ULI Resilience Program

White Paper Series

Resilience Strategies along the Rural–Urban Transect

Urban Land Institute

Center for Sustainability

About the Urban Land Institute

THE MISSION OF THE URBAN LAND INSTITUTE is to provide leadership in the responsible use of land and in creating and sustaining thriving communities worldwide. ULI is committed to

- Bringing together leaders from across the fields of real estate and land use policy to exchange best practices and serve community needs;
- Fostering collaboration within and beyond ULI's membership through mentoring, dialogue, and problem solving;
- Exploring issues of urbanization, conservation, regeneration, land use, capital formation, and sustainable development;
- Advancing land use policies and design practices that respect the uniqueness of both the built and natural environments;
- Sharing knowledge through education, applied research, publishing, and electronic media; and
- Sustaining a diverse global network of local practice and advisory efforts that address current and future challenges.

Established in 1936, the Institute today has more than 34,000 members worldwide, representing the entire spectrum of the land use and development disciplines. Professionals represented include developers, builders, property owners, investors, architects, public officials, planners, real estate brokers, appraisers, attorneys, engineers, financiers, academics, students, and librarians.

ULI relies heavily on the experience of its members. It is through member involvement and information resources that ULI has been able to set standards of excellence in development practice. The Institute has long been recognized as one of the world's most respected and widely quoted sources of objective information on urban planning, growth, and development.

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About the ULI Urban Resilience Program

THIS PAPER HAS BEEN PRODUCED AS PART OF THE URBAN LAND INSTITUTE'S Urban Resilience Program, which is generously supported by the Kresge Foundation and the ULI Foundation. The Urban Resilience Program works to help communities prepare for increased climate risk in ways that allow not only a quicker, safer return to normalcy after an adverse event, but also an ability to thrive going forward. Through careful land use planning, wise investment in infrastructure, and smart building design, we can protect the value we have created in our cities and make them more robust when facing adversity.

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Overview

This paper provides public and private decision makers a guide for identifying and prioritizing actions leading to increased resilience in the built environment. Although not an exhaustive discussion on the topic, the paper discusses the implications and potential effects of extreme weather events based on the location of a single property or an entire community along the rural-to-urban continuum.

This paper serves as a companion to two other recent publications by Urban Land Institute on the subject:

- *Resilience Strategies for Communities at Risk* (2014)
  This paper provides 23 recommended strategies for communities to build resilience, categorized as land use and development; infrastructure, technology, and capacity; finance, investment, and insurance; and leadership and governance.
- *A Guide for Assessing Climate Change Risk* (2015)
  This paper summarizes the process of risk assessment and provides guidance to local governments for how to understand risk in their communities.

Resilience across the Rural-to-Urban Transect

Resilience has taken on increased prominence as both a concept and a design strategy relative to the built environment. The Urban Land Institute has joined with a number of other industry partners in a shared statement defining *resilience* as the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events. Through its work in the real estate and land use sector, however, ULI has established a more proactive definition. In its initial 2014 report, *Resilience Strategies for Communities at Risk*, ULI suggested that resilience is "the ability not only to bounce back but also to 'bounce forward'—to recover and at the same time to enhance capacities of the community or organization to better withstand future stresses."[1]

Resilience continues to gain emphasis in real property and community planning sectors as recurring headlines highlight extreme weather events. Whether historic drought in California or record snowfall in Buffalo, New York, the array of extreme weather events touches every corner of the United States, affecting communities large and small. Although climate change and its imminent effect on weather patterns were presaged over two decades ago, the fact that extreme weather events are occurring with increased frequency and intensity is raising awareness and concern about where and how we build. The United Nations Intergovernmental Panel on Climate Change, in its *Climate Change 2014 Synthesis Report*, indicates that "for countries at all levels of development, . . . impacts [from climate-related extremes] are consistent with a significant lack of preparedness for current climate variability in some sectors."[2]

A community cannot say it has achieved resilience at any point in time. Instead, resilience exists along a continuum of action and constant evolution. The concept, operating in the same manner as concepts such as sustainability, accessibility, healthy community design, and fiscal responsibility, should function as yet another lens through which a community or a developer makes planning, physical design, and ongoing operations decisions.

High-profile events such as Hurricane Katrina in 2005 and Superstorm Sandy in 2013 brought into question our understanding of resilience as a fundamental component of the built environment, foregrounding its importance when making investment, design, planning, and community-support decisions. The need for resilience, however, is not limited to big cities. Unlike larger metropolitan areas, small towns and rural communities may have a greater need to proactively consider their resilience because of a comparative lack of financial and human resources necessary to address forward planning and provide emergency response. Resource availability and the need for resilience planning may, in fact, be inversely related along the rural-to-urban continuum.

Using the Transect to Guide Resilience Planning

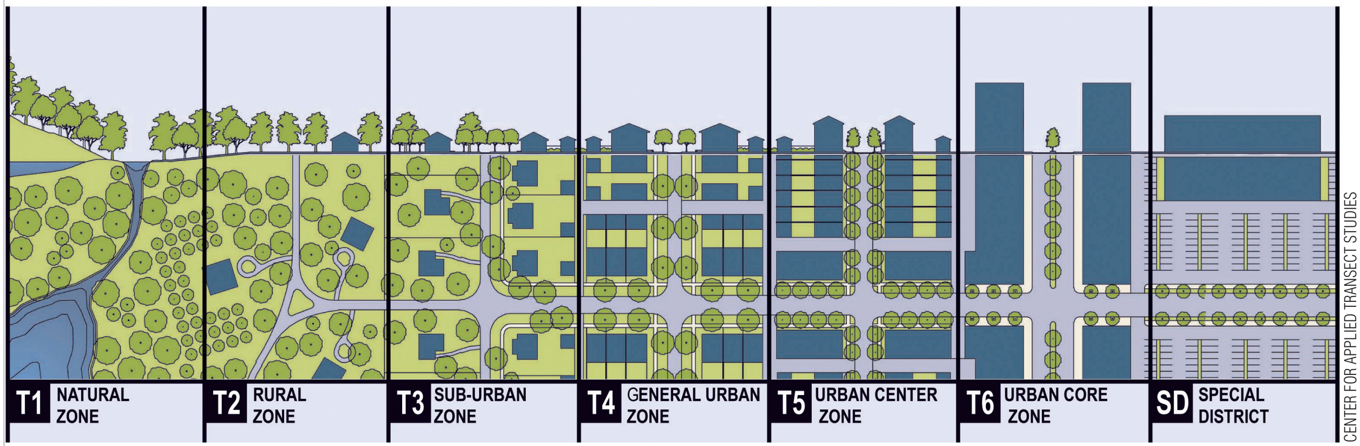
Regardless of community size, the location, concentration, and intensity of development (throughout the community as a whole or in various neighborhoods and districts) play an integral role in resilience planning.

To facilitate an understanding of these factors, the rural-to-urban transect is a planning tool that organizes human settlement patterns along a continuum from undeveloped natural areas to dense urban cores.3 Much in the same way that ecologists organize plant and animal communities—classifying key characteristics of habitat, maturity, and diversity—the transect, advanced a decade ago, can help planners identify characteristics and indicators that are relevant in categorizing communities along different points of the rural-to-urban continuum.

The transect evaluates density, building form, infrastructure systems, and ecological systems. It is composed of six "Transect Zones" or "T-Zones":

- T1 Natural Zone—land that is undeveloped and largely in its wild state;
- T2 Rural Zone—sparsely settled lands in open or cultivated state;
- T3 Suburban Zone—low-density residential areas, adjacent to higher zones of mixed use;
- T4 General Urban Zone—primarily residential urban fabric, but inclusive of mixed uses;

The transect is a planning tool that helps categorize different development patterns by shared characteristics. The six zones of the rural-to-urban transect are shown here.



- T5 Urban Center Zone—higher-density, mixed-use buildings that accommodate retail, offices, rowhouses, and apartments; and
- T6 Urban Core Zone—highest density and height, with the greatest variety of uses, and civic buildings of regional importance, typically found only in large towns and cities.

Decision makers and developers can use the transect to guide resilience planning, thereby helping them understand what solutions may be most relevant—in terms of both appropriateness and cost-effectiveness—to define critical issues and potential tools that are location based.

For example, the list of potential strategies for addressing runoff-induced flooding of rivers and streams can vary from a rural area to an urban area. Development in a T2 Rural Zone—where densities are lower and land is more readily available (and typically less expensive)—has the potential to act broadly within support of the floodplain. Restricting land use to create clearly defined "no-build areas" and incorporating land into recreational areas, open space, or wildlife preserves can provide stormwater detention for extreme rain events. In such T2 zones, the best solution may be to let rivers function as rivers, precluding potential development in critical storage areas and removing barriers to natural flooding—a process necessary for healthy ecosystems and natural resilience. If lands are properly set aside and designed assuming periodic flooding, letting a river be a river within T2 areas will reduce damage farther downstream, where development and land costs are likely to be greater. This approach is a cost-effective alternative to highly channelized or armored strategies and actively contributes to ecosystem health and community livability. The reduced cost of protecting downstream properties using a natural systems approach may in turn provide a creative mechanism for funding upstream land acquisitions.

Resilience in Practice

In Louisa County, Iowa, farmers tired of repeated flood damage to their properties from the Iowa River decided to participate in a federal buyout program of their affected land. Since the 1910 building of levees in this area, the river had flooded 17 times by 1993.

Recognizing the long-term cost savings of the buyout, state and federal agencies and foundations collaborated to secure enough funding so that the farmers received a fair price for their land to relocate to non-flood-prone areas. At the same time, the program cost 50 percent less than levee repair, payment for damages, and subsidies.[4] In turn, the levee district was dissolved, and the 2,500-acre Horseshoe Bend division of the Port Louisa Wildlife Refuge was created. The refuge has allowed improved floodwater storage, restoration of riverine wetlands, and improved wildlife habitat and fisheries, all while better protecting communities downstream.

Greater white-fronted geese and mallards at the Port Louisa National Wildlife Refuge.

JESSICA BOLSER/USFWS

In urbanized areas (T4–T6 zones), riverbanks are necessarily more constrained, bounded by higher levels of development and land price. Flooding in a T4–T6 area has the potential to generate increased property damage, while the cost to restrict development may be prohibitive. In this context, resilience planning may require a holistic approach to the entire hydrologic cycle. Rather than simply focusing on the river corridor, treating the entire stormwater system—from green roof attenuation to parking-lot surface retention, roadways designed to infiltrate and detain excess rain in high-precipitation events, and so on—may need to become part of a more complex and highly integrated approach to resilience.

Vancouver, British Columbia, recommends nine primary actions in its strategy for climate adaptation.[5] One of these actions is to "complete and implement a citywide integrated stormwater management plan." This action includes three subactions:

- Planning and design approaches, such as limits to impermeable surfaces;
- Runoff storage and conveyance, such as using pocket parks for street runoff, rerouting stormwater to water bodies, or nonpotable water storage/use; and
- Infiltration and detention practices such as green roofs, street infiltration bulges, or downspout rock pits.

Resilience in Practice

In California, San Jose's three-mile Guadalupe River Park is a major public recreation and quality-of-life feature that also greatly improves the capacity of the river to handle increased runoff caused within its T5 setting.

In Pennsylvania, the University of Pennsylvania's 24-acre Penn Park transformed a parking lot at the intersection of major highway and mass-transit infrastructure into a center for active recreation and open space in West Philadelphia.[6] Situated within the floodplain, the park uses berms and underground cisterns with 300,000 gallons of storage to reduce and contain stormwater runoff.

MICHAEL PATRICK

Guadalupe River Park, San Jose, California.

Applying Resilience Strategies to Zones along the Transect

Across rural, suburban, and urban communities, climate-induced hazard events create a wide range of effects that often reveal a community's vulnerabilities. At the same time, hazard events can expose a community's capacity to move through and beyond emergency response needs effectively and efficiently. Distinctions between rural, suburban, and urban communities—their settings, density of development, configuration of infrastructure, economic base, and so on—point to a need for different priorities and potentially different solutions when planning for resilience.

T1—Natural Zone

Protecting and actively maintaining undeveloped and wild lands should be an active strategy for communities and developers planning at the threshold of natural zones. As previously discussed, these lands can be a vital part of an area's overall ecosystem, and maintaining their integrity can serve to buffer nearby development from the effects of hazard events.

To facilitate this type of planning, national nonprofit the Model Forest Policy Program works with communities to create actionable climate adaptation plans. The organization worked with Marquette County, Michigan, and the Superior Watershed Partnership and Land Trust, a regional nonprofit, to create a forest- and water-focused climate adaptation plan, assessing resource risks and vulnerabilities and their potential effects on community well-being.[7] Together, the group was then able to develop an action plan in support of clear resilience goals. The following objectives effectively considered development and conservation:

- Revising conservation subdivision regulations to create incentives for developers to provide greater densities and community services, while achieving open space conservation;
- Protecting critical watershed features with enhanced land use, including planning, zoning, acquisitions, and easements, especially river corridors and floodplains to preserve vegetation, retain hydraulic features, and ecological services; and
- Implementing a Marquette County Purchase of Development Rights program to secure lands from development.

Recognizing that natural areas support developed areas in a symbiotic manner, and how to optimize that relationship, is a critical aspect of resilience planning.

T2—Rural Zone

With more than 84 percent of land area in the United States classified as rural, these sparsely inhabited areas are associated with higher rates of poverty[8] and often rely on a singular industry—agriculture, forestry, tourism, or outdoor recreation—that can be highly vulnerable should a hazard event such as flooding, drought, wildfire, or mudslides occur. Higher rates of age-adjusted mortality, disability, and chronic disease in rural areas, when compared with urban populations, are also likely to be exacerbated by climate change.[9]

For rural zones, the resource capacity to plan for and respond to extreme weather events represents one of the greatest challenges. In 2014, the National Climate Assessment (NCA) found that 73 percent of metropolitan counties have land use planners, compared with 29 percent of rural counties not adjacent to a metropolitan county.[10] The community of Waterbury, Vermont (population 5,000), had a municipal staff composed of three professionals, five office employees, and ten members of its highway crew when Hurricane Irene hit in 2011. After eight inches of rainfall in a 12-hour period, flooding from the Winooski River damaged 220 homes and businesses, displacing the municipal offices, the police department, the Vermont State Hospital, and the Waterbury State Office Complex, which employed 1,500 people.

What small communities lack in professional resources, however, they often make up for in community resolve and social connectivity that can be harder to replicate across larger-scale communities. Following Hurricane Irene, Waterbury residents and town leaders used the elementary school as a makeshift command center to organize volunteers who helped rescue stranded residents and animals, shut down wastewater pumping stations, and managed debris.[11]

Rural populations are comparatively dispersed and physically isolated, often relying heavily on private vehicular transportation for everyday activities. Transportation networks available in rural areas, which are predominantly composed of roads used for personal and commercial vehicles, may have limited connectivity or redundancy because of the cost and feasibility of navigating difficult terrain combined with comparatively minimal use. During a hazard event, impacts to this infrastructure can lead to particular difficulties in providing emergency response.

During a devastating flood in 2013, the community of Estes Park, an outdoor recreation destination in northern Colorado, lost its primary vehicular connection to neighboring communities on U.S. Highway 34. As a result of this lost connection, Estes Park hospital staff had to be shuttled by helicopter to the hospital to meet medical needs.[12] With an in-town population of 5,900 and a volunteer, resident-run town government, costs to maintain this and supporting services amounted to $700,000 for one month. This amount represents approximately 5 percent of the town's annual budget.


A house damaged by the 2013 flood in Estes Park, Colorado.

For communities in rural, suburban, and urban areas, planners and developers should assess infrastructure assets, including power, water, transportation, communications, and emergency services infrastructure that may be vulnerable to a hazard event. Particular considerations for areas in the T2 zone include the following:

- Establishing connectivity, redundancy, and alternate means of access into and through the community;
- Prioritizing and safeguarding accessible emergency services within the community should outside access be lost;
- Self-organizing volunteers and community members to fulfill roles that might otherwise be filled by professional staff in larger communities; and
- Educating constituents on potential effects of climate-induced events, such as prolonged drought, wildfires, flash flooding, and extreme heat or cold, and offering preparedness measures.

T3—Suburban Zone

Although suburban communities generally possess a comparatively greater capacity to plan for and respond to extreme weather events by virtue of their proximity to urban centers, this position—at the interface between an established city and more natural surroundings—can create an equally precarious position when a hazard event occurs.

Many suburban communities (often considered bedroom communities to neighboring urban areas) are typically without a dominant industry or centralized source of employment. As a result, their residents rely on transportation infrastructure to get to and from employment and for everyday activities. In suburban communities surrounding major cities, regional responses to extreme weather events may face longer delays for restoration of services, because resources get allocated first to those areas with the highest density of jobs and residents. New Jersey Transit rail service was not fully restored for 11 weeks after Superstorm Sandy, whereas the majority of New York's Metropolitan Transit Authority transit network was restored within a week after the event.[13] During that time, many employees commuting to New York from New Jersey faced heavy delays in alternative forms of transportation, often leaving up to two or three hours earlier to arrive at the workplace and adding to congestion and complications in an already overtaxed transportation network.

Compromised access to employment cores may be common in both inner-ring and outer-ring suburbs during hazard events. At the same time, outer-ring suburbs are also on the front lines of wildfire, landslide, and mudslide risks by virtue of their position at the threshold between urban and natural environments. Wildfires in Texas that occurred between 2010 and 2011 revealed that 14,506 communities in 254 counties were at risk, with state and local fire departments bearing $327 million in costs.[14] In these communities, homes located within 50 feet of each other can increase the risk of structure-to-structure ignition in wildfire areas, thus discouraging density and perpetuating development tendencies toward sprawl.[15]

At the outer edges of North Salt Lake, Utah, a developer requested to vacate the ongoing development of Eaglepointe Estates following a landslide in August 2014 that wiped out one home and damaged a nearby tennis club and three to four lots. The landslide was apparently triggered by heavy rainfall and has left the future of adjacent, occupied properties in question. The event has called into question the type of development North Salt Lake can continue to allow.

Planners and developers should focus on the following issues when considering resilience in the T3 zone:

- Diversifying economic drivers to promote quicker recovery when a hazard event compromises access to employment centers;
- Developing alternative and redundant transportation methods to access employment centers;
- Developing robust telecommunications networks to support telecommuting when transportation routes or employment centers are inaccessible; and
- Developing communication protocols for keeping community members informed on service access and recovery efforts.

T4 to T6—Urban Zones

Urban zones, as population centers and economic hubs, have significant risks and needs to plan for resilience. However, these areas generally have greater professional capacity to plan for and respond to hazard events.

Cities across the country face a full range of hazard event types. Given the age and complexity of urban infrastructure, infrastructure resilience may be the most critical component of resilience planning in the T4–T6 zones. The 2014 NCA notes that "essential infrastructure systems such as water, energy supply, and transportation will increasingly be compromised by interrelated climate change impacts" in urban settings, where "climate-related disruption of services in one infrastructure system will almost always result in disruptions in one or more infrastructure systems."[16]

Superstorm Sandy left many communities without power for an extended period.

TANENHAUS

Widespread loss of power in cities, for example, immediately affects public health, transportation, and business operations. These effects are felt across entire metropolitan areas and, by extension, in the national economy. Although the recovery response rate in urban areas may often appear to be more rapid than in suburban or rural communities because of these effects, the ability to make critical decisions and remain agile during a hazard event can be hindered by a comparative increase in government bureaucracy and a lack of interagency or interdepartmental coordination. As a result, large-scale city agencies and utilities often experience unanticipated, on-the-ground indirect effects.

In the Brooklyn neighborhood of Red Hook in New York City, high-rise, elevator-accessed public housing buildings without power during Hurricane Sandy left many elderly and disabled residents stranded. Residents requiring regular medication and attention were without a means to communicate and fulfill their needs. Absent an organized response by city agencies, community groups in Red Hook organized volunteers to go door-to-door throughout the neighborhood, identifying whether or not residents were still in their units and, if home, whether they required medication or medical attention.

Low-income residents are often disproportionately affected by hazard events. In a report prepared by the Center for American Progress, low-income residents who were displaced from their homes often found that they were unable to afford replacement housing in the same community. Close to half the 86,000 affordable rental units in New Orleans were lost as a result of Hurricane Katrina, "[creating] a situation where costs soared for those units that were available."[17] With high replacement costs and significant development constraints, the number of new affordable units is significantly lower than before the hurricane: for 5,000 units of public housing demolished, 800 new units were constructed.[18]

The density that makes urban zones function as thriving economic engines can also make them challenging during times of extreme weather events. The sheer number of people in the midst of a crisis requires an ongoing, widespread communications approach that carefully considers how residents access information. Clear protocols and formats should be established well in advance of an event; complex and redundant communication networks are a critical operational element that cannot be created spontaneously.

Considering the higher levels of density in T4–T6 zones, planners and developers should focus on the following issues when considering resilience in this setting:

- Identifying specific infrastructure vulnerabilities, and developing contingency plans for rerouting or adapting systems to compensate, should a failure occur;
- Creating and maintaining redundant communication networks to maximize community access to regular and accurate recovery and service updates; and
- Establishing on-the-ground, neighborhood-level support protocols to provide more effective recovery and service access and communications.

Approaches to Resilience

For municipal leaders, community planners, and asset managers, knowing where and how to start to develop a resilience strategy can be overwhelming, especially if the community or portfolio has yet to face significant effects. A number of tools and resources are available to assess potential risks, which are largely driven by geography and the characteristics of the built environment. These tools and resources are highlighted in "The Geography of Risk."

The Geography of Risk

Although hazard events often seem random in the precise locations where they occur, the prevalence of particular hazard event types may be organized broadly by large-scale regions, according to the U.S. National Climate Assessment (NCA).[19] These regions are categorized as follows:

- Northeast;
- Southeast;
- Midwest;
- Great Plains;
- Southwest;
- Northwest;
- Alaska;
- Hawaii and Pacific Islands;
- Coasts; and
- Oceans.

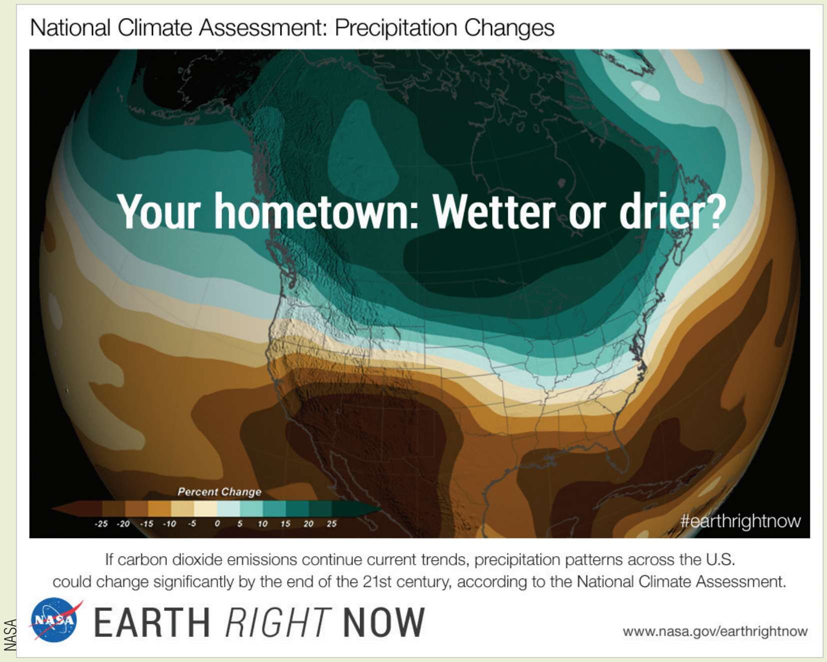
Within these regions, multiple hazard event types may be evident. The following hazard event types are potentially affected by climate change:

- Increased rainfall;
- Flooding;
- Landslides and mudslides;
- Drought and wildfires; and
- Extreme temperatures.

Increased rainfall, leads to **flooding**, which can cause a variety of damages to property, infrastructure, public health, and safety, often disrupting business and municipal operations for protracted periods.

Although the occurrence and intensity of severe precipitation events has increased throughout the United States, according to the 2014 NCA, the Northeast has experienced a greater recent increase in extreme precipitation than any other region in the United States.[20] *Extreme precipitation* is defined as the top 1 percent of storms, measured by the amount of precipitation in a 24-hour period. Between 1958 and 2010, the Northeast saw a 71 percent increase in the amount of precipitation falling in very heavy events.[21] By comparison, the Midwest experienced a 37 percent increase in extreme precipitation between 1958 and 2007.[22] The Southeast is expected to see greater incidences of extreme precipitation as a result of hurricanes, while the Great Plains are expected to see greater incidences of extreme precipitation as part of increased seasonal fluctuations throughout the year.

The Northeast will see more frequent heavy rain events in the future whereas the Southwest will get drier.



NASA

As an outgrowth of increased, severe rainfall, **landslides** and **mudslides** can suddenly and dramatically alter communities, displacing residents, destroying transportation infrastructure, and posing significant safety risks. Landslides and mudslides can occur in areas of unstable, steep slope. Although they can occur throughout the country, the U.S. Geological Survey indicates that the country's major mountain ranges—the Appalachian Mountains, the Rocky Mountains, and the Pacific Coastal Ranges—as well as some parts of Alaska and Hawaii have severe landslide problems.[23]

Droughts cause domestic water shortages, increase the potential for brownouts and blackouts, significantly affect agricultural economies, and can transform vulnerable landscapes into deserts. Ecosystems, stressed by a lack of rainfall, can experience insect outbreaks that can kill large stands of trees, exacerbating the potential for **wildfires**. Increased incidences of wildfire, in turn, leave areas vulnerable to **flash flooding** when rain ultimately arrives. Throughout this cycle, property and safety risks are ever present.

Whereas increased rainfall and incidences of landslides and mudslides are often immediately recognizable, the onset and duration of a drought is harder to clarify. Nevertheless, the National Climatic Data Center reports the United States has suffered 21 droughts from 1980 to 2013 that have resulted in damages of $202 billion.[24]

Incidences of drought are particularly evident in the Southwest, stretching along the southern Plains and up the West Coast. For the Southwest, as the nation's largest producer of water-intensive, high-value specialty crops, water scarcity may compromise the livelihoods of rural farmers through displacement. California's ongoing drought is expected to cost $2.2 billion in agricultural losses in 2014 alone.[25] In the southern Plains, rates of water loss in 2011 were double the long-term average.[26]

Unfortunately, increased incidences and severity of droughts may be expected as average temperatures continue to rise, increasing the likelihood of wildfires. Although wildfire management techniques such as prescribed burns can be used in areas that are sparsely populated, development that continues to progress beyond urban and suburban centers into forested areas faces increased property and safety risks.

Of all hazard event types, **heat waves** are the most deadly in the developed world.[27] In the summer of 2003, the deaths of more than 35,000 people were attributed to a heat wave in western Europe. Heat waves and increasing levels of insolation tax mechanical cooling systems and local energy grids, resulting in brownouts and blackouts that pose health risks for vulnerable populations, safety risks, and a wide variety of threats to public and private operations.

As previously discussed, rising temperatures are also related to increased incidences and severity of droughts and their resultant effects. In addition to the regions affected by droughts, higher temperatures in the Southeast contribute to the formation of harmful air pollutants and allergens and reduced livestock productivity and crop yields.[28] In the opposite corner of the country, the NCA notes that "[o]ver the past 60 years, Alaska has warmed more than twice as rapidly as the rest of the U.S., with average annual air temperature increasing by 3°F and average winter temperature by 6°F."[29] For indigenous coastal communities, the rising temperatures are already causing displacement.

Rising temperatures, increased precipitation, and acidification of water bodies can threaten natural assets and ecosystems that provide diverse food sources and fuel tourist economies, indirectly affecting community livability and property value. In New England, rising sea temperatures are anticipated to cause lobsters to migrate farther north, while in some beach communities, more coastal ocean areas have seen a higher presence of shark attacks, directly or indirectly affecting local tourist economies.[30]

Across hazard event types, regional trends in incidences and severity are helpful orienting devices for broad consideration. Ultimately, these effects are only fully digested at the local level, where they pose unique challenges for communities of different forms and densities.

Resilience planning is most effective when findings and strategies are aligned systematically throughout visioning documents, planning tools, development strategies, and regulations. Resilience planning techniques should adapt as opportunities and challenges arise for particular communities and properties, because resilience is a constant process of review and evaluating actions. The importance of anticipating extreme weather events by adopting resilience strategies within planning documents and zoning regulations cannot be understated. Resilience is not intended to be a disaster relief strategy, but a proactive effort to relieve pressures when an extreme weather event arrives and to bounce forward.

Planners and property developers can consider the process of resilience planning through five general approaches: *avoid, anticipate, adjust, armor,* and finally, *accept*.

Risk and Probability: The 100-Year Storm Is Not *the* 100-Year Storm

Weather events such as storms and floods are frequently referred to in terms of their return period: "the 50-year flood," "the 100-year storm." However, this designation is misleading, because the return period really refers to the event's expected probability in any year, not to how long it may take to return. Just as a lucky dice player might roll two sixes in a row, despite the 16 percent probability of rolling a six on each throw, so might an unlucky community face two 100-year storms within a 20-year period. The probability of such independent weather events is given by what is known as a binomial distribution. For example, the following table shows the results of the distribution for the probability of a certain number of 100-year storms (0.01 probability in any year) over a 100-year period:

LIKELIHOOD OF A 100-YEAR STORM

Number of storms in 100-year period	Probability (%)
0	36.6
1	37.0
2	18.5
3	6.1
4	1.5

As expected from the name, the most likely scenario, at 37.0 percent probability, is one 100-year storm in a 100-year period; however, almost as likely is seeing no such storms at all. Perhaps more alarming are the probabilities of seeing more than one such storm—a roughly 26 percent chance of seeing two or more of these serious storms in a 100-year period.

If one looks at the probability of seeing the 100-year storm over any 20-year period, the results are also instructive.

LIKELIHOOD OF A 100-YEAR STORM

Number of storms in 20-year period	Probability (%)
0	81.8
1	16.5
2	1.6
3	0.1

Although 81.8 percent of the time one would not expect to see a 100-year storm, a 16.5 percent chance—almost one in six—exists that one of those storms would happen in any given 20-year period. In addition, do not forget the small but certainly not zero chance of seeing two of these storms in a given 20-year period.

Planning for risk of extreme weather events is challenging enough, but it must be based on an understanding of the actual risks and probabilities of occurrence—not confused by the shorthand language used to describe such events.

Avoid

A greater understanding and appreciation of natural systems and their dynamics should allow communities and developers to avoid placing assets in harm's way. This approach may require updating zoning and general plans to restrict development in floodplains and key coastal areas or identifying zones with high potential for damage from wildfires fueled by buildup of organic detritus or drought. For property developers, acquisition criteria should place increased importance on selecting locations that avoid critical risks associated with the likelihood of climate-induced impacts.

Many regulatory tools currently in use do not reflect this approach. Following significant floods in the summer of 2014, Toronto, Canada, is now grappling with how to best update land use and zoning codes to reflect findings that what used to be its 100-year flood may now happen with much greater frequency.[31]

Anticipate

Programmatic risk evaluation requires a deliberate and ongoing process to evaluate how potential events might affect operations and recovery time. Services and operations that often go unnoticed on a daily basis become increasingly visible in their absence following an event. Food supply chains, fresh water, transportation, and telecommunication systems can break down because of power loss during an event and take weeks to reestablish.

With this in mind, two questions are necessary to consider:

- How can a community or property operate as efficiently and successfully as possible during a hazard event, with minimal physical damage as well as minimal health and safety risks?
- How can a community or property prepare to return to normal functionality as quickly as possible?

In the cases of Superstorm Sandy and Hurricane Katrina, many buildings lost functionality early because electrical systems housed in their basements were flooded. Although backup generators were in place to supplement power in the event of a grid failure, flooding of switchgear and vital components was not anticipated. More important, even if the components had not flooded, transportation and logistical networks also broke down, precluding the ability to access necessary gasoline to run the generators.

For coastal communities and properties of all scales facing flooding through a combination of extreme weather events and sea-level rise, detailed mapping of coastline elevations can be a key data tool offered at the state level. In Florida, a $29 million Statewide Regional Evacuation Study Program was launched with the immediate goal of improving evacuation procedures for hurricanes, but ultimately it informed traffic, housing, and community improvements.[32]

Communities and properties facing landslides and mudslides as a result of increased rainfall should evaluate at-risk areas by updating slope and geotechnical maps, while communities facing higher temperatures and drought conditions may consider evaluating vulnerable forests for wildfire risk.

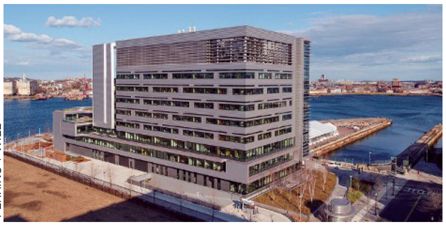
The process of *scenario planning*—exploring what might happen to a community or property in a range of potential extreme weather events of different intensities—can help illuminate potential gaps and risks that might be addressed by thinking differently about a building's design program, spatial organization, or day-to-day operation.

Adjust

When programming for new construction or planning a major renovation, the adjustment process requires putting into new designs considerations raised through the anticipation phase. Consider these examples:

- New York University's Furman Center issued a report following Hurricane Sandy describing the city of New York's building code revisions.[33] Now, all living space and mechanical systems in new residential construction are to be located above what is known as the Design Flood Elevation (DFE). The DFE is a higher elevation than the Base Flood Elevation used by the Federal Emergency Management Agency (FEMA) and varies by flood zone. Only parking, building access, storage, and crawlspace enclosures are allowed below the DFE, and any enclosed spaces must be wet floodproofed.[34] Only flood-damage-resistant materials can be used below the DFE, and all utilities, including electrical, heating, ventilation, plumbing, and air-conditioning equipment, must be located above the DFE.
- Recalling the disastrous challenges faced by hospitals following Hurricane Katrina, the design for New Orleans's new Veterans Administration hospital has been adjusted for lessons learned, including placing electrical distribution systems on the fourth level to avoid potential shutdown caused by future floodwaters. The building was also programmed to house a 6,000-square-foot warehouse to store provisions needed to sustain operations and habitation for up to five days without outside support.
- After watching scenes of patients throwing chairs through their hospital windows in New Orleans after air-conditioning systems failed, causing unbearable temperatures inside, Partners HealthCare in Massachusetts required that its new hospital building include operable windows.

Although these examples represent practical, building-level responses, broader regional initiatives are important to consider as well. In the suburbs of Atlanta, Georgia, DeKalb County's sanitation department makes electricity from its landfill emissions. When a brownout hit the community in 2007, residences retained power through this alternative source.[35]


PERKINS + WILL

In response to lessons from Hurricane Katrina, the Spaulding Rehabilitation Hospital in Charlestown, Massachusetts, was designed with resilience in mind.

In rural communities that thrive on agriculture, threats to food production as a result of drought have inspired farmers to practice innovative water conservation techniques. In the region surrounding San Diego, California, farmers are "some of the most water-wise in the state, lining canals and using drip irrigation and micro sprinklers to spread the valued resource," with the goal of providing San Diego with 37 percent of its water.[36] Anticipating wildfire, Santa Fe, New Mexico, is investing in forest management techniques to thin growth and plan prescribed burns so that effects are minimized.

Armor

A less desirable and more costly strategy for resilience is to armor facilities. When all other routes are exhausted, or when facilities are mission critical—such as airport runways, primary community ingress and egress routes, energy, telecommunications, water and wastewater infrastructure—armoring may be the only option. For areas with high property value, the increased costs associated with armoring could still be financially cost-effective.

Following devastating floods in 2013, the community of Estes Park in northern Colorado incurred significant health and community risks when one of its neighborhoods lost a primary sewer trunk line to the community's wastewater treatment plant. Nearby Loveland barely escaped complete loss of its potable water supplies as the last of three transmission lines stayed intact against raging floodwaters. With limited options to reroute these trunk lines, both communities will need to invest in significant armoring of the lines to prevent a reoccurrence of risks to the community.

Accept

Finally, acceptance of potential or continued loss may be a difficult concept for residents, or those involved in operating communities or properties, but when costs and benefits are weighed, acceptance may simply reflect the price of living in harm's way.

When the town of Estes Park lost its primary vehicular connection to neighboring communities on Highway 34, it was rebuilt at significant public expense following a 1976 flood, using an armored approach. Despite these efforts, the connection was lost again during flooding in 2013. As transportation officials look at the design and costs of rebuilding a route that could withstand future floods, many in the state's leadership suggest they may need to accept the notion that regular rebuilding of the road is inevitable—and may be a more prudent use of limited capital dollars on a net-present-value basis.

Resilience Strategies for Different Phases of the Development Cycle

Although a community's location along the transect can suggest certain strategies for resilience, considering different strategies for different phases of development is also relevant. If a community is fully built out, building resilience through rehabilitation of existing properties may be more feasible than other strategies. If, instead, plenty of undeveloped land is available, beginning by incorporating resilience into land use planning and regulation may be a wise first step. This section summarizes some key resilience strategies based on stage of the development cycle.

Renovation and Replacement

If a decision is made to undertake renovations to make assets in place more resilient, consider this decision alongside larger resilience strategies to strengthen critical infrastructure such as roadways and bridges, encasement of key utility lines, and shoring up of building foundations or seawalls. Especially in vulnerable communities, viewing every renovation or investment project as an opportunity to rebuild better than before is important.

For the small, densely populated community of Greensburg, Kansas, an EF5 tornado in 2007 destroyed or severely damaged 90 percent of all structures, with 600 homes lost.[37] The community, as in most communities at risk of tornado effects, rebuilt in place, though at a greatly reduced density based on population loss. More stringent building practices were adopted, including increased wind protection and storm shelters, alongside broader sustainable practices for construction. At only one square mile, the town additionally took the opportunity to reconsider its downtown as a walkable mixed-use environment with strategic access for residents to the town hospital, schools, grocery store, and city hall.

In Cedar Falls, Iowa, consistent, severe flooding remains a critical concern for the city's power plant, which is located adjacent to the Cedar River and is cost prohibitive to relocate. In consideration of this and other factors, significant efforts to minimize flood damage from the Cedar River through a combination of local, state, and federal funding have resulted in an award-winning plan that includes a combination of engineered improvements to the river channel, stormwater system improvements, property buyouts, floodplain map updates, floodplain management, and regular updates to the Hazard Mitigation Plan.[38]

Major infrastructure improvements typically fall under the purview of the state and federal governments. In New Jersey, microgrids are currently being considered to allow New Jersey Transit to function on its own source of power should power from the local utility fail during a storm. During normal operations, the microgrid's power generation will feed into the local utility, allowing the microgrid to earn money on its investment.[39]

Relocation

Where possible, relocation strategies for buildings and properties sited in vulnerable areas should be considered, whether through a buyback program for private properties or, at a minimum, safer locations for critical facilities.

With over 25 percent of its land area and 15 percent of its roadways subject to flooding, the city of Augusta, Georgia, has consistently and proactively considered flood mitigation as part of its ongoing planning efforts.[40] Over the past 15 years, the city has used local, state, and federal funding to institute a buyout program to acquire severely or repetitively damaged homes and properties subject to flooding.

After Hurricane Irene, the town of Waterbury, Vermont, applied for FEMA support and funding to create a long-term community recovery plan. Several sites for the relocation of critical facilities such as the municipal building and police station were being considered following substantial damages.

Main Street in Greensburg, Kansas, after the tornado in 2007.

TY NIGH

The ability to implement these types of considerations will vary given the location, form, and density of development in the near term, but long-term community planning should consider a broader interpretation of "highest and best use" when assessing the placement of critical facilities and infrastructure.

New Development

When undertaking new construction and renovations for resilience, observations gained through the anticipation process should lead to new design solutions or ways of approaching design.

In response to wildfire risk, new residential construction in San Diego County, California, is required to specify roof and siding materials that are resistant to fire. All homes must have sprinklers, roof eaves must be enclosed, and windows must have frames that don't melt in a fire.[41] In *Housing in America: Integrating Housing, Health, and Resilience in a Changing Environment*, the comprehensive efforts that the community of Talmadge in San Diego undertook to proactively address wildfire risk necessarily went beyond building-level improvements to landscape improvements, which included thinning vegetation, separating plantings, and creating a 150-foot swath of "defensible space" between residences and the Talmadge Canyon rim.[42] This community and many communities across the country are guided by a community wildfire protection plan. In addition, communities can be

recognized as Firewise Communities by adopting specialized requirements for home sites and buildings that fall within areas rated to be at risk for wildfires. Developments may then receive support from the U.S. Forest Service for FEMA Mitigation Action Plans.[43]

In Cedar Falls, Iowa, a revised floodplain ordinance that exceeds FEMA requirements for the National Flood Insurance Program is the underlying regulation for new development in vulnerable areas. Within the 500-year, or 0.2 percent floodplain boundary, structures must be elevated one foot above the 500-year elevation. New development lots within this boundary are prohibited. Critical facilities are to be located outside this boundary.[44]

The 2007 Witch Creek fire in San Diego, California.

STATE FARM

Conclusion

Cities and towns across the country are challenged to respond in real time to the growing data on extreme weather events. Meanwhile, events are rapidly testing future scenarios in communities large and small. Brian Swett, former head of Environment, Energy, and Open Space for the city of Boston, framed the issue of resilience for Boston University's Initiative on Cities as follows: "Some people think the perceived opportunity of climate change action is the status quo. . . . But the status quo is not where we're going. We're going to a significantly detrimental place where no one wants to be."[45]

Municipalities, asset managers, property owners, and businesses need to carefully consider resilience strategies when evaluating the cost and criticality of infrastructure and development. For every $1 spent on disaster preparedness and resiliency, FEMA estimates that taxpayers can avoid at least $4 in future losses.[46] Currently, however, the Center for American Progress found that *spending on response and recovery to hazard events is six times greater than spending on preparedness.*[47]

Knowing where to start in pursuit of resilience can be a daunting task. In prioritizing actions, one should ask three interrelated questions:

- What hazard events are you most exposed to?
    - ▷ A property or community's location within the larger continental geography increases (or diminishes) the potential for certain climate-related events.
- Where are you located along the rural-to-urban transect?
    - ▷ Community density and intensity play an important role in defining potential risks to real property and community life by influencing the scale of potential impact and available resources to rebound.
    - ▷ The scale of the community, and its connectivity to larger regional networks, helps (or increases the risk) during weather-induced events.
- Is the strategic response a one-time action or long-term commitment?
    - ▷ Is the response physical in nature, and can it be addressed during the design process?
    - ▷ Is the response related to operations and maintenance, which must be constantly monitored and managed?

Ultimately, being prepared for impacts caused by climate change involves coordination, both within and beyond communities. Climate-induced events typically affect multiple communities, either directly or through reverberant effects, so pooling resources at the local, state, and federal levels to develop regional responses will enable more effective solutions.

In February 2014, the White House announced a $1 billion Climate Resilience Fund as part of the 2015 budget, with three goals:

- Invest in research and unlock data and information to better understand the projected impacts of climate change and how we can better prepare our communities and infrastructure;

- Help communities plan and prepare for the impacts of climate change and encourage local measures to reduce future risk; and
- Fund breakthrough technologies and resilient infrastructure that will make us more resilient in the face of changing climate.[48]

Although the notion of climate-change-induced events is broad in its scope, it is even more complex when applied to the diversity and scale of settlement patterns throughout the built environment. A need to aggregate lessons learned and focus limited resources to achieve effective and efficient use of resources is one advantage of using the transect approach to resilience planning when working across the rural-to-urban continuum.

Resources

American Planning Association (APA)

- Coastal Zone Management guides, resources, and data and tools
  www.planning.org/nationalcenters/hazards/coastalzonemanagement/guides.htm
  www.planning.org/nationalcenters/hazards/coastalzonemanagement/resources.htm
  www.planning.org/nationalcenters/hazards/coastalzonemanagement/datatools.htm
- James C. Schwab, ed., *Hazard Mitigation: Integrating Best Practices into Planning* (APA Planning Advisory Service, 2010)
- Integrating Hazard Mitigation into Local Planning and Community Development
  https://www.planning.org/research/hazards
- *Policy Guide on Planning and Climate Change*, adopted April 27, 2008, updated April 11, 2011
- Post-Disaster Annotated Bibliography
  www.planning.org/research/postdisaster/bibliography.htm
- Post-Disaster Resource List
  www.planning.org/research/postdisaster/resources.htm
- *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*

Coastal Hazards Center

http://coastalhazardscenter.org/about-us

The U.S. Department of Homeland Security (DHS) Science and Technology Directorate Coastal Hazards Center of Excellence performs research and develops education programs to enhance the nation's ability to safeguard populations, properties, and economies from coastal hazards. DHS established the center in 2008 in response to Hurricane Katrina. It is the only DHS Center of Excellence dedicated solely to the study of natural disasters.

- Products and Tools
  http://coastalhazardscenter.org/research/products-tools
- MUNICIPAL: Decision Technology for the Restoration of Critical Infrastructure Services
  http://coastalhazardscenter.org/dev/wp-content/uploads/2014/03/Wallace_fact_sheet.pdf
- Measuring Recovery through Healthy Community Indicators
  http://coastalhazardscenter.org/dev/wp-content/uploads/2014/03/horney_factsheet_vam_-1.pdf
- Resource Library
  http://coastalhazardscenter.org/education/resource-library

Community Wildfire Protection Plan

www.forestsandrangelands.gov/communities/cwpp.shtm

Federal Emergency Management Agency (FEMA)

- James C. Schwab, ed., *Hazard Mitigation: Integrating Best Practices into Planning* (APA Planning Advisory Service, 2010)
  https://www.fema.gov/media-library/assets/documents/19261?id=4267
- Integrating Hazard Mitigation into Local Planning: Case Studies and Tools for Community Officials
  www.fema.gov/media-library/assets/documents/31372?id=7130
- *Local Mitigation Planning Handbook*, March 2013
  www.fema.gov/media-library/assets/documents/31598
- “Mitigation Planning Fact Sheet,” November 2012
  www.fema.gov/media-library/assets/documents/5756?id=2066
- Threat and Hazard Identification and Risk Assessment (THIRA)
  Comprehensive Preparedness Guide (CPG) 201, Second Edition, released August 2013

Firewise Communities
www.firewise.org

Initiative on Cities
www.bu.edu/ioc

National Climate Assessment
http://nca2014.globalchange.gov

National Climatic Data Center
www.ncdc.noaa.gov

National Oceanic and Atmospheric Administration (NOAA)

- NOAA’s Climate Program Office and Sector Applications Research Program funded a Drought Ready Communities project with a planning resources kit, ending in summer 2010 with *Drought-Ready Communities: A Guide to Community Drought Preparedness,* updated May 2011. http://drought.unl.edu/Planning/PlanningProcesses/DroughtReadyCommunities.aspx.
- NOAA Digital Coast (http://coast.noaa.gov/digitalcoast/)—a central, user-friendly, cost-effective repository for data, tools, and training that coastal managers, planners, and decision makers need to improve coastal economies and ecological health—makes data accessible and easier to use.

The Nature Conservancy

- The Urban Water Blueprint (http://water.nature.org/waterblueprint/#/intro=true) maps dozens of city watersheds and makes a compelling argument for a greener approach to engineering the flow to our tap. Instead of relying on costly capital projects to filter sediments and pollution, urban officials should invest in the “natural infrastructure” of riverbanks, forests, and farmlands that affect the quality and quantity of their water before it even reaches city boundaries.

Urban Land Institute

- Urban Resilience Program
  http://uli.org/research/centers-initiatives/urban-resilience-program/
- Reports
  http://uli.org/research/centers-initiatives/urban-resilience-program/reports/
- Technical Advisory Program panels

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10. Jerry M. Melillo, Terese Richmond, and Gary W. Yohe, eds., *Highlights of Climate Change Impacts in the United States: The Third National Assessment* (Washington, DC: U.S. Government Printing Office, 2014), 95.

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