Appendix J: Cost-Effective Public Assistance Hazard Mitigation Measures

FEMA considers the following mitigation measures to be cost-effective PA mitigation if the measures do not exceed 100 percent of the eligible repair cost (prior to any insurance reductions). The mitigation measures must meet all eligibility requirements described under the Hazard Mitigation section in Chapter 8. There may be instances where these measures are required by codes or standards[527] (see the Codes and Standards section in Chapter 8). In these cases, the work is completed as part of the PA repair project and requires no additional cost-effectiveness evaluation. Resilience beyond that which is required by codes and standards is implemented as PA mitigation. All mitigation measures are subject to general eligibility requirements, including compliance with Environmental and Historic Preservation (EHP) laws, regulations, and EOs.

I. Drainage Structures

For Sections I.A and I.B (below), PA and EHP staff coordinate to determine whether a hydrologic and hydraulic (H&H) study is needed. Applicants must submit an H&H study to determine the appropriate culvert size with no adverse up or downstream impacts and National Flood Insurance Program regulations when:

- The facility is in a special flood hazard area;
- There is a potential adverse impact to the floodplain;[528]
- There is a potential adverse impact to a federally listed threatened or endangered species, critical habitat, or essential fish habitat;[529] or
- It is required to demonstrate compliance with the Clean Water Act.

A. Replace the structure with multiple structures or a larger structure. Applicants may use existing SLTT drainage criteria for sizing replacement culverts. Applicants must consider replacement structures with regard to the total drainage system.

B. For the purpose of erosion control, add properly designed entrance and exit structures, such as a headwall, wingwalls, flared aprons, or energy dissipation measures to increase efficiency and help to minimize scour and erosion. Depending on the severity of erosion, solutions for bank protection may include gabion baskets, rip rap, cast-in-place concrete, crushed stone or rock, grouted rip rap,[530] sheet-piling, geotextile fabric (for roads that were paved prior to the event), or similar measures to control erosion. Additionally, the use of nature-based solutions, which includes vegetation or a combination of vegetation and construction materials such as live fascines, vegetated geogrids, live crib walls, brush mattresses, root wads, or similar measures are eligible. Applicants should consider using eligible nature-

[527] 44 Code of Federal Regulations (C.F.R.) § 206.226(d).
[528] 44 C.F.R. §§ 9.11(d)(4) and 60.3(b)(7), (c)(10), and (d)(3).
[529] Endangered Species Act 16 U.S.C. §§ 1531-1544 and Magnuson-Stevens Fishery Conservation and Management Act.
[530] Projects involving grouted rip rap may be subject to an environmental assessment and may not be allowable in all instances.

based solutions such as bioswales, bioretention, rain gardens, and similar techniques that may be used in public drainage systems.

C. Culverts

1. Where the alignment of a culvert is inconsistent with existing water flow, realign the culvert vertically or horizontally or relocate the culvert to improve hydraulics and minimize erosion and scour. Applicants must consider realignment of structures with regard to the total drainage system.
2. Extend the culvert discharge to mitigate erosion and scour by extending the discharge end beyond the toe of the embankment.
3. Install a debris barrier to prevent debris blockage or fins designed to orient floating debris for passage through the culvert.
4. Install a debris barrier riser to allow debris to float up with the rising floodwaters without blocking flow into the culvert.

Example: Relief Culvert

Adding a relief culvert located at the same crossing site as a damaged culvert and in the embankment above the flow line of the primary culvert or located upstream of the main culvert. A relief culvert provides an alternate route for the flow if the main culvert is over capacity or gets plugged and prevents sedimentation through the high-flow scouring action.

II. Transportation Facilities

A. Bridges

1. Where traffic counts are low, replace with low-water crossings.
2. Install cables to restrain a bridge from being knocked off piers or abutments during floods or earthquakes.
3. Install girder and deck uplift tie-downs to prevent their displacement from the substructure.
4. Install Longitudinal Peaked Stone Toe Protection with nature planting, upstream of a failed abutment, to provide a stable floodplain bench for the protection of the abutment and the adjoining bridge approach. Consider other relevant nature-based solutions such as engineered logjams, log vanes or log bendway weir.

B. Marine pier ramps: If attached to decking, install open decking or floating decking with uplift-resistant tie-downs and fasteners.

C. Roadways and railways: Where shoulders are susceptible to overflow from adjacent water courses, stabilize shoulders and embankments with geotextile fabric (such as an erosion control blanket/rolled erosion control product (RECP) or a turf reinforcement mat) and revetments.

D. Roadways: Use geotextile drainage blankets between the pavement section and subbase to strengthen subgrade.

III. Mechanical, Electrical, Plumbing Components

A. Provide seismic bracing for electrical lines, conduit, piping, ductwork, water heaters, and other mechanical, electrical, plumbing (MEP) equipment.

B. Roof-mounted equipment: Secure to roof top via a continuous load path, using tie-downs, straps, or other anchoring systems that will resist expected wind forces.

C. Elevate or dry floodproof components or systems vulnerable to flood damage, including equipment controls, electrical panels; heating, ventilation, and air conditioning/machinery rooms; emergency generators; and fuel tanks. When wiring cannot be elevated, replace with equipment suitable for submerged applications.

D. Install switches, circuit isolation and/or quick connect capability to facilitate rapid connection of backup power for any damaged or susceptible mechanical and electrical components.

E. Install camlocks, transfer switches, and electrical panels to facilitate the connection of portable emergency generators.

IV. Pipes

A. Install pipe joint restraints, flexible piping at pipe/conduit connections, or replace pipes with more ductile material.

B. Install continuous lining or encasement to prevent infiltration or structural collapse.

C. Underground Pipes: Install shut-off valves so that damaged sections of pipe can be isolated.

V. Water/Wastewater

A. Pumps: If pumps and their attached motors are damaged by stormwater inundation, replace them with submersible or inline pumps as appropriate.

B. Sewer access covers: Elevate to the hydraulic grade line. When elevation is not feasible or practicable, install devices to prevent infiltration into access holes such as cast-iron watertight frames and covers.

C. Well systems: Seal exposed portions of well casing or raise the elevation of the well head to prevent infiltration of flood waters.

D. Raw water intakes: Install buttressing to prevent damage from erosion, scour, and flood debris.

VI. Electric Power Systems

A. Provide looped distribution service or other redundancies in the electrical service to critical facilities, such as hospitals and fire stations. This measure does not entail overall power grid capacity expansion.

B. Install surge suppressors and lightning arrestors.

C. Transformers:

1. Elevate pad transformers above the base flood elevation.
2. Support pole-mounted transformers with multiple poles.

D. Power poles:

1. Replace damaged poles with higher-rated poles (preferably two classes stronger) of the same or different material. When replacing poles with higher-rated poles, install guys and anchors to provide lateral support for poles supporting pole-mounted transformers, regulators, capacitor banks, reclosers, air-break switches, or other electrical distribution equipment.
2. Add cross-bracing to H-frame poles to provide additional strength.
3. Power lines: Add guy-wires or additional support.

VII. Storage Tanks

A. Anchor or otherwise protect from movement by strengthening or stiffening base connections.

B. Install self-initiating disconnects and shut-off values between tanks and distribution lines to minimize damage and leaks.

VIII. Buildings and Structures

A. For small support buildings subject to uplift or rollover from high winds, securely anchor the buildings to foundations to prevent toppling or becoming missile hazards.

B. Elevate, wet floodproof, or dry floodproof buildings. Dry floodproofing may include installing flood barriers. Wet or dry floodproofing may include nature-based solutions such as rain gardens, bioswales, constructed or restored wetlands that reduce flood risk. Nature-based solutions used alone however do not provide wet or dry floodproofing.

C. Footings: Where spread footings have been undercut by scour, underpin footings.

D. Siding: Replace with a stronger siding to prevent future disaster damage (e.g., wind, wildfire) with stronger attachments to the wall sheathing and structure.

E. Vents: Replace with water-resistant vents.

F. Non-structural building components: Brace interior walls, partitions, parapets, anchor veneer or cladding, suspended light features, drop ceilings, soffits, and other non-structural elements that could collapse and cause injury or block safe exit of a building during an earthquake or high-wind event.

G. Furnishings: Provide seismic ties, straps, or clips to secure replaced furniture, cabinets, computers, bookcases, and other furnishings.

H. For buildings and structures outside of the wildland-urban interface (where FEMA building code policy already requires these mitigation measures), create defensible space around facilities or structures with wildfire risk by removing or reducing the volume of flammable vegetation. The volume of vegetation should be minimized (e.g., hardscaping) by thinning or replacing flammable vegetation with less flammable, non-invasive species. Less flammable vegetation includes high-moisture plants, trees with low sap or resin content, plants with thick leaves, and drought tolerant vegetation. Native species are preferable as non-native options are less likely to withstand weather conditions, creating a fire risk.

I. For buildings and structures outside of the wildland-urban interface (where FEMA building code policy already requires these mitigation measures), non-combustible construction materials: Replace and upgrade construction materials with non-combustible alternatives for facilities with wildfire risk.

J. Roofs:

1. Install hurricane clips, fasteners, anchors, straps, and connectors that are compatible with the roof system and corrosion-resistant in coastal areas.

2. Strengthen the high-wind pressure areas (e.g., corner zones, roof soffits, overhangs).
3. Strengthen roof openings, such as hatches and skylights.
4. Low slope roofs: Replace and upgrade materials for entire roof covering with a fully adhered roof covering, such as a modified bitumen membrane roof. FEMA does not provide PA mitigation funding for loose laid insulation or membranes as punctures can cause large amounts of water intrusion. Additionally, FEMA does not provide PA mitigation funding for loose laid roof membranes with loose ballast stones as the stones can become projectiles in high winds and cause damage.
5. Gable roofs: Replace and upgrade materials for the gable-end framing with hipped roof framing to reduce wind forces (lower edge pressure; reduced projected wind area) and strengthen the roof framing.
6. Gutters and downspouts: Upgrade to direct water away from the structure to prevent interior or basement water damage.

K. Doors and Windows:
   1. Upgrade the weather stripping to prevent water infiltration.
   2. Replace doors, door frames, hinges, and hardware with wind-resistant units.
   3. Strengthen windows.
   4. Replace glass with impact-resistant material.
   5. Install shutters on windows:
      a. Of critical facilities, such as hospitals.
      b. On the lower floors of noncritical facilities most likely to be struck by debris.
      c. Of buildings with very high-value contents that can be damaged by water (such as libraries and document centers).
      d. Of buildings when failure of roofing materials or other portions of nearby structures could create impact hazards.

L. Replace impervious paved surfaces with permeable pavement alternatives. Alternatives include permeable concrete, porous asphalt, permeable interlocking pavers, plastic grid pavers, or other systems that enable water infiltration while maintaining structural integrity. Permeable pavement projects should include aggregate and geotextile fabric layers to meet project-specific requirements such as desired storage capacity, pavement strength, or subgrade composition. [531]

M. Construct new or install pre-fabricated tornado or hurricane safe room. Safe rooms must be part of the footprint of the facility that is being repaired due to damage caused by the declared incident. Safe Rooms should provide life safety protection and be designed to meet the design and construction criteria in *Safe Rooms for Tornadoes and Hurricanes* (FEMA P-361)[532].

IX. Signage

A. Replace sign panels and their supports with a stronger type of system of supports and panels. Consider using multiple support posts and stronger panels and fasteners.

[531] For more information, refer to: Stormwater Best Management Practice, Permeable Pavements | epa.gov.
[532] For more information, refer to: *Safe Rooms for Tornadoes and Hurricanes* (FEMA P-361).