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The No-Name Floods of 2015

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The No-Name Floods of 2015

Lessons from South Carolina

BY BARBARA HESSELGRAVE

In early October 2015, residents along the southern and mid-Atlantic East Coast of the US held their breath as reports on Hurricane Joaquin's gathering strength—but uncertain landfall destination—created mounting anxiety.

Luckily, Joaquin moved back out to sea. But while hurricane landfall became a non-issue, other meteorological forces in its wake conspired to create a far worse scenario than anyone expected. For residents of South Carolina, October 2015 was the scene of unprecedented flooding.

Every Thousand Years—Or Maybe Next Year

Within days, officials and the media were dubbing it the "1,000-year storm," which suggests that the last horrific flood took place during the Norman Conquest (1066) and that another of the same caliber is a safe 10 centuries away. Unfortunately, both are myth.

According to blog reports during the storm by University of Georgia professor Marshall Shepherd, who is also a *Weather Channel* host and past president of the American Meteorological Association, "Most people do not actually understand the concepts of what a 100- or 1,000-year rain event means. Many people literally assume it means this event can only happen every 1,000 years."

But, he explains, the popular but erroneous "1,000-year" moniker has very little to do with actual years, and everything to do with statistical probability. Which means a similar disastrous event could occur next week, next year, or hundreds of years from now.

Although statistical probability helps in the predictive value, the US Geological Survey describes the 1,000-year concept as based on data gathered over a period of at least 10 years to create what it terms a frequency analysis tool. Experts look at magnitude and duration of rainfall events, streamflow measurements, and other data as the basis for calculating recurrence intervals. But for people who were watching the water rise by the hour, this was hardly important; as Marshall says, "It was just unbelievable."

The Sequence of Events Leading to Disaster

According to Derrec Becker, public information coordinator for the South Carolina Emergency Management Division, "The nature of flooding is unlike any other disaster. It doesn't get a lot of attention until it actually happens and kills people."

Becker says this was not a one- or two-day event, but an emergency of 20-days' duration from October 4 to 23. Rainfall, flooding, evacuations, heavy infrastructure and property damages, and water supply emergencies created an around-the-clock crisis for the entire state, but especially in the hardest-hit midlands region. However, the agency had already been on high watch and preparing for Joaquin, monitoring the hurricane's path, and on September 30, 2015, urging residents and agencies to be "ready to respond if the need arises."

By October 1, officials were predicting heavy rain and flooding even if the hurricane headed out to sea. Before the dinner hour that same day, the governor had declared a state of emergency, saying "Heavy rain from a separate weather system will create flash flood conditions throughout the entire state." On Friday, October 2, one flood-related death had been reported and the worst was still to come, with flood warnings being issued for 14 counties.

Becker says the state was able to quickly get a presidential declaration of a federal emergency, which helped to mobilize agencies, and to request assistance. On Saturday, October 3, when President Obama declared a federal emergency, nearly 9,000 people were already without power. By Sunday, October 4, there were more than 300 reports of flooded roads, the eastern shore Edisto Beach sea wall had been breached, sanitary sewers were overflowing in North Charleston, and five weather-related deaths had been reported. By Tuesday, October 6, the death toll had risen to 17 people, primarily from auto-related drownings as people attempted to drive on flooded roadways.

Becker says devastating rainfall in the presence of already high tides set the scene for devastation. "We were

Although Hurricane Joaquin headed out to sea, a separate weather system caused heavy flooding.

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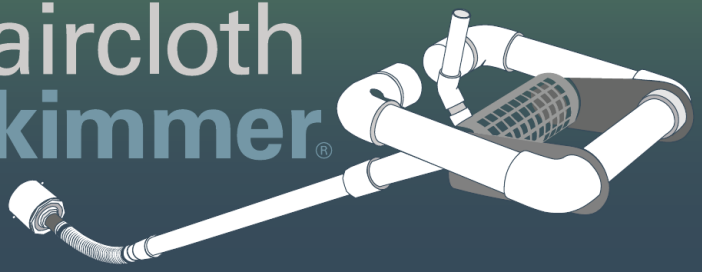

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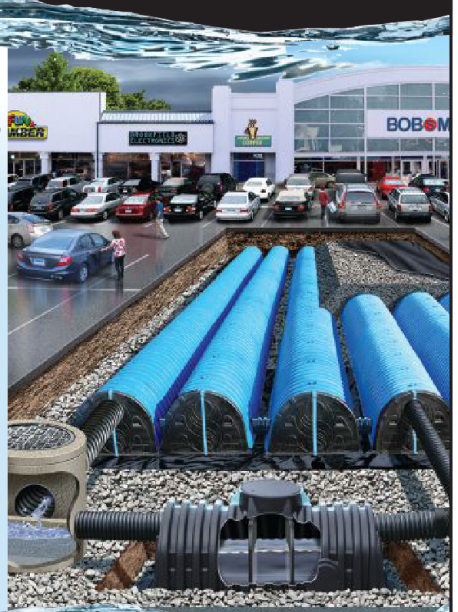

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already fighting the effects of King Tides, and four days of rain—reported from the various rain gauge stations as between 22 and 27 inches—were funneling straight in from the hurricane."

Preparing in the Historic Districts

East of the midlands, the region of the state most significantly affected, architect Jerry English of Charleston architecture firm Cummings & McCrady describes the concerns on the coastal side when storm events are approaching. "Over here on the coast, we had the highest rainfall in this storm event, even more than the midlands who got 17 inches; we got 27 inches of rain over a three- or four-day period. But because our area is so low, you don't get a lot of quick runoff, so much [of that water] goes into the city of Charleston Harbor."

English says all of the area's stormwater is redirected to natural water bodies. "The city has put in some major storm drainage improvement with deep excavation tunneling and pumping."

He was a principal on the Charleston team that had recently finished a

CENTURIES OF EXPOSURE

The most recent High Battery construction project involved a 120-foot semicircular section of the promenade area called "The Turn." This vulnerable portion of the historic peninsula was the most severely affected portion of the entire 1.2-mile stretch of sea wall, and efforts to rebuild it had been in the planning stage for more than a decade. The sea wall was originally built in stages, first as an earthwork in the 1700s, when seawater was pumped out and the area in to extend the land affording military protection, and later to build homes. The sea wall was rebuilt several times with stone and ship ballast. Several breaches from hurricanes in the late 1800s initiated a new High Battery, constructed between 1909 and 1911. A century later, in 2014, the newest incarnation of the seawall was finished.

sea wall restoration, replacing a wall built just prior to World War I. The new sea wall portion protects the historic peninsula of the High Battery promenade that faces Charleston Harbor and looks out to Fort Sumter. The promenade is a popular walkway for tourists enjoying the city's historic cobblestone streets, elegant pastel color homes, and rich Colonial and Civil War history. English says, "Our most important concern we have about any storm is trying to determine when landfall will occur and how this is happening relative to the state of the tides."

The tides, he says, "are central to any view of whether there could be flooding or damage." In October 2015, weather experts reported that the already high "King Tides" of late September precipitated the highest tides recorded in Charleston Harbor—greater than 8 feet—since Hurricane Hugo set a record of 12.56 feet in 1989.

English cites wave action as another serious concern. "Wave action has greater effect than wind. In designing the new High Battery, we were using new tough standards based on better knowledge and years of weather data analysis. Everything from tides, wave action, and seismic considerations are used, and then we also have to adhere to our strict historic preservation policies in the materials and building process."

While floodwaters covered the new High Battery and roadways beyond during October, the new sea wall performed perfectly. The city is continuing the renovation of the remaining mile-long adjoining Low Battery sea wall, which English anticipates will take many more years for completion.

"Our most important concern we have about any storm is trying to determine when landfall will occur and how this is happening relative to the state of the tides."

The King of Tides, and a "Lunar Standstill"

Becker explains that "King Tides," a term that originated in Australia, denotes the phenomena of higher-than-normal tides that can occur during an astronomical alignment of the sun, moon, and Earth; it is not a scientific term. These high tides can occur twice a year when, literally, the planets are aligned.

Also contributing to the higher

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water was a "supermoon," a phenomenon that occurs only once every 18.6 years when the moon is full and closer to Earth in its orbit. Astronomers refer to this event as a lunar standstill; the most recent one caused reports of record high tides on September 29, 2015, all along the eastern North American coast, from New Brunswick to Florida. Consequently, the lowlands of South Carolina were already in a flooding stage even before the rainfall.

While the coastal areas of the state are no strangers to hurricanes, Becker explains that the South Carolina midlands, the Piedmont region that is hilly and full of rivers, have never experienced anything remotely close to this disaster in known history. "Charleston has had decades to develop mitigation with its exposure to storms, but here in the midlands, this has never happened. The entire region got a lot of rain, and the worst hit were watershed areas along rivers. We were facing an already-waterlogged river system that typically is not prone to flooding. But the sheer *volume* of water is what has dubbed this the '1,000-year' flood."

Becker adds that weather experts have since estimated "about 5.8 trillion gallons of water were dumped on us over a period of a few days." For comparison, that is almost six times the amount of water in Florida's Lake Okeechobee. The renowned Everglades lake is nearly 9 feet deep, 29 miles wide, and 35 miles long; magnify this by five and it's a lot of water!

So, it's no surprise that many of the midland's earthen dams that have stood the test of time failed in the face of this water onslaught.

An Alley of Rain

"I was literally watching the water rise, and it finally stopped a few inches from my first floor," says local midlands-area resident and engineer Brian Bates of Columbia, SC, civil structural engineering firm Woolpert Inc.

Bates, who says he has lived on a manmade lake for almost all of his 49 years, has "never seen anything remotely like this."

Flood damage occurred throughout the state.

He notes, "The coastal folks give us grief about how much rainfall we are complaining about, but here, the topography is different. When it floods in Charleston, the water comes up, floods everybody a little, and then goes down and back out to sea."

Flooded roadway in Columbia

But the midlands, which includes the capital city of Columbia and surrounding counties, is centrally located in the state, and flooding is a very different scenario.

"We're on the fall line between the mountains and the coastal plain, and the slope of the ground dictates what the water is doing," adds Bates. "The Saluda and Broad rivers collide at the fall line to form the Congaree River, where it transitions from rapids, rushing water, and rocks to a wide, slow-moving river with a large floodplain due to back pressure, or tailwater effect, from the coast, which adds an interesting piece."

He describes how the rain over four days was funneling straight in from east to west, from moisture that was left from the receding hurricane, and being drawn inland by a slow-moving low-pressure system that was moving west to east and a high-pressure system in the north.

"It [the water] basically was just sucked into this corridor, creating an alley of rain that ran just north of Interstate 26 into Columbia. After that there was no more moisture, and it just kind of petered out."

Bates remarks that this flooding marks an event on par with Hurricane Hugo of 1989 and Hurricane Hazel of 1954 as the disaster benchmarks for South Carolina. But, he adds, it doesn't really have a name, so people are simply calling it the October Flood, because it isn't technically associated with Hurricane Joaquin in any direct manner. Nonetheless, "It was a historic event, destroying dams, roads, in some places complete buildings, and houses that were swept away."

In this scenario, Bates emphasizes, "It was water *velocity* that was a big deal, plus the quantity, and this is what breaks dams and breaks them quickly—fast-moving water."

It's a Big and Little Dam Problem

Historically, small dams were built throughout the state for farm ponds, public and private recreational lakes, source water reservoirs, and mills. Bates says, "I was always told growing up that during the Great Depression, the Works Projects Administration created perhaps hundreds of the dams across the state." The WPA was initiated by the federal government to provide jobs and improve infrastructure.

However, only classified dams are on the Department of Health and Environmental Control (DHEC) list. Bates says there are probably about 5,000 dams in total, but only "about 2,500 are noted as classified dams." Another estimated 2,500 are unclassified. The difference, he explains, is that only classified dams are inspected, but with thousands to inspect, it's still a daunting job left to a small staff to assess these structures. This leaves thousands of unclassified structures that never receive any attention.

Areas near rivers were especially hard hit.

Most of the dams in the state are "primarily earthen dams that were built years ago, some as low as 8 feet, and some exceeding 25 feet high. Some of them are armored with concrete," says Bates. An unknown number have also been built on private properties as subdivisions arose around artificial lakes; these are even less likely to conform to any strict engineering standards.

Although Bates applauds the sound construction of the older dams of the WPA, the Civilian Conservation Corps,

and the Soil Conservation Service, he says, "These are now 80 years old. Those guys did a great job; however, nobody could take into account how the watershed would be developed."

In today's world, "We get a lot more water, moving a lot faster than the designers ever dreamed of."

While there was much finger-pointing in the headlines over failing dams and lack of inspections, Bates is quick to cite the real source of the problems. Braving the storm, he and local officials personally inspected the dams during and following the flooding.

"There were dams that were breached, no question, but in view of the amount of rainfall, it was runoff that was the major issue. The water coming from the breach of dams was dwarfed by runoff in most cases."

Bates describes one scenario in which the owners of a building in the floodplain of Gill's Creek reported more than 6 feet of water inside. The owners were angry, saying that the breached dam upstream caused the water to collect in their facility. However, Bates says, he did a quick calculation and determined "the water that came from the dam failing was an order of magnitude lower than the flow rate associated with the runoff from the watershed. We had water flowing at approximately 20,000 cubic feet per second in the channel and floodplain at that location, but only about 1,800 cubic feet per second of that was a function of the draining of the upstream lake.

"The timing of that building's flooding was at the peak of the storm's runoff, and the water was so far out of the banks at that point that the water from the dam breach probably added less than six inches to the six feet."

He illustrates the magnitude of this amount of water. "Imagine a stack of one-cubic-foot blocks; now picture 20,000 of them, and then imagine that this stack is passing you by *every second*. That's how much water there was, and why we call it unprecedented, historic flooding."

And it is this extraordinary flow rate that causes the breaks in dams, and sometimes loss of life.

"You just can't imagine what it's like to witness these dams breach," he says. "We were watching Cary Lake dam as it's breaching, listening to the guardrails shred. There's no wind, but the fact is water is just not

"These dams are now 80 years old. **Those guys did a great job; however, nobody could take into account how the watershed would be developed."**

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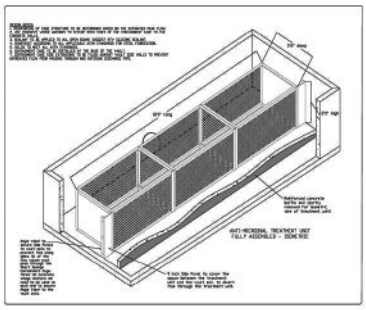

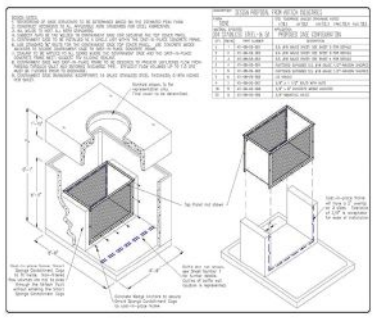

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compressible, and when there's four feet of water over the road, anything in its path is no match for those millions of gallons of water."

He adds, "People have no idea how fast water is moving, and they try and cross flooded roads and are swept away. A big SUV is just like a twig and is no match for this fast-moving water." The majority of deaths related to the storm were from people being trapped in cars and swept away.

A Technique You Can't Really See, But It Works

Bates found that dams that had been constructed with emergency spillways almost always survived the storm's onslaught.

"These earthen dams have a clay core and a primary spillway, which is typically a concrete box with one or two sides lower than the top. When the water gets high, it goes into the top of the box and then through a barrel pipe to the downstream side of the dam."

Most dams also have a secondary spillway, typically some configuration of a concrete flume that goes over the dam and drops down the backside to accommodate higher flow rates. "It channelizes the water so it never touches the unarmored earth of the dam," explains Bates. What differentiated the dams that survived from the ones that were highly damaged or failed (often in the same series) was the existence of an emergency spillway.

Bates says an eight-hour site visit to assess area dams six days after the flood and a debrief with the state engineer confirmed "any of these that had true emergency spillways had minimal damage; some had none, but they all survived."

However, not everyone can actually tell just by a cursory look whether this type of emergency spillway exists. "It takes high water flow and puts it around the dam by going around one end and then linking back in with the creek downstream of the dam. It's a gentle, vegetated, broad, flat trapezoidal section that is cut into existing ground, not the fill material of the dam," says Bates. But it's not always obvious to casual onlooker.

Pointing to the original builders who designed this type of prevention structure, he says, "My old Bureau of Reclamation Small Dam Design book shows how you're supposed to design and build these. These guys were brilliant, and it was written in the '50s. Everyone should have a copy."

Furthermore, he says, the cost of creating this emergency spillway at the time a dam is built is insignificant, but retrofitting an existing dam is nearly cost prohibitive.

So why don't more dams have this protective structure?

"Because they have *roads* over the top of them," he says. "Dams with a road on the top require a bridge to be built over the aforementioned secondary flume spillway. If the dam also has an emergency spillway, then you will either allow the road to overtop during emergency situations or build an additional bridge. Allowing the road to overtop would have significant safety and legal liability issues. Bridges are expensive. These non-emergency-spillway dams are almost always within the category of what we call classified dams"—the ones that do receive state inspection. Still, many of them failed. Bates emphasizes that the nomenclature "classified" and "unclassified" can also be a source of confusion, as both types of dam could be on the same system.

	Rainfall (Inches)									
Gauge Name	Total	1 Hour	2 Hours	3 Hours	6 Hours	12 Hours	24 Hours	2 Days	3 Days	4 Days
KCAE	11.46	1.56	2.83	3.60	5.46	7.33	8.68	10.75	11.35	11.46
KCUB	12.45	1.67	3.16	4.49	6.43	8.48	9.71	11.79	12.40	12.45
KMMT	11.47	2.41	4.36	6.75	8.23	8.66	10.20	11.08	11.37	11.46
Trib to Rocky Branch	11.30	1.87	2.86	4.17	5.96	7.73	8.83	10.57	11.27	11.30
Columbia-GILA RG	16.20	2.88	5.05	7.15	9.82	12.04	13.47	15.28	16.18	16.20
Columbia-GILB RG	13.84	2.77	4.69	6.73	9.34	11.46	12.33	13.82	13.84	13.84
Columbia-GILC RG	10.88	2.14	3.20	4.60	6.58	8.37	9.17	10.83	10.88	10.88
Columbia-RocA_RG	13.63	1.17	2.26	3.30	6.12	8.63	10.10	12.58	13.49	13.63
Columbia-RocB_RG	12.39	2.59	3.62	4.95	6.60	8.54	9.74	11.66	12.26	12.39
Columbia-Kin_RG	14.65	1.99	3.10	4.70	7.06	9.31	10.69	12.69	13.42	13.94
Columbia-SmiB-RG	14.58	2.39	3.72	5.41	7.92	10.18	11.69	13.72	14.50	14.58
PRG06	14.63	2.28	4.08	5.82	8.57	10.67	12.12	13.88	14.51	14.63
PRG05	13.32	1.80	2.84	4.29	6.46	8.64	9.91	11.86	12.38	12.82
PRG03	11.97	2.12	3.04	4.35	6.09	8.04	9.23	11.14	11.87	11.97
PRG04	12.95	2.08	3.27	4.80	6.92	8.94	10.30	12.18	12.81	12.92
PRG01	13.81	2.46	4.39	6.02	7.87	10.06	11.36	13.36	13.80	13.81
PRG07	14.11	2.39	3.97	4.88	7.36	10.13	11.77	13.64	14.05	14.10
PRG02	15.43	2.78	4.85	6.65	9.18	11.31	12.71	14.52	15.42	15.43

Planning for the Future

While you can never really predict a disaster, you can be prepared for it, Bates affirms, and outlines what he believes would be appropriate measures to help in the future.

He says the State Dam Safety Program needs to be properly funded, and it needs to be coordinated with the state flood program.

"It doesn't make sense to have the dams program in the Department of Health and Environmental Control (DHEC) and have the Flood Mitigation Program within the Department of Natural Resources. Dams are now in DHEC, and they dropped the program funding to just $200,000 a year. It needs to be at least two to three *million* dollars for the whole state."

He further emphasizes that the dam standards need to be revisited, particularly to upgrade the standards that determine whether a dam is classified.

"For example, we saw three classified dams on a creek, and they are subject to inspection. But the dam downstream of those dams was not classified. Once you have a classified dam on a system, *everything* on that reach should be classified all the way to the river. In this case, the substandard dam blew out, never having been inspected and maintained."

The standards, Bates says, should be redrafted for dams to be engineered and built to probable maximum storm

Gauge Name	Total	Return Interval (Years) 1 Hour	2 Hours	3 Hours	6 Hours	12 Hours	24 Hours	2 Days	3 Days	4 Days
KCAE	200	1	5	10	50	100	100	200	200	100
KCUB	200	1	10	50	100	200	200	200	200	200
KMMT	500	5	50	500	500	200	200	200	200	100
Trib to Rocky Branch	200	2	5	25	100	100	100	100	200	100
Columbia-GILA RG	1000	10	200	500	1000	1000	1000	1000	1000	1000
Columbia-GILB RG	1000	10	100	500	1000	1000	500	500	500	500
Columbia-GILC RG	200	2	10	50	100	200	100	200	100	100
Columbia-RocA_RG	500	< 1	2	10	100	200	200	500	500	500
Columbia-RocB_RG	200	10	25	50	100	200	200	200	200	200
Columbia-Kin_RG	500	2	10	50	200	200	200	500	500	500
Columbia-SmiB-RG	1000	5	25	100	500	500	500	500	1000	500
PRG06	1000	5	50	200	500	500	500	1000	1000	500
PRG05	200	1	5	25	100	200	200	200	200	200
PRG03	200	2	10	25	100	100	100	200	200	200
PRG04	200	2	10	50	200	200	200	200	200	200
PRG01	500	5	50	200	200	500	500	500	500	500
PRG07	500	5	25	50	200	500	500	500	500	500
PRG02	1000	10	100	500	1000	1000	1000	1000	1000	1000

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The president declared a federal emergency on October 3, 2015.

standards, and they should require dams to have emergency spillways.

Collecting Aerial Imagery

In an effort to address the immediate needs of those affected by the disaster and to document the event for future study, Woolpert, headed up by Bates's initiative, set off in a plane to collect perishable aerial imagery. Two days after the largest rainfall ever recorded in the midlands, aerial imagery was taken and then uploaded to a website hosted by the company at its Dayton, OH, headquarters. This made the information immediately available to local and stage agencies and the South Carolina Army National Guard. Dr. Patrick Bresnahan, geospatial information officer for Richland County, says the imagery provided by Woolpert was valuable immediately, made available by a cloud-based app technology.

"The Woolpert app worked and was very much needed since everybody's out in the field," he says. "Having that imagery tool, before and after the event, has been great. It has been used every day and continues to be a key part of our recovery efforts."

Bates adds, "We [Woolpert] had the ability to do it, and we had the resources. If we had a chainsaw and that was needed to help our neighbor, we'd use a chainsaw. We had an airplane, so we used an airplane."

Bates says gratitude for the company's swift action was unanimous. Some officials who used the Woolpert cloud-based photogrammetry within 24 hours said it could have taken weeks to secure that service if they'd had to go through official channels, prompting Bates belief in pre-arranged contracts and signatures.

"Each level of government should have these arrangements signed and ready to go, whether it is a flood, wildfire, storm surge, earthquake, whatever. We need information for first responders and the emergency management folks on the ground. But these must be people who are verified as experts, and not just people with a plane and a camera."

Jill Stewart, P.E., manager of the DHEC Dam Safety Program, outlines the agency's strategy going forward. She reports that DHEC has formed a partnership with HDR Engineering to review and enhance the agency's Dam Safety Program and its inventory of 2,370 dams. "Immediately following the historic flooding, our agency, with the assistance of HDR and the US Army Corps of Engineers, have proactively assessed all Class One and Class Two dams statewide. This includes a total of 652 dams, of which 76 were issued

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Emergency Orders. Another 167 dams were issued letters requiring owners to perform necessary maintenance and repairs with assessments performed by engineers."

Stewart adds that DHEC has also requested additional funding from the state in the 2016–17 budget, citing a proposed bill that has already been entered by the state's speaker of the house that would make statutory changes and provide additional owner responsibility.

Keeping a dam safe to withstand a future rainfall, Stewart says, would include three key points. "First, ongoing maintenance and observation is crucial. Dams should be free of trees and other woody vegetation to maintain integrity, and control structures such as a valve or gate on a reservoir should be regularly tested to ensure proper functionality.

"Second, in the event of a weather forecast calling for heavy rains, the operator should take measures to lower the water level in order to make room for the storm volume."

Finally, she says, dam owners should routinely review their emergency action plans (EAPs) and exercise the plans on a regular basis. Such a plan, Stewart explains, "outlines steps to take and who to contact when they detect a situation that may lead to dam failure."

These situations she notes, "may include overtopping of the dam or failure of the outlet structure, among other scenarios."

EAPs generally guide the operator, depending on the severity of the situation, to contact state officials (DHEC or EMD), call downstream property owners, and in certain situations work with local officials to close roadways.

Still Cleaning Up by the New Year

By the beginning of 2016, South Carolina FEMA released damage assessments from the flooding, but according to Derrec Becker, "We're still just a few months out from this disaster, and we're in the planning stages; it's going to be months before we have a final complete assessment and strategy for the future."

He adds, "Our initial saving grace was that emergency operations centers were already in high alert and activated in anticipation of Hurricane Joaquin. We were on high ground, responding to requests from resources."

The state had help in resources from 11 states, as far away as North Dakota and Alaska, and damages have been now assessed as "a little under $1.5 billion," reports Becker.

This figure includes uninsured damages to personal property, the cost of insured damages, and the economic impact on tourism. It also includes the economic costs from lost livestock and crops. "The entire cotton, soybean, and peanut stock has been ruined; the water came in and sat in the fields before it could be harvested, so it's virtually a total loss," he says.

"We're still in the recovery phase. Since the flood, we've identified strategies that would help, such as better coordination between municipal and county communications and enhanced training. We're looking at different things for emergency planning, because you can never have too many resources. How can we better serve our residents?"

As of January, Becker says, the department had inspected more than 83,300 properties and awarded nearly $80 million in grants to survivors for housing and other essential needs, operating 30 disaster recovery centers in 24 counties. FEMA has also provided $17.2 million to state and local governments and local communities for debris removal and the repair, restoration, replacement, and mitigation of damaged public facilities.

"We are a small state, and with our experience in addressing every kind of natural and manmade disasters, we have a long history of going out to help others. We were very fortunate in getting speedy help ourselves from our out-of-state colleagues when we needed it."

Asked if there were any unexpected disaster-related scenarios, Becker reports, "Well, there were a few displaced alligators and snakes showing up in yards," but their removal falls to the purview of the Department of Natural Resources. Nonetheless, finding large reptiles on the front lawn is a disconcerting discovery for anyone, especially already overwhelmed residents.

No supermoon is predicted for 2016, and perhaps King Tides will be a non-issue this year. But as experts caution, you can't plan for a disaster, but you *can* be prepared, and South Carolina will surely be on high alert this fall.

Barbara Hesselgrave *is a writer specializing in environmental topics.*

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