Electrical Mitigation

General Approach

Primary Components

- Relocation:** Generally most appropriate option
- In-place elevation:** Appropriate if sufficiently reduces flood risk and meets NFPA 70 (NEC) access requirements
- Component protection (Dry floodproofing): Potential option

Secondary Components

- Elevation or relocation:** Most appropriate options
- Consider replacing vulnerable components with those suitable for submerged installation
- Install components to be electrically isolated

Existing Buildings

- Provide flood protection measures as equipment is replaced.

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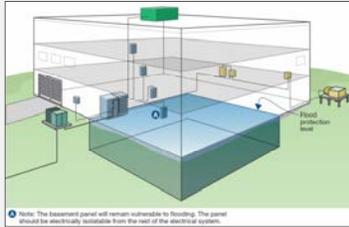
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Non-Residential Electrical Mitigation (continued)

Primary Components: Transformers, Service Equipment

Relocation: Usually most effective approach

- **Power Transformers:** Feasible if service equipment relocated
- **Service Equipment:** Most effective, but requires space to be created for equipment
- **Other Primary Components:** Treat similarly to service equipment

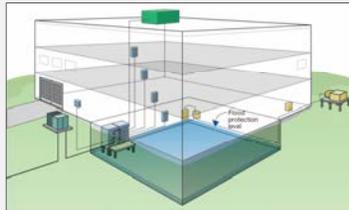


Non-Residential Electrical Mitigation (continued)

Primary Components: Transformers, Service Equipment (continued)

In-Place Elevation: Appropriate if sufficiently reduces flood risk

- **Transformers:** Feasible if service equipment elevated
- **Service Equipment:** Effective, but must maintain clearances
- **Other Primary Components:** Use if elevation sufficient



Non-Residential Electrical Mitigation (continued)

Secondary Components - Wiring, Branch Circuits, Receptacles, Switches, Lights:

Elevation = Preferred mitigation approach

- Place secondary components at or above flood protection level.
- Components that must be placed below flood protection level should be
 - 1) Suitable for submerged conditions, and
 - 2) Electrically isolated from rest of the system using branch circuits protected by GFCIs
- Minimize devices needed for life safety below flood protection level on branch circuits with GFCIs or wiring installed in non-metallic conduits
- Route conductors or conduits around flood barriers in dry floodproofed area to alleviate/minimize penetrations

Non-Residential Electrical Mitigation (continued)

Emergency and Standby Power Systems

- **Elevation:** Use to protect primary and secondary components whenever feasible.
- In existing buildings where elevation not feasible, electrically isolate secondary components vulnerable to flooding
- **Key Reference:** FEMA P-1019 (2014) provides details on emergency power systems for critical facilities



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Non-Residential Electrical Mitigation (continued)

Miscellaneous Electrical Systems

Mitigate using same approach as branch circuits: Elevate where possible, or retrofit/isolate.

IT and Communications

- Equipment and wiring below flood protection level should consider access for repairs/ replacement
- Install taps off CATV splitters feeding outlets below flood protection level to facilitate isolation
- Locate key IT equipment rooms (server rooms) at/above flood protection level

Closed Circuit Television (CCTV)

- Include devices allowing isolation of components/wiring installed below flood protection level

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Review Activity 2.2

What's wrong with these pictures?



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Review Activity 2.2 (continued)

What's wrong with these pictures?



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Review Activity 2.2 (continued)

What's wrong with these pictures?

EMERGENCY GENERATOR FLOOD PROTECTION MEASURES



ELEVATION

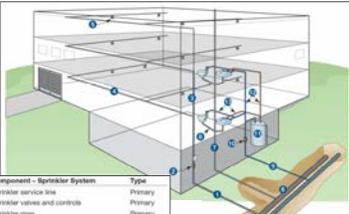
FLOODWALL

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Non-Residential Plumbing Systems

- Include domestic water systems and drain, waste and vent (DWV) systems
- May include fire protection (sprinklers), flammable gas, roof drainage, and pools and spas



Component - Sprinkler System	Type
1 Sprinkler service line	Primary
2 Sprinkler valves and controls	Primary
3 Sprinkler riser	Primary
4 Sprinkler lateral piping	Secondary
5 Sprinkler head piping	Secondary

Component - DWV	Type
1 Building sewer line	Primary
2 Non-Waste/Vent piping riser	Primary
3 Drain-Waste/Vent piping serving individual fixtures	Secondary

Component - Domestic Water	Type
1 Domestic water service line	Primary
2 Water service valve	Primary
3 Water header	Primary
4 Hot and cold water piping main	Primary
5 Hot and cold water piping serving individual fixtures	Secondary

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Flood Risks to Plumbing Systems

- Flood damage to water heaters, booster pumps, lift pumps and some valve components and fittings
- If water pressure lost, floodwaters can infiltrate and contaminate systems/private wells
- Physical damage to exposed components from velocity flow, wave action, and debris impact associated with moving floodwater

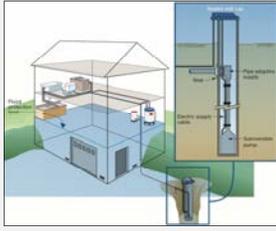
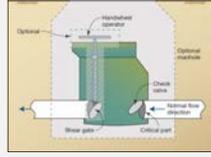


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Residential Plumbing Mitigation - Summary

- **Elevate** components where possible
- **Floodproof** below required flood elevation
- **Install valves** to prevent wastewater backflow



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Non-Residential Plumbing Mitigation

Potable Water Systems: General Approach

Elevation:

- Raise system components in place to reduce flood exposure
- Often the only practical option in existing buildings

Relocation:

- Mitigates vulnerable components by moving to a higher level/floors; often results in lowest residual risk
- May require displacement of other equipment or functions in building to accommodate relocated equipment

Component protection:

- Place equipment and components below flood protection level in **substantially impermeable** enclosures or vaults designed and installed to protect against infiltration

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Non-Residential Plumbing Mitigation

Primary Components: Meters, Heaters, Pumps, Piping

- **Water Meters:** Generally placed below grade by service provider; elevate at or above flood protection level if possible
- **Booster pumps:** Elevate at/above required elevation with electrical supply and controls, or dry floodproof
- **Water heaters:** Elevate at/above flood protection level or dry floodproof
- **Main piping lines:** Elevate/protect valves and fittings, protect risers in elevated buildings from moving floodwater
- **Caution:** Install exterior plumbing components facing downstream in riverine floodplains and landward in coastal areas.

Drain, Waste, and Vent (DWV) Systems

- Same as Residential - Protect piping; install backflow valves

Non-Residential Plumbing Mitigation (continued)

Fire Protection Systems

- Many flood-resistant components since piping is watertight (wet systems) or airtight (dry systems) and installed along building ceilings
- Elevate components when possible to prevent floodwater from coming in contact with fire suppression piping and reduce corrosion risk
- If piping must be installed in flood-prone areas, design system to facilitate floodwater and corrosive contaminant removal
- Elevate fire pumps and controls at/above flood protection level or dry floodproof



Non-Residential Plumbing Mitigation (continued)

Pools and Spas

- Codes, standards and best practices for construction in SFHAs: ICC 2015 Swimming Pool and Spa Code (ISWPC), ASCE 24-14, FEMA P-55, FEMA P-499
- **ISWPC provisions (Sections 304.4 and 304.5):**
 - Elevate equipment at/above design flood elevation, or anchor to prevent floatation and protect to prevent water entry/accumulation
 - Install GFCIs on branch circuits extending below design flood
- **ASCE 24-14 Section 9.6:**
 - Design in-ground and above-ground pools to withstand all flood-related loads and load combinations.
- **Elevate** pool and spa equipment at/above regulatory flood elevation or prevent water entry and accumulation (flood-resistant)

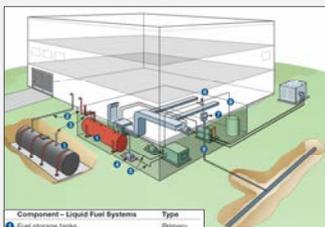
Review Activity 2.3

- 1) What caused this damage?
- 2) What could have mitigated this damage?



Non-Residential Fuel Systems and Tanks

- Can be liquid fuel systems or flammable gas (LP/NG).
- Can supply fuel to HVAC (furnaces/boilers), plumbing (water heaters)
- Flammable gas systems can supply gas-fired appliances, standby generators



Component - Liquid Fuel Systems		Type
1 Fuel storage tanks		Primary
2 Vent lines		Primary
3 Fill lines		Primary
4 Fuel pumps, filters and conditioners		Primary
5 Fuel supply and return lines required for system operation		Primary
Component - Flammable Gas Systems		Type
6 NG service valve		Primary
7 NG meter/regulator		Primary
8 NG service piping		Primary
9 Flammable gas lines serving individual equipment		Secondary

Flood Risks to Fuel Systems & Tanks

Potential flood damage risks:

- Control devices destroyed, pilot lights extinguished
- Fuel oil/propane tanks often dislodged or displaced by buoyancy
- Submerged tanks crushed
- Above-ground tanks and lines damaged by hydrodynamic, debris or wave action



Residential Fuel Mitigation - Summary

- **Elevation:** Most effective method
- **Dry floodproof and seal** fuel tanks that cannot be elevated

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Non-Residential Fuel Tank Mitigation

Fuel System Components: Vent/Fill Lines, Piping, Pumps

- **Elevation** above flood protection = most effective risk reduction method
- Vent/Fill lines and Piping to boilers, furnaces, or emergency power systems
 - Include valves to prevent tank contamination or fuel leaks
 - Anchored to resist flood forces, sealed to prevent leakage or contamination
- Fuel pumps – flood protection using submersible pumps:
 - Pump controls and motors - elevated, dry floodproofed, or designed for submerged operation
 - Connected to emergency power system

Fuel Storage Tanks

- Same as Residential: Elevation most effective; Protect piping

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Non-Residential Fuel Tank Mitigation (continued)

Fuel Storage Tanks

Fuel tanks below flood protection level:

- Tanks available that resist flood forces and prevent fuel leaks during floods
- Can install in substantially impermeable vaults to prevent tanks, piping and equipment from floodwater exposure

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Review Activity 2.4

What's wrong with these pictures?



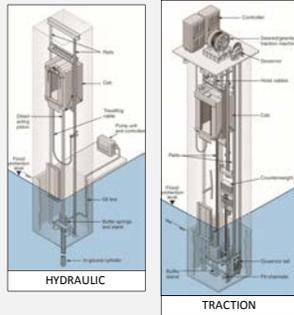
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Conveyances – Residential and Non-Residential Elevators

Elevators include cab that moves along rails located in shaft powered by motor(s) and other equipment:

- **Hydraulic elevators** push elevator cab using a piston (common in low-rise construction)
- **Traction elevators** hoist cab using cables (common in high-rise construction)

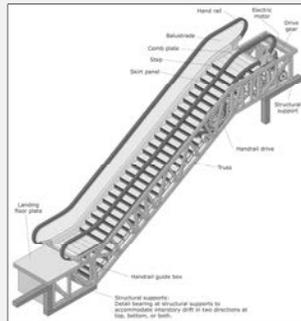


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Conveyances – Non-Residential Escalators

Escalators - moving staircases consisting of a continuous loop of stairs on tracks

- Powered by one or more motors and other equipment
- Most located inside the building, but some are outdoors



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Flood Risks to Conveyances

- Flooded elevator/lift components can be damaged or destroyed, leaving systems inoperable and trapping vulnerable residents inside flooded buildings
- Elevator shafts can be structurally damaged by hydrostatic, hydrodynamic, flood-borne debris impact, and/or breaking wave forces



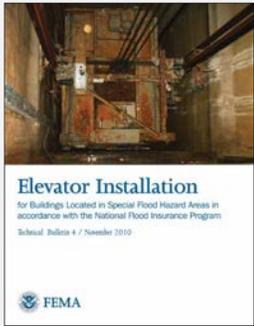
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Mitigation for Elevators

Elevator Shafts and Enclosures

- Design shafts to resist hydrostatic and hydrodynamic forces, erosion, scour, and waves (V Zones)
- Shafts and enclosures extending below required flood elevation must:
 - Be constructed of flood damage-resistant materials
 - Located on landward side of building for increased flood damage protection
 - Include nearby or adjacent structural elements designed to account for obstructed flow impacts



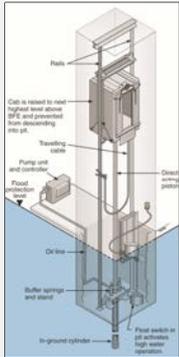
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Mitigation for Elevators (continued)

Elevator Cabs and Equipment

- Install **detection systems** with float switches in shafts to prevent cab descent into floodwater
- Locate equipment (electrical controls, hydraulic pumps) above required flood elevation where possible
- Protect equipment below required flood elevation using flood damage-resistant components (NEMA Type 4-rated enclosures, water-resistant components)



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Mitigation for Elevators (continued)

Elevator Cabs and Equipment (continued)

- Consider **relocation** to mitigate elevators in high-rise residential buildings and critical facilities such as hospitals, where vertical transportation is essential to support operations
 - Raise one or more building elevators so shaft landing terminates on a higher floor, with elevator pit and equipment raised at/above flood protection level
 - When supported by emergency power, raised elevators allow continued service during flood events that disable other elevators
 - Approach was adopted by some New York City hospitals after elevators inundated by Sandy (2012)

Mitigation for Escalators

Indoor Escalators

- Can locate most components at/above flood protection level

Outdoor Escalators

- If at/above flood protection level but exposed, use flood-resistant materials and connect to pumps to limit runoff into escalator landings

Indoor and Outdoor Escalators

- Minimize equipment below flood protection level
- If installed below flood protection level, design and construct to facilitate post-flood repair and restoration

Review Activity 2.5

What's wrong with these pictures?





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