MANAGING INLAND FLOOD RISK IN THE CONTEXT OF THE AUGUST 2016 LOUISIANA FLOOD

Flood risk is ubiquitous. In any given week, a storm with the potential to produce flooding is occurring somewhere in the United States. The transfer of flood risk from the National Flood Insurance Program (NFIP) to the private (re)insurance and capital markets is beginning, and as a result flood risk management has become a focus of attention. A probabilistic modeling approach is the only method that can account for the complex interplay of all the variables and factors associated with flood risk assessment and management.

In this issue brief, we will examine in detail one recent event—the August 2016 Louisiana flood, which AIR estimates will cost between USD 8.5 billion and USD 11 billion.[1] The answer to the question of who ultimately pays for flood losses of this magnitude is changing, so companies need to know what tools are available today for managing this risk.

THE AUGUST 2016 LOUISIANA FLOOD

Unprecedented rains caused catastrophic flooding in southern Louisiana during August 2016. In the course of seven days from August 9 to 16, a record-breaking downpour dumped more than 30 inches of rain in some areas, which resulted in accumulations of around 7 trillion gallons in Baton Rouge and environs. The Baton Rouge Area Chamber (BRAC) reported that more than 145,000 homes accommodating more than 359,000 people, and as many as 12,000 businesses employing more than 136,000 people, were located in flood-affected areas of the nine parishes within Louisiana's Capital (Baton Rouge) Region. The flooding caused 13 deaths and required more than 30,000 people to be rescued; at the flooding's worst, around 11,000 people sought refuge in shelters. The floodwaters damaged or destroyed more than 50,000 homes, 20,000 businesses, and 100,000 vehicles. The federal government declared 20 parishes major disaster areas. This event is considered the most damaging flood event since Hurricane Sandy impacted the Northeast in 2012.[2]

METEOROLOGICAL SUMMARY

From August 9 to August 16, slow-moving torrential downpours plagued much of southern Louisiana. The culprit, a tropical depression–like low pressure system that slowly drifted across Louisiana, intensified as it moved west. Because it formed and remained over land, it was technically not considered a tropical depression, despite its closed warm-core low. Nevertheless, the counterclockwise (southerly) flow off the Gulf of Mexico, where sea surface temperatures were at almost record high levels, brought tremendous amounts of moisture inland across southern Louisiana; the maximum instantaneous precipitable water in the atmosphere during the storm period was at a historic level (precipitable water is a good indicator of how much rain might fall as a result of a low pressure system). The combination of these factors, with the large-scale rising motion provided from the low pressure system, resulted in slow-moving torrential rainfall and thunderstorms that spread from Lafayette to Baton Rouge.

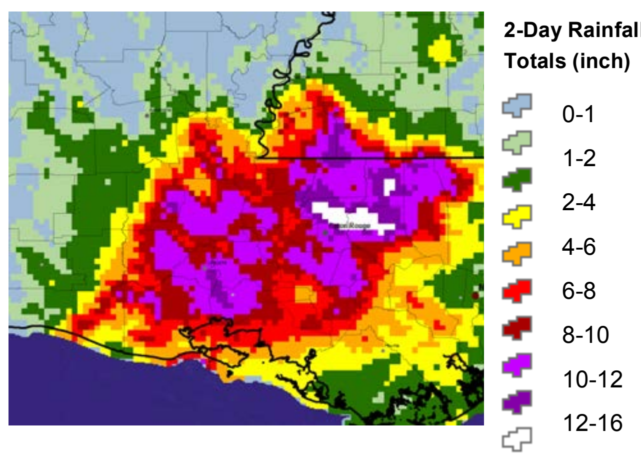

Figure 1. Merged gauge and radar observation-based two-day rainfall totals ending 12:00 UTC on August 13, when most of the precipitation had fallen over the area. (Source: National Weather Service, adapted by AIR)

Record rainfall totals fell across a large portion of southern Louisiana as the slow-moving tropical depression–like system crawled across the region (see Figure 1). As a result, some rainfall values were in the range of a 1,000-year return period in the parishes of St. Helena, Livingston, and East Baton Rouge (see Figure 2). Parts of the region received two to four times the average total monthly rainfall for August in just three days. As the storm moved west, the heaviest rainfall moved with it, but localized downpours continued to plague the area through the weekend of August 13 and 14.

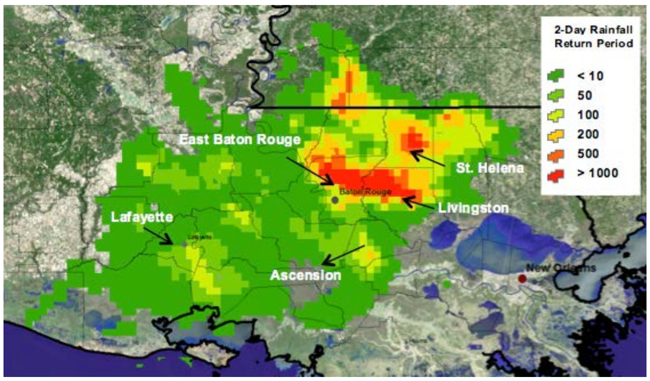

Figure 2. Exceedance probability expressed as return period for the two-day rainfall accumulations shown in Figure 1. (Source: National Weather Service, adapted by AIR)

With 26.97 inches of precipitation, August 2016 was the wettest month for Baton Rouge since record-keeping began 174 years ago. The previous monthly record was set in May 1907 when 23.73 inches fell. The Louisiana statewide precipitation total for August 2016 was 12.91 inches, 8.27 inches above average for that month, and surpassed the previous record of 9.71 inches set in 1948. Local storm rainfall totals ranged from 12 inches to more than 24 inches, with 31.39 inches falling near Watson, 27.47 inches in Brownfields, and 26.14 inches in White Bayou.

As a result of the record-breaking rainfall across a vast area of more than 50 miles by 100 miles—covering Baton Rouge, Lafayette, and adjoining suburbs—historic crests at several river gauging stations of the USGS in Louisiana were surpassed. Three highly impacted parishes, Ascension, East Baton Rouge, and Livingston, are situated along the Comite and Amite rivers, which experienced major flooding. The watersheds of these rivers, in large part, are in East Baton Rouge, Livingston, and St. Helena parishes. Considering that large portions of these three parishes (50%, 70%, and 85%, respectively) experienced a higher than 100-year return period two-day rainfall, and some areas (25%, 15%, and 30%, respectively) received a higher than 500-year rainfall (Figure 2), it is not surprising that all these relatively small rivers in the region were overflowing simultaneously.

The very heavy rainfall in the watersheds of the Amite, Comite, Tickfaw, and Tangipahoa rivers resulted in flood levels up to 6 feet over their previous historic records. The estimated flows at these flood levels correspond to a 1,000-year return period (i.e., an exceedance probability of 0.1%). As a result, there were riverine flood events at the Amite River near Denham Springs, the Comite River near Olive Branch, the Tickfaw River at Montpelier, and the Tangipahoa River at Robert; river gauges at these locations crested more than 4 feet, 3 feet, 0.20 feet, and 3 feet higher than previously set historic highs in 1983, 1961, 1921, and 1974, respectively.

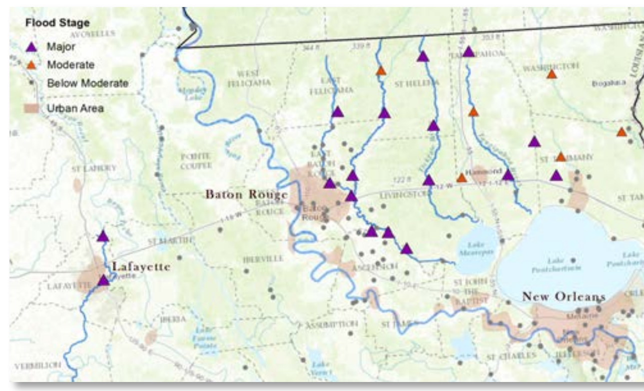

Figure 3. Stream gauges along the Amite, Comite, Tickfaw, Tangipahoa, and Vermilion rivers in southern Louisiana recorded moderate to major flooding during the seven-day period ending August 16, 2016. (Source: National Weather Service, adapted by AIR)

ON- AND OFF-FLOODPLAIN FLOODING

The historic flooding in and around Baton Rouge and other parishes was a combination of several causative factors, including riverine (on-floodplain) flooding, water backing up in tributaries due to high flood stages in main rivers, called “backwater,” and significant local flash flooding (off-floodplain flooding) caused by intense rainfall, flat terrain, and limited drainage capacity, which was further exacerbated by backwater effects. Many of the flooded areas were outside the FEMA 100-year flood zone and therefore not considered at high risk. For this reason, the event caught many residents and community leaders by surprise.

The AIR Inland Flood Model for the United States explicitly models this off-floodplain risk, which can represent a significant portion of the total loss caused by flooding. AIR estimates that 29.5% and 19.7% of all losses in East Baton Rouge and Lafayette parishes, respectively, will originate from off-floodplain flooding that is caused by a combination of intense precipitation, saturated soils, and inadequate drainage conditions.

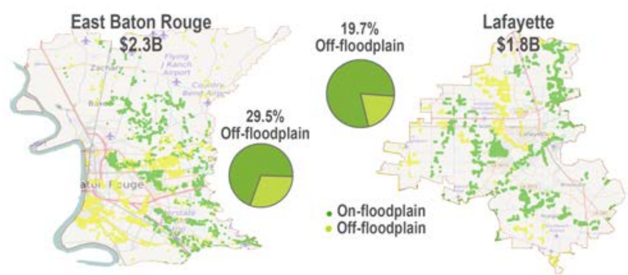

Figure 4. Significant off-floodplain loss contribution in the heavily impacted East Baton Rouge and Lafayette parishes.

Areas most heavily impacted by flooding where FEMA had not indicated there was a high flood risk include neighborhoods in Monticello and northeastern Baton Rouge, both of which are south of the Comite River in East Baton Rouge Parish. More than 1,400 risks in AIR's industry exposure database (IED) indicate ground-up losses (which include exposures eligible for coverage regardless of whether they are actually insured and without any application of deductibles or limits) of more than USD 2,000 each, for a total of more than USD 7 million—a large figure for off-floodplain losses from small neighborhoods. These modeled off-floodplain locations were validated against the aerial photographic information available from NOAA (Figure 5) and show good agreement.

Estimated ground-up losses in Ascension and Livingston parishes tally USD 3.4 billion, only 5–6% of which represent losses due to off-floodplain inundation. Significant riverine flooding occurred in both these parishes, caused by streams and rivers overflowing their banks as well as overtopping and/or failing levees in some instances. AIR defines on- and off-floodplain losses as incurred due to inundation from riverine flooding and from localized flooding from heavy precipitation, respectively. The lower off-floodplain loss contribution in these two parishes reflects significant riverine flooding.

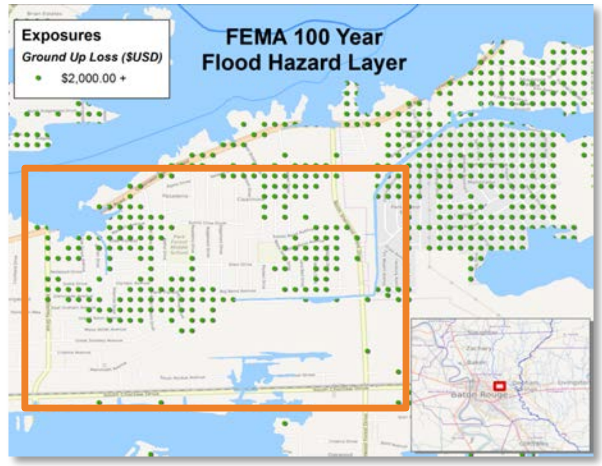

Figure 5. Significant flooding occurred outside of FEMA designated high flood risk areas, for example, in neighborhoods of Baton Rouge between Monterrey Blvd and N Sherwood Forest Drive. The top figure depicts AIR exposures (green dots) that are outside of FEMA's 100-year flood zone (in blue color) and for which AIR estimated a loss of at least $2000. Flooded streets (in brown color) in aerial imagery in the bottom figure validate the model results.

Ascension Parish experienced a levee failure, contributing significantly to the on-floodplain losses. On Monday, August 12, rising water from the Amite River overtopped the Laurel Ridge Levee (depicted in black in Figure 7) in Ascension Parish. Nearby cities that were affected from the overtopping include Gonzales and Sorrento, both of which suffered significant flood damage.

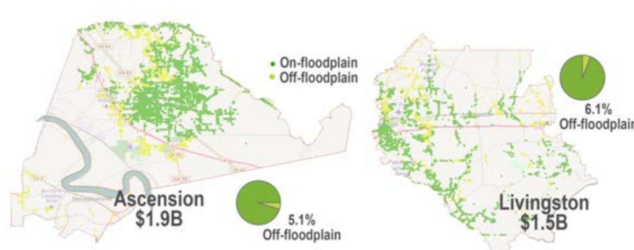

Figure 6. Significant riverine flooding in Ascension and Livingston results in lower off-floodplain contributions in these parishes. Dollar values represent total on- and off-floodplain ground-up losses.

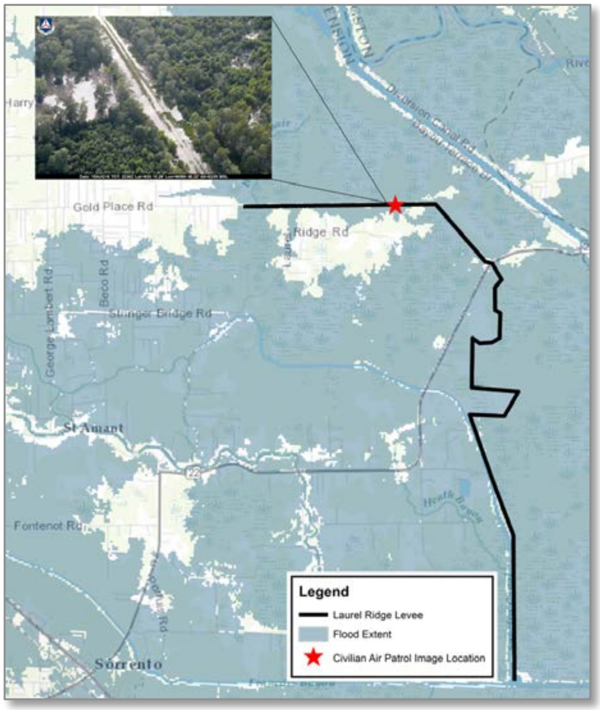

Figure 7. Levee overtopping on Amite River in Ascension County. (Source of photograph: Civilian Air Patrol)

WAS THIS EVENT CAUSED BY CLIMATE CHANGE?

A question that has arisen following the August 2016 Louisiana flood is whether it was caused by climate change. One cannot and should not attribute any given event to climate change. The science of climate change attribution, which is a relatively new branch of climate change science,[3] is designed to evaluate the impact of climate change on weather extremes. To have high confidence in a finding, three criteria have to be satisfied. The first is that the signal must show up to some degree in the observational data record. The second is that simulations using a General Circulation Model (GCM) initialized with pre- or early-Industrial Revolution levels of CO2 and run for several decades show a change when compared to GCM simulations run with current levels. The third is that a conceptual understanding of how climate change influences the phenomenon in question must exist. If all three criteria are met and point in the same direction (e.g., increasing frequency) then there is a high degree of confidence that climate change is influencing a weather phenomenon, such as flooding.

Currently the highest confidence for climate change attribution exists for temperature-related extremes. Next in line for most confidence are drought and flood events (heavy precipitation) – like the one in Louisiana in August 2016. A very recent study[4] published by Van der Wiel *et al.* quantified the effect. The historical record for such heavy precipitation events in the region show that they have increased in frequency since the early 1900s. Very high resolution (25 km) GCM simulations were also performed with CO2 concentrations at 1900 and current levels; the comparison showed an increase of such events by a factor of two.

Conceptually, an increase in heavy precipitation events can be linked to the Clausius-Clapeyron equation, which holds that the amount of water vapor that the atmosphere can hold increases exponentially with temperature. Thus there is high confidence in the Van der Wiel *et al.* study's published statement that such heavy precipitation events have increased in frequency by two to five times because of climate change. The study went on to show that the intensity of such events has increased by five to 25 times. A remarkable aspect of this study is that it was published within three weeks of the actual event. Although the numerical simulations had already been performed before the flood, the analysis of the output in the context of this flood was done in response to, thus after, the flood. A quick response as to whether climate change played a role was important because the general public and flood management agencies were concerned that this was the case but had no data to back up this assertion.

VULNERABILITY OF THE LOCAL BUILDING STOCK

The State of Louisiana has a long history of floods, and flood mitigation efforts have been in place for many years. Many of the parishes, such as East Baton Rouge, joined the National Flood Insurance Program (NFIP) in the 1970s whose floodplain management and property protection measures are enforced via land use planning and zoning in flood hazard areas.

Despite these efforts, many structures in the area remain vulnerable. In Louisiana statewide, more than 80% of residential construction is wood, and an estimated 5% have basements. The presence of a basement increases the risk for contents and building damage. More typically, buildings are on slab foundations, which are designed to withstand flotation, collapse, or lateral movement that can be inflicted by floodwaters. Crawlspace foundations in residential buildings are required to have flood openings no more than 1 foot above the grade.

More than half of the commercial buildings are steel and concrete. Unlike residential structures, commercial buildings are often engineered and built to stricter standards, and are thus less vulnerable than single-family homes. Still, mechanical, electrical, and plumbing (MEP) systems can experience severe damage, which results in high losses.

Commercial business can add flood insurance as an endorsement to their property policy, although it is often subject to sublimits. Hurricane Katrina revealed that commercial insurers did not always have good information about their exposure to floods and even today estimates of total industrywide insured flood values remain hard to obtain. In addition, large commercial structures frequently have some level of flood mitigation defenses that can be accounted for in AIR's Touchstone® platform.

In the U.S., residential flood insurance is typically offered to homeowners only through the NFIP, which lets residential property owners purchase flood insurance from the government. FEMA estimates that only 42% of homes in high-risk areas of Louisiana have flood insurance, while only about 12% of homes in low- and moderate-risk zones do. Across East Baton Rouge Parish, no more than 15% of all homes have flood insurance, and in the other hard-hit parish, Livingston, the rate is 23%. Only about one third of homes in areas defined as "high flood risk" in these two parishes have insurance. In some areas, insurance penetration is much lower, for example, in the significantly impacted St. Helena Parish, only 1% of all homes are insured, and no more than 4% of these are insured in "high flood risk" areas.

These floods were certainly devastating for homeowners, but they also had a crippling impact on public institutions, businesses, and industries in the area. As many as 265,000 students, nearly 30% of the school-aged population in Louisiana, were out of school for almost one month. The East Baton Rouge and Livingston school systems took the brunt of the disaster—all 77 schools in East Baton Rouge Parish and all 45 schools in Livingston Parish remained closed for 22 days and 28 days, respectively. In Livingston Parish, 15 schools were badly damaged by 4 to 8 feet of flooding; a few schools will not be able to reopen until January 2017. A very large number of school buses of the East Baton Rouge schools—100 out of 571—were flooded, and 68 new buses were ordered to restart the schools. It is reported that the East Baton Rouge school suffered more than USD 50 million of losses and a significant part of it may not be covered by insurance as it exceeded the policy limit.

ASSESSING THE IMPACT OF THE LOUISIANA FLOOD

In the case of the August 2016 Louisiana flood, AIR issued a series of communications via the ALERT™ (AIR Loss Estimates in Real Time) website designed to help clients understand the potential impact on their books of business. These began on August 16 with a detailed summary of the event, along with maps from the National Weather Service. A follow-up description was provided on August 26 along with a list of affected ZIP Codes and Touchstone-ready shapefiles showing flood inundation extents and depths.

These initial on-floodplain flood footprints, which were based on reported and estimated (where reports were unavailable) river flows and the AIR Inland Flood Model for the United States, were designed to be used in Touchstone's Geospatial Analytics Module or other GIS applications to better understand exposure at risk.

On September 16, AIR issued a final summary description of the event along with five simulated scenarios formulated using the latest information on precipitation, river gauge data, and levee overtopping and failure. These scenarios provided a range of possible realizations of both the riverine (on-floodplain) flooding and off-floodplain flash flooding caused by a combination of intense rainfall, flat terrain, and limited drainage capacity. The range of scenarios reflected uncertainty in rainfall observations and in the probabilistic modeling of levee failure.

In Touchstone, companies can use the scenarios to assess losses to their portfolios. In CATRADER®, companies can leverage AIR's industry exposure database (IED) to generate industry ground-up insurable losses—which include all exposures eligible for coverage (regardless of whether they are actually insured). Companies can then determine their share of industry losses.

With this final update, AIR released an industrywide ground-up insurable loss estimate of between USD 8.5 billion and USD 11 billion. Of the total, 67% of losses are to residential lines of business and 32% are to commercial lines. Roughly 75% of the total losses are estimated to have come from the four parishes shown in Table 1.

Table 1. Modeled Losses for the Top 4 Affected Parishes for Each of the Five Simulated Scenarios Posted on the ALERT Website on September 16 (USD Millions)

Parishes	Event 1	Event 2	Event 3	Event 4	Event 5
East Baton Rouge	1,978	2,069	2,007	2,309	2,629
Lafayette	1,687	1,959	1,769	1,930	2,003
Ascension	1,655	1,926	1,711	1,819	1,874
Livingston	1,169	1,305	1,361	1,523	1,545

PARISH-LEVEL EVENT LOSS FREQUENCY IN THE AIR INLAND FLOOD MODEL FOR THE UNITED STATES

While catastrophe models can be used to estimate losses in real time as actual events unfold, their primary purpose is to provide information about the potential for large losses *before* they occur so that companies can prepare for their financial impact. The AIR Inland Flood Model for the United States contains a large catalog of more than 685,000 events, each representing a realistic realization of a potential future flood affecting one or more regions of the country. These events and associated losses are derived from 10,000 years of stochastic simulations that are based on the physical modeling of rainfall and consequent riverine and off-floodplain flooding processes. The ranked set of the maximum loss in each year generated by these events in Louisiana comprise the industry Occurrence Exceedance Probability (OEP) curve for that state.

AIR placed the losses from the scenarios generated for the August 2016 Louisiana flood into the context of the OEP curve for Louisiana and determined that, for Louisiana statewide, the losses from this event correspond to an exceedance probability (EP) of about 2.4%, or a return period of about 40 years ($1/0.024 \approx 40$ years). While rainfall totals in many areas were extreme, a 40-year return period with respect to statewide losses is not surprising—and is indeed well within the range to which companies should be managing their risk. The extreme losses at the tail of the distribution for Louisiana are driven not by rainfall but by the failure of levees, including those around New Orleans—a true catastrophe that was not in play in this situation.

Louisiana is largely low-lying with many lakes, rivers, and streams. The state experiences flooding virtually every year. According to historical data from the National Weather Service (NWS), Louisiana's parishes experience flooding more than once every 20 months, on average—resulting in a higher probability of flooding than almost any other state.

Around the state, the highest precipitation totals are typically observed in the southeastern part of the state, and typically include cities and towns flooded by the Amite and Comite rivers and their tributaries. The most damaging historical floods in this area occurred in 1977, 1979, 1980, 1983, and 1990.

As in the 1983 flood, the August 2016 event caused the Amite River to flood, especially in the parishes of East Baton Rouge and Livingston. However, while the similarities between the 1983 and 2016 floods are striking, the 2016 event featured even more extreme precipitation, which, in turn, led to even larger losses across four parishes.

As was seen in Table 1, AIR estimated losses of more than USD 1 billion in each of the following parishes: Ascension, East Baton Rouge, Lafayette, and Livingston. How often can this particular scenario be expected to occur? It speaks to the robustness of the AIR model that it can answer the question: the exceedance probability is about 0.1% (or a return period of 1,000 years). Further, if we examine one of the ALERT scenarios—say Event 4, for which the total loss for all four parishes was USD 7.5 billion—the AIR model assigns an exceedance probability of 0.08%, or a return period of about 1,250 years. Such estimates corresponding to simultaneous flooding across multiple parishes—or, in fact, any region of the U.S. whether they are prone to flooding or not—can be a helpful perspective for insurers, as well as for other stakeholders in flood risk management.

Table 2. Modeled Loss Estimates (USD Millions) and Exceedance Probability and Return Period for the Top Four Affected Parishes in ALERT Event 4

Parish	Modeled Loss	Exceedance Probability of Loss (Return Period)
East Baton Rouge	2,309	0.7% (140-year)
Lafayette	1,930	0.30% (333-year)
Ascension	1,819	0.5% (200-year)
Livingston	1,523	1.0% (100-year)

It should be noted that when significant floods occur, there is a tendency to headline them as 100-year floods or perhaps, in more extreme cases, 1,000-year floods. However, as AIR's analysis of this event shows, there is no such thing as a 100-year flood from a hazard perspective. Every event is unique and while certain areas (or parishes, in this case) might be experiencing a 100-year hazard, other nearby areas could be experiencing a much more (or much less) extreme situation; such complexity is inherent in the flood peril. The same holds true for losses—and that is the value of understanding probabilistic losses using a catastrophe model.

PREPARING FOR THE FUTURE

Changes in legislation and new, creative thinking are beginning to facilitate private (re)insurers' return to the flood insurance marketplace. With the appropriate risk assessment tools, companies will find opportunities to develop a range of products from which customers can choose what best meets their needs.

Floods are highly complex processes, thus managing flood risk is a complicated task; the flood intensity and the associated losses at a given locality depend on many factors. Floods can be a consequence of a significant regional- or continental-scale precipitation system lasting for days but, at times, they can also result from highly localized, very intense, and shorter meteorological events. Floods are often caused by distinct rain events; however, multiple back-to-back and overlapping rain events resulting in significant flooding are not uncommon. Similarly, both large-scale topographic features and differences in local elevation play a significant role in the flood risk attributed to any given location and thus make flood risk assessment a non-trivial task.

Floods are also highly managed, owing to flood protection systems such as dams, levees, temporary barriers, and mobile flood walls in some cases, and operational decisions made in others. The complexities inherent in managing flood risk also include the continual changes in the characteristics of insured properties, such as new construction materials and building design practices. To manage flood risk well, companies must account for the many such complexities that affect flood risk across the country.

A robust catastrophe model accounts for all the complexities of the flood peril probabilistically; of particular importance for estimating flood occurrence losses is a model's ability to accurately simulate individual storms—especially high intensity systems that linger over a relatively small area, as this storm did. The AIR Inland Flood Model for the United States captures events like the August 2016 Louisiana flood as well as even more extreme precipitation events that can lead to even larger-scale disasters, such as those driven by levee failures along the Mississippi River. As such, the model remains the best tool available for providing underwriters, risk managers, and other stakeholders with a comprehensive tool for assessing and managing inland flood risk.

With a tool available now that offers a granular view of risk and allows quantification of that risk, there are long-term opportunities for private insurers, including gaps to fill in the residential flood insurance market. Private insurers may offer superior performance in terms of building up surplus, underwriting properties, spreading risk through reinsurance and capital markets, determining actuarially sound rates, and prioritizing and implementing mitigation strategies. And on the commercial/industrial side, the insurance industry only covers a limited amount of this risk now, which opens up opportunities for companies to think about how the market can be developed and grown.

[1] These numbers represent modeled industry ground-up insurable losses—which include exposures eligible for coverage (regardless of whether they are actually insured) without any application of deductibles or limits.
[2] http://www.ncdc.noaa.gov/billions/events
[3] NAS, 2016: Attribution of Extreme Weather Events in the Context of Climate Change
[4] Van der Wiel *et al.* 2016: Rapid attribution of the August 2016 flood-inducing extreme precipitation in south Louisiana to climate change. Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-448.

ABOUT AIR WORLDWIDE

AIR Worldwide (AIR) provides catastrophe risk modeling solutions that make individuals, businesses, and society more resilient. AIR founded the catastrophe modeling industry in 1987, and today models the risk from natural catastrophes, terrorism, and pandemics globally. Insurance, reinsurance, financial, corporate, and government clients rely on AIR's advanced science, software, and consulting services for catastrophe risk management, insurance-linked securities, site-specific engineering analyses, and agricultural risk management. AIR Worldwide, a Verisk Analytics (Nasdaq:VRSK) business, is headquartered in Boston with additional offices in North America, Europe, and Asia. For more information, visit
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