A community’s lifelines are its infrastructure—the roads, bridges, water and power systems, services, and buildings that are vital to a community’s operation and quality of life. Maintaining these elements is crucial for economic, social and physical well-being.

Infrastructure has influence reaching far beyond the actual facilities. Coastal zones are the locations of oil and gas facilities that produce and distribute energy products throughout mid-America. Coastal harbors support commercial traffic between ocean and inland terminals. Infrastructure connects manufacturing and other businesses with regional, national, and international markets. Electric power generation, water supplies, wastewater treatment facilities, utilities and communication networks serve regional and local businesses and residents. Finally, the transportation network that coastal residents will use to evacuate when needed is likely the primary reason the term “lifeline” was coined. Hurricanes Katrina and Rita clearly illustrated these dependencies and what happens when infrastructure is damaged or destroyed.

Critical facilities (one type of infrastructure) are crucial to the health and welfare of the population and are especially important after extreme hazard events (FEMA, 2001b). If these facilities are flooded or otherwise disabled the community cannot function effectively, lives are lost, and recovery is hampered. This became painfully clear after floodwall failures, overtopping of levees, and storm surge from Hurricane Katrina. For all practical purposes New Orleans, St. Bernard Parish, and parts of St. Tammany and Plaquemines parishes in Louisiana and the southern quarter of Harrison, Hancock, and Jackson counties, Mississippi, were uninhabitable after the hurricanes. Public records were inaccessible or destroyed. Governments were forced to operate from facilities outside their jurisdictions. Structures burned and were beyond the reach of the fire departments because access roads and bridges were either flooded or damaged. Hospitals were unable to continue functioning or provide adequate care for patients.

The interconnectivity of our infrastructure can result in extreme coastal hazards having far-reaching long-term impacts. Coastal communities should adopt higher standards for infrastructure to make it resistant and resilient to coastal hazards. A community also should use the placement of infrastructure to guide or direct development away from the coastal high-hazard zones in order to maintain sustainability and a high quality of life.

**BASIC: RESPONSE AND REPLACEMENT**

Infrastructure with water-dependent uses must be located in or near the coastal zone. The basic level of management assumes that communities do the minimum to maintain infrastructure and wait to upgrade and repair damaged infrastructure until after a hurricane strikes, shorelines erode, or a tsunami inundates low-lying towns. Historically, elected officials and public administrators are pressured to address the immediate problems of most concern to the public. Governments are also pressured to respond quickly after disasters and are not usually held
accountable for advance preparations. Consequently, many decision makers take a short-range perspective, with a planning horizon that reaches to the next election; a few years in the future.

Complicating local preparations for future disasters is a reluctance to spend public funds for protection against events that may not occur in this lifetime. The recent failure to upgrade the levees and floodwalls protecting the New Orleans region prior to Hurricane Katrina testifies to the death, suffering, and enormous costs that result from taking only the minimum, basic steps for protection infrastructure. In addition, communities must recognize that even well maintained levees can be overwhelmed by flood levels that exceed the levee design level.

**Roads, Bridges, Culverts, and Public Utilities**

When new developments are built, the communities generally extend services to meet the demand. If a flood problem is reported, such as a washed out culvert, public works crews usually replace it in similar condition at public expense. As a result, flood damage increases as the years go by. Federal Executive Order 11988, Floodplain Management, actually requires new and replacement structures, when federal funding is involved, to be designed and built so as to cause no increase in flood elevations. Communities can avoid this problem by requiring that all replacement structures not increase flood levels. A better approach is to reduce flood levels and erosion.

![Bay St. Louis bridge and highway destroyed following Hurricane Katrina](image)

**Private Utilities**

At the basic level, local governments leave locating, extending, and maintaining services to the utility companies.

**Public Property**

Unfortunately, in some situations, public buildings damaged in a flood are not protected from the base flood when rebuilt. There are at least two reasons for this. First, the high value of the building means it takes a lot of structural damage to exceed the 50% substantial damage threshold required by the NFIP to require compliance. Second, many communities do not understand that, under the NFIP, public property must meet the same rules as private
development. Often public agencies do not seek or obtain building permits and place infrastructure wherever development occurs, without regard to the flood hazard.

If a public building in the regulatory floodplain is substantially damaged from any cause, its replacement must be protected from the base flood, under the NFIP standards.

**BETTER: PROTECTION MEASURES AND PROCEDURES**

A community using the better approach inventories the infrastructure exposed to damage from coastal hazards, takes steps to protect it in a timely manner, and sets protection standards for new facilities. Finally, maintenance and replacement programs have formal procedures that account for coastal hazards.

**Roads, Bridges, Culverts, and Public Utilities**

A community operating at the better level has an inventory and a plan to upgrade/mitigate the risks at their facilities including routine procedures for regularly examining the potential for damage to roads, bridges, culverts, and water or sewer lines. Often a culvert has been sized inappropriately or the road was not designed for high water. At the time of repairs, maintenance, or replacement, culverts should be enlarged and/or realigned to reduce future flood damage. Roads can be raised above the base flood elevation so they remain open for evacuation and response and recovery operations. If development has not yet taken place, roads and public utilities can be used to guide or direct development away from high-hazard areas.

**Public Property**

An inventory of all public buildings should be made to determine which are exposed to coastal hazards. With support from FEMA, the National Institute of Building Sciences (NIBS) has developed a natural hazard loss estimation methodology (HAZUS) that communities can use to access their hazard exposure. Public buildings at risk should be given a hazard audit to identify low entry points, warning times, and similar factors. Communities using this better approach can use the results of this audit to recommend steps the building owner can take to prevent future damage. At a minimum, a community at the better level should have wind and flood insurance (as well as fire insurance) on all public buildings and facilities in the [mapped] Special Flood Hazard Area and in any other known flood hazard areas.

Whether insurance was required or not, the community risk manager or appropriate office should be consulted about the buildings’ exposure to coastal hazards. An “all risk” insurance policy should be verified to determine if it specifically covers damage from flooding, storm (tsunami) surge, storm waves, and shoreline erosion.

The amount of disaster assistance a community receives for its damaged public buildings is reduced by the amount of insurance coverage (structure and contents) a community should carry on the building REGARDLESS of whether the community is carrying a policy.

Maximum flood insurance coverage amounts available from the NFIP are $500,000 for the structure and $500,000 for contents. After a disaster, public assistance funds will only reimburse a community for flood damages to an uninsured or underinsured building in the
mapped floodplain with structure and/or contents damage that exceeds the amount of coverage that should have been in place. In essence, disaster assistance for public buildings has a very large deductible equal to the NFIP flood insurance policy that should be carried on the building. Communities at the better level do not wait for the disaster to be caught short. They purchase insurance coverage for floods and other natural hazards that might damage or destroy their public buildings.

Critical Facilities

Public property often includes critical facilities that should be designed to not be compromised during a flood or hurricane. It is up to local communities to determine which facilities are critical to the community. Examples of critical facilities that many communities identify include:

- Structures or facilities that produce, use, or store highly volatile, flammable, explosive, toxic, and/or water-reactive materials;
- Hospitals, nursing homes, and housing likely to have occupants who may not be sufficiently mobile to avoid death or injury during a flood and that will need emergency services during and following the event;
- Police stations, fire stations, vehicle and equipment storage facilities, and emergency operations centers that are needed for emergency activities before, during and after a flood;
- Access roads and public and private utility facilities that are vital to maintaining or restoring normal services to flooded areas before, during, and after a flood;
- Water supply and waste water facilities that provide for public health and safety;
- Schools and evacuation centers; and
- Power and communications facilities and systems.
As with public property and private utilities, a community at the basic level may not devote any special attention to its critical facilities until after they are damaged. They may have been inventoried by the emergency manager and listed in a disaster response plan. Even if they have practiced mitigation such as elevating a fire station above the base flood, the apparatus may not be operational. If the surrounding streets are flooded, the operations units cannot leave the station.

Determinations of what constitutes critical facilities are also made by federal and State governments, and by corporations responsible for operating such facilities. After Hurricane Katrina, the White House recommended that the federal Department of Homeland Security work with the private sector to finalize an Interim National Infrastructure Protection Plan to better protect and quickly assess the impact of future disasters on critical infrastructure (White House, 2006).

Protecting critical facilities serves several purposes: it reduces damage to vital public facilities, it reduces pollution of flood waters by hazardous materials, and it ensures that the facilities will be accessible and operable during and following most flood emergencies. FEMA 543 is a useful design guide for critical facilities (FEMA, 2006b).

As with publicly owned buildings, it can be well worth the cost to conduct a flood audit to determine ways to protect the facilities through retrofitting or a flood protection project.

A community’s emergency manager should help the facilities managers prepare emergency action plans to ensure maximum protection during a flood or other coastal hazard event. Public response efforts should be coordinated with those action plans. For example, early flood warning should give public and private property owners enough time to move hazardous materials or sensitive machinery and equipment to high ground. The better community plans are tied to regular inspections and funding for repairs of any structural protection measures.

“The disruption of lifelines has a direct impact on the world’s regional economies and the health of its citizens. Therefore, it is important that we understand natural hazards, how they can impact lifelines, and what can be done to minimize the impacts when they occur” (ASCE, 2002, p. iii).

**NAI LEVEL: PLANS AND ALTERNATIVES**

Infrastructure, and the role of infrastructure in facilitating coastal development, has potentially adverse impact on neighbors and on the community. The range and consequence of such impacts should influence how the potential impacts are addressed. It is hard to imagine any more far-reaching impacts from natural coastal hazards than adverse impacts on others who depend upon infrastructure that has become damaged or destroyed. A major effort in following the NAI principle should be to improve the resistance of infrastructure to damage from coastal hazards and improve the resilience of infrastructure so that it recovers quickly when catastrophic events occur. A “liability audit” is recommended to assess situations for potential liability incurred by the providers of infrastructure (see Kusler, 2002).

Infrastructure can be thought of as a web containing sources, nodal points, and lines of linkage. A source may be a manufacturing plant, power plant, or a water treatment plant. A nodal point might be a regional distribution center for a business or a substation for an electric utility.
Highways and power transmission lines are examples of lines of linkage between sources, nodal points, and clients.

The intricate web of infrastructure can be made resilient in absorbing the adverse impacts of small events such as erosion in one location that causes closure of a coastal road. Alternate roads in the area can minimize the temporary disruption of local traffic. However, the adverse impacts of extreme coastal hazards like hurricanes, severe extra tropical storms, and tsunamis become cumulative impacts that cascade through communities and the region. The intricate web of possible interactions in the infrastructure can pose a challenge to those who attempt to improve resistance and resilience and isolate or minimize the unavoidable impacts from extreme events.

One lesson to be learned from the 2004 tsunami in the Indian Ocean and Hurricane Katrina on the Gulf Coast in 2005 is that, the FIRMs reflect moderate not extreme events. One way to reduce or eliminate the exposure of infrastructure to coastal hazards is to relocate facilities out of the hazard area (Pope, 1997). Relocation of roads, power lines, water and sewer lines, pipelines and small buildings may be more common, and more feasible, than relocation of large buildings.

**Rocks, Bridges, Public Utilities, Public Buildings**

Capital expenditures may include acquisition of land for public uses, such as parks, wetlands, or natural areas, and extension or improvement of roads, utilities, channels, and drainage structures. Many communities adopt a capital improvement plan and/or budget that specifies what will be built or replaced in the near future. A community using an NAI approach examines its plans and budgets to ensure that

- Major investments in new fire or police stations or emergency centers (and access to them) are not located in a Special Flood Hazard Area, a surge zone, or along a shoreline subject to erosion. If this is impossible such facilities should be sited where they will be accessible and operable during major (500 year) flood events. Significant protection measures (elevation, floodproofing) should be incorporated as a safety margin for the facilities themselves.

- Public services such as roads, sewer, or utility improvements do not encourage more development in a floodplain or coastal high hazard area. In low-lying areas or on islands where it is not possible to avoid siting emergency facilities in flood hazard areas. Such facilities are elevated and arrangements made with neighboring communities to ensure that emergency services can be provided if some facilities become temporarily inaccessible. Not installing water or sewer lines into a floodplain may not halt development, but it can deter it or result in less-dense development if the buildings must rely on wells and septic systems. Flood impacts, along with pollution impacts of septic systems, must be mitigated.

**Parks**

The best use of floodplains is generally considered to be open space. Keeping the area natural means no damage from flooding and no adverse impact on others. Communities using the NAI approach expand their ownership or control over open flood prone areas in order to maintain or enhance the natural and beneficial functions of floodplains.
Comprehensive plans and capital improvement programs in these communities ensure that areas subject to flooding now or in the future are preserved as open space by acquisition or purchasing conservation easements. With an easement, the owner may undertake some development and use of the property, but property taxes are reduced or a payment is made to the owner in exchange for an agreement to hold part of the property as open space.

Some areas where storm surge exceeds a selected depth can be identified as very high-hazard zones. Local governments should zone these as open space better set aside for recreational activities, integrated into the nonpoint pollution abatement system, or wetlands.

Areas included in a greenway plan can follow the water bodies and often starts with existing parks. Over the years, lands along the greenway can be purchased or developers can be encouraged or required to dedicate riparian land to connect the open spaces. Often developers view these parcels as undevelopable or too expensive to build on. (See also the regulatory approaches reviewed under “preserving important areas.”) The National Park Service and the Urban Forestry Program are two federal programs that will share the costs of creating green space and linking to other green spaces, especially in urban areas. Local governments facilitate Transfers of Development Rights (TDRs) to achieve greenways.

Greenways and waterfront parks in coastal watersheds have an added benefit over other types of open space. They attract people to the water. People learn to appreciate the natural and beneficial functions of the flood prone areas and develop an interest in protecting them. Many State coastal management programs support public access projects in coastal communities. These projects have included: developing public access guides or management plans; installing trails, observation platforms, fishing piers, boat launch ramps and educational signage; and enhancing amenities at existing access sites

**Critical Facilities**

Under the NAI approach, communities set higher regulatory standards for new critical facilities with the intent of not exposing them to flooding, surge, storm waves, or shoreline erosion. The federal regulations (44CFR60.22) state that “floodplain management regulations adopted by a community should prohibit nonessential or improper installation of public utilities and public facilities in flood-prone areas”. Executive Order 11988 requires federal agencies funding and/or permitting critical facilities to avoid the 0.2% (500-year) floodplain or protect the facilities to the 0.2% chance flood level.

At the No Adverse Impact (NAI) level, communities advance their thinking beyond protecting critical facilities to locating them outside the 0.2% (500-year) floodplain entirely. This not only helps ensure critical facilities remain operational but avoids the adverse impacts that construction, improvement, and even protection of these infrastructure facilities will have on other properties, the environment, and natural systems. NAI communities prohibit new critical facilities from the 0.2% chance floodplain unless there is absolutely no alternative (very small low lying community or island) and require existing critical facilities to be protected and accessible during a 0.2% chance flood and that contingency plans—perhaps a mutual support agreement with a neighboring community—are in place. Protection and accessibility could be extended to address surge or shoreline erosion. The Community Rating System provides credits to communities that take these actions.
Guidelines have been developed for owners/operators of oil and natural gas pipeline systems and electric power systems to use in dealing with earthquakes, floods, hurricanes, tornados, windstorms, icing, and ground displacements caused by landslides, frost heave, and settlement (ALA, 2005a; ALA, 2005b). The ASFPM, working with the American Public Works Association, developed a report of case studies that looked at how communities address flood hazards when planning, building and maintaining local road systems (ALA, 2005c). The APA (2005) has published a book on landslide hazards and planning.

There is a National Infrastructure Protection Plan (NIPP) that provides guidance in prioritizing infrastructure for protection (White House, 2006). The White House report notes that there is no supporting implementation plan to carry out protective actions during a natural disaster. The report recommends that the Department of Homeland Security, working with the private sector, revise the National Response Plan and finalize the NIPP to “rapidly assess the impact of a disaster on critical infrastructure…inform Federal response and prioritization decisions and to support infrastructure restoration” (White House, 2006, p. 61). The report also recommends a stronger Infrastructure Support Branch in the National Operations Center of the Department of Homeland Security to “coordinate with critical infrastructure sectors….and develop recommended preemptive and responsive actions to remediate or mitigate the impact of the loss of critical infrastructure” (White House, 2006, p.110).

**Risk Management of Infrastructure**

Risk management; a practice that is increasingly being applied to infrastructure (ASCE, 2002; ASCE, 2005; ALA, 2005d). Most of the work done to date has addressed flood and earthquake risks. There has been some work on risks from landslides but relatively little on risk management for other natural hazards that affect the coasts (ASCE, 1996). Risk management has been recommended as a standard practice in the design, operation, and maintenance of coastal facilities (Mockett and Simm 2002; Housley and Thompson, 2003). Risk management methods have been developed and used that cover the entire useful lives of facilities and projects of any kind, including infrastructure (U.K. Civil Engineers and Actuaries 1998, 2005).