Firefighters wade toward floating trailers, near which victims await rescue on roofs and in trees. Other trailers, ignited by broken gas lines, blaze in the background.

Photos by the author

Delayed disaster

Earthquakes and tornadoes may be sudden, but at least they signal their arrival. However, that's not the case when business as usual obscures the onset of life-threatening conditions.

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How do you know when a disaster is taking place? It's not as easy to pinpoint as you might think, regardless of whether you're one of the general public or a trained emergency responder.

As a research scientist specializing in severe weather, I've been on scene following many deadly incidents, and I've learned that the seemingly simple step of disaster recognition can lag the onset of life-threatening events by a significant margin. As an example, I'll discuss the July 28, 1997, flash flood in Fort Collins, Colo., and the response by the Poudre Fire Authority.

Regions in and around mountainous terrain are susceptible to weather effects that don't occur in other parts of the world. Sharply changing topography provides a mechanism for modifying both airflow and water runoff. Such is the case for Fort Collins, a city of more than 100,000 people situated along the eastern foothills of the Rocky Mountains in north central Colorado.

The elevation rises gradually by more than 2,000 feet from the eastern Colorado border to the city center. Easterly low-level winds, called upslope winds, can bring what is typically moister air from Kansas and Nebraska right up to the base of the mountains. Warm, moist rising air is a key ingredient for thunderstorms. If atmospheric instability is present, strong storms are pretty much guaranteed.

A flash flood occurs when heavy rain persists over canyons, large river basins or sloping terrain for several hours, particularly when soils have been saturated in advance. In such cases, catastrophic events develop quickly.

Lay of the land

As with most cities on the high Plains, Fort Collins has its own unique set of runoff and drainage problems. In addition to the Cache La Poudre River, which crosses through northern and eastern Fort Collins, the urban area is crisscrossed by a series of creeks and irrigation ditches running both east-west, and north-south. One such ditch, the Pleasant Valley and Lake Canal, winds its way from its origin north of the city along a convoluted path into and through several west Fort Collins subdivisions. Near the south end of the city, it crosses a normally tranquil and shallow west-east running stream known as Spring Creek.

But rivers, creeks and irrigation canals aren't the only important hydrological factors affecting the area. The elevation along the western edge of Fort Collins averages 5,200 feet. On the other side of town, six miles to the east, the average elevation is just under 4,900 feet. This gentle-but-persistent 300-foot drop in terrain across the entire city makes for a significant difference in var-

ious weather situations. For example, western Fort Collins usually gets more upslope precipitation than eastern sections.

From a drainage standpoint, the sloping terrain means a very persistent west-east runoff gradient during heavy rains. To complicate matters even further, the runoff terrain isn't flat across the city. Water drains into broad, shallow "drainage basins" that channel the runoff as it moves east. These basins are about 1 to 3 miles wide, depending on local terrain. Within each basin are quirks in both local topography and human engineering, making local runoffs differ dramatically from the general trend.

On July 27, 1997, the passage of a cool front just before noon put Fort Collins into a strong upslope flow pattern. The potential for increasing low-level moisture was particularly significant in this case, since the middle and upper atmospheres were already moist from a strong southerly "monsoon" flow off the Gulf of Mexico and Pacific Ocean.

Rain began in the city around 4:30 p.m. Intense upslope flow and increasingly heavy showers continued all night, bringing rainfall totals as high as 3 to 4 inches in western Fort Collins by noon the following day. Similar daily rainfall totals occur every so often in the region, however, so the few reports of flooded fields, high-running creeks and nearly full irrigation canals weren't unusual enough to elicit all that much in the way of special response.

Dive rescue personnel use boogie boards and rafts to assess rescue needs as the crisis in the trailer parks unfolds.

Watching the water level

The National Weather Service recognized the potential for trouble when it issued a Flash Flood Watch at 5 p.m. on Monday, July 28. In the text of the message, forecasters warned that the atmosphere over northern Colorado was saturated and that heavy thunderstorm rains were likely. But a "Watch" is just a forecast based on atmospheric potential, and no special plans were in place in the city's response plans to deal with "potential."

Heavy rain began again just after 5 p.m. This time the action was centered over western Fort Collins. A series of individual rain cells formed southwest

of the city, then moved off slowly toward the north-northeast. The cells brought periods of extremely heavy rain, mixed with shorter periods of drizzle. Low-lying fields and intersections began flooding within 1½ hours, but it took another hour for the situation to become serious.

Post-event interviews I conducted with more than 250 people traveling through and living in the affected areas found an overall lack of concern early in the evening. Drivers continued about their business, slowing somewhat as they drove into heavier downpours, but people reported being either pleased to see the rain or irritated by the slower driving times. Between 5 and 7 p.m., not many in the general population recognized the situation as dangerous.

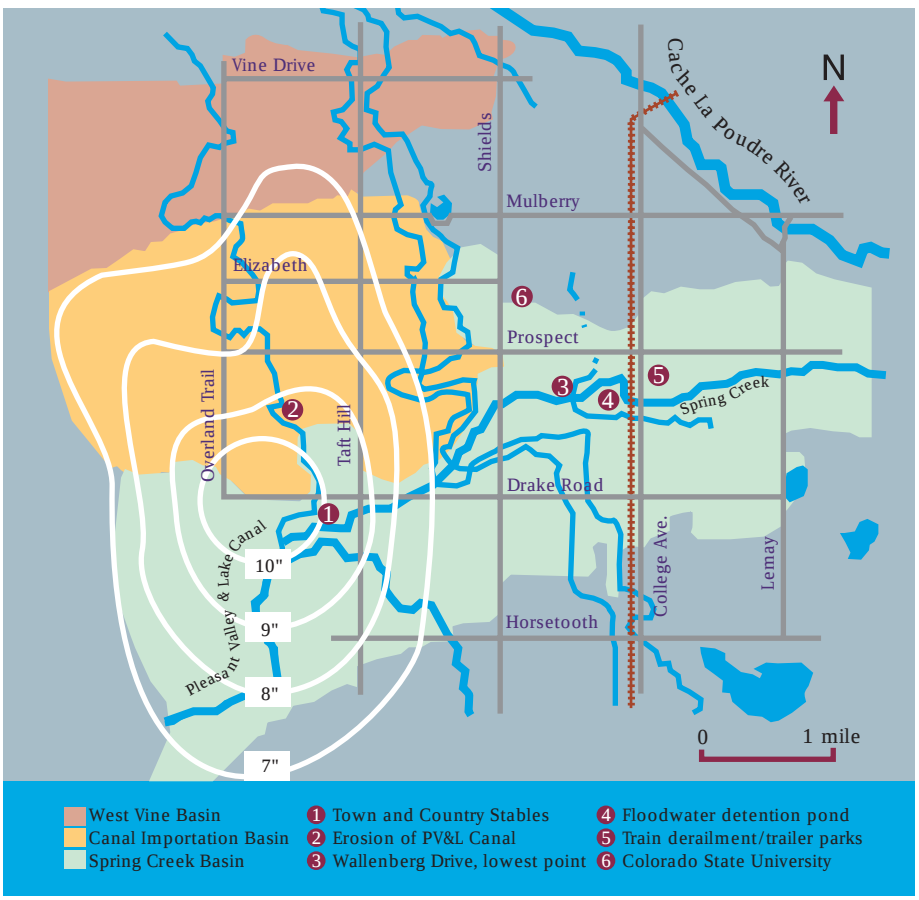
By 7:30 p.m., however, flags were beginning to go up for people in specialized professions, as well as for a few unlucky souls whose problems had begun early. An engineer from the city's Stormwater Utility got concerned enough to set out for an inspection trip of the PV&L Canal. Police officers began to report more and more intersections under water. Here and there, the general public experienced problems, such as water leaking in through basement window wells in low-lying areas on the west side of town.

Around this time, E-911 dispatch began to get sporadic calls for help with basement flooding. The National Weather Service issued an Urban and Small Stream Flood Advisory at 7:36 p.m. for eastern Larimer County, specifically mentioning Fort Collins. It warned of the likelihood of small creek and stream flooding, noting that the ground was already saturated from the previous evening's rain.

Despite the ominous signs of a growing threat, no one as yet saw the situation as becoming deadly. During the early hours of the storm, the Weather Service did not issue an actual Flash Flood Warning. This "highest-level-of-alert" would have triggered scroll bars on major television stations to mobilize both the general public and the city's emergency staff.

Based on the available information, forecasters were having a hard time justifying taking this important step. Part of the problem was that the atmosphere was so warm and moist that radar rain-rate calibrations were off. Hail concentrations normally found in the upper reaches of the storms were missing, and Doppler radars, calibrated to a "normal" storm, were understating rainfall amounts by as much as 50%.

In addition, no eyewitness reports were reaching the Weather Service. Local weather spotters perceived the event as "extremely heavy rain," but they didn't recognize it as particularly threatening. At 7:30 p.m., the heaviest storms were far too transient for any pattern to emerge. A Flash Flood Warning was finally issued at 9:40 p.m.



Still business as usual

Just before 8 p.m., E-911 dispatch began sending firefighters out to a few houses to help with pumping, but even this wasn't all that unusual. Flooded basements happen in Fort Collins with every extreme rain event, and the Poudre Fire Authority offers help on a non-emergency basis whenever resources aren't being used elsewhere.

Local traffic volumes on city streets remained near normal, and interviewees in my post-event survey reported feeling nothing more than minor irritation as they continued with their evening activities. However, some rather bizarre behavior began around this time.

At roughly 8:15 p.m., several Colorado State University students were seen by police officers and the city's emergency manager riding "boogie boards" down Elizabeth Street on sheets of one-foot-deep water, toward the Shields intersection, where the water was about 2 feet deep. Here, where the northern half of the Canal Importation basin drains onto the CSU campus, they were met by friends in high-centered pickup trucks, and driven back west for another "run." In the southern half of the basin, the volume of traffic increased as residents with large pickups and SUVs came out to test their vehicles in the high water.

Things really began to liven up about this time. The E-911 call volume increased sharply, going from just six calls between 8 p.m. and 8:15 p.m. to 18 calls in the next 15 minutes. Several calls concerned the PV&L Canal overflowing into houses. What wasn't known at the time was that a major backup in the canal's flow was occurring just north of Spring Creek, where 3-foot-deep runoff water swept across a 10- to 12-acre open space. This water rushed eastward at about 15mph, then banked right and flowed south toward the creek. It was running across the top of the PV&L Canal in a place where the canal runs west for several 100 yards in a direction opposite the underlying flow. The general runoff, plus the canal's diverted water, now roared toward Spring Creek.

One of the early E-911 calls was from the Town and Country Stables, which sat in a lowland area right in the path of this overflow. Firefighters came on scene just after 8:30 p.m. to find water depths

ranging from 6 to 12 feet. They spent a harried 30 minutes getting horses to safety. A quarter-mile downstream and a half-hour later, other rescuers began a 2½-hour odyssey trying to find a way to pull a woman and her son from a tree half submerged in 8 feet of rushing, swirling water.

Water pours onto the campus of Colorado State University, where parked cars are caught as the flow increases. The next morning, the Lory Student Center sits in the middle of a lake.

Closer to the center of town, the southern half of the Canal Importation basin had begun to reach its capacity, and calls began to come in about flooded basements and floating cars. Many of the second variety included reports of vehicles floating east in 4-foot-deep water with people trapped inside.

Down at the end of a small lowland cul-de-sac in a middle-class subdivision, the bank of the PV&L Canal overtopped and began to erode away. Runoff water that had previously been held back by the canal embankments now poured into houses, soon reaching as high as the first-floor ceilings. The engineer who'd gone down to check on the canal was caught by this event, and nearly drowned before grabbing onto a passing tree.

Water raged down streets and through a local drainage channel at 1,750cfs, heading east where the flow cut across main north-south streets. There it had trapped other drivers who failed to recognize the deadly nature of the flow.

A late realization

The call rate at the dispatch center was now at nearly one every 30 seconds, and the city's emergency manager called for all off-duty firefighters, ambulance staff, police officers and dive-rescue personnel to be paged out. The response community had at this point recognized the unusual nature of the storm.

However, as the call rate accelerated, radio frequencies became jammed with traffic, and dispatchers had trouble keeping track of where fire, police and ambulance units were in the chaos of trying to prioritize calls. To make matters worse, response times were doubled or even tripled as routes to various locations became blocked by the deep fast-flowing water.

In several cases, firefighters were blocked from reaching one call and diverted on their own to rescue trapped people they encountered elsewhere. Often it would take five minutes or more to get through to the dispatch center and inform them of the change of mission. Fort Collins was now behind the curve, and many firefighters and police officers began searching for and rescuing citizens on their own.

Along Elizabeth Street and other streets across west Fort Collins, boogie boarders were toppled into the furiously flowing water and had to be rescued. Dozens of automobile drivers were pulled from cars that tumbled along in deepening water. Near the Elizabeth and Shields intersection, industrial-sized dumpsters smashed into vehicles, clearing the roadways.

The water washed onto the campus of Colorado State University, flooding the campus police and dispatch center, smashing through large picture windows in the Morgan Library, and inundating the massive student center complex. A man who'd been trying to squeegee trickles of water from the west entrance of the student center left just seconds before 4- to 5-foot-high water broke through the double glass doors.

In the basement of the library, workers who were mopping up trickles of water in a large storage area heard a wall groan and ran for the stairs less than 30 seconds before the wall caved in. Nearly 500,000 books were destroyed. Many people who had been in either building missed being killed or injured by minutes.

Back to the south, Spring Creek now charged eastward with flow rates of more than 6,000cfs. This water was joined by water exiting the southern end of the Canal Importation Basin at 1,350cfs, as well as water coming in from south of the main channel at 850cfs.

Along these routes, houses flooded, basement walls collapsed and motorists were washed into deepening waters. At the confluence of the three flows, trucks, vans and SUVs were swept into a pile at the end of Wallenberg Drive, the lowest street in the region. A two-car garage was washed off its foundations, nearly dragging some of the fleeing drivers, who were wading through chest-deep water, along behind it.

Things fall apart

The combined flow at this point sent more than 8,250cfs of water directly into a large 50-acre lowland area that had been designed to be a massive floodwater detention pond. On the north, west and south sides of the region, the terrain slopes gently downward toward the center. The "relatively lowest" eastern side is bordered by a massive 19-foot-high railroad embankment. Several culverts had been engineered into the embankment to allow both Spring Creek and huge quantities of excess water to move east in a more controlled fashion.

The entire detention facility had been designed to collect and hold nearly double the predicted 500-year flood overflow. Its total capacity of more than 16 million cubic feet was nearly reached by 10:45 p.m., at a time when the E-911 call rate from the western part of the city was running one every 16 seconds. No stream or depth gauges had been installed in the lowlands, so the buildup went unmonitored. Also, since the area is large, unlit and housing-free, there was virtually no way for anyone to observe the potentially deadly situation.

The first sign of the final phase of the catastrophe came when several people to the east of the railroad tracks noticed that Spring Creek was running exceptionally high between the railroad bed and College Avenue, the main north-south street through the city. Nearby houses were beginning to flood, and E-911 calls from this area began to filter into the overworked dispatch center. Only one engine was available in reserve, and it headed down College at 10:44 p.m.

While it was on its way, and while most rescuers worked furiously two miles to the west, a 12-by-14-foot culvert under the tracks failed from a combination of turbulence and the enormous pressure. A few minutes later, the deepening water, which had continued to rise despite the release of 3,300cfs through the failed culvert, began overtopping the railroad bed. Unfortunately, in an example of the poorest possible timing, a freight train had started across this section of tracks minutes before the overtopping began.

The combined flow from the culvert and the overtopping surged into two trailer parks directly east of the tracks. Several witnesses who'd driven through the parks just 20 minutes earlier saw only rain-dampened roads. By 11 p.m., however, 8-foot-deep raging waters were floating trailers and sweeping victims into the 12-foot-deep Spring Creek channel. Broken gas lines had ignited three mobile homes, which burned fiercely in the middle of the flood waters. The train derailed, and a nearby store exploded. Sixty-two people were in the process of being injured, and five women had already drowned.

From 5 p.m. to 11 p.m., the total rainfall in extreme southwest Fort Collins was 10 inches. In eastern and northern Fort Collins, residents looked out their windows at what for them would be an inch or two of rain and went to bed.

Lessons learned

The Fort Collins flood brought with it a number of lessons for the local response community and emergency management staff, especially regarding the issue of recognition.

1) Emergency managers must be aware of every type of natural disaster to which their area is prone.
2) Emergency staff must train to be more alert than the general public to their daily environment.
3) A system must be in place to facilitate the exchange of information and environmental cues that will help recognize a developing catastrophe.
4) Emergency responders should welcome "false alarms" as a useful component of their job. Part of planning for the worst is acknowledging that natural disasters are so unusual that recognition can often be the most difficult step.

With these lessons in mind, the Fort Collins Office of Emergency Management has formed a working partnership with the National Weather Service. The goal is to streamline information exchange on "threat" days to help both agencies carry out their responsibilities more effectively.

There are a large number of other steps in progress designed to facilitate education, mitigation, observation, and recognition of critical threat. Those that are up and running include:

- Additional rain and stream flow gauges are being installed throughout the city, especially within the more flood-prone areas.
- A low-power AM radio station is being set up to keep the public constantly informed during disasters.
- Natural disaster information cards have been designed to help dispatchers carry out their duties more effectively, available at <www.ci.fort-collins.co.us/c_safety/oem/overview_ndic.htm>.

Finally, many city workers are now trained to think of themselves as emergency responders during natural disasters. They're becoming more "weather-alert" through training and experience, a skill that will facilitate a more effective response in the future. In the case of flooding, for example, Stormwater Utility staff plan to be part of a large observing network that will help the emergency manager intelligently assess the general threat and identify localized problems. FC

In the early morning hours of July 29, 1997, the devastation is obvious. Here, the east side of the Pleasant Valley and Lake Canal embankment has been scoured away by rushing overflow.

As a research meteorologist with the National Oceanic & Atmospheric Administration, John Weaver specializes in severe thunderstorms. For the past seven years, he has also been the department photographer for the Poudre Fire Authority in Fort Collins, Colo. Following the 1997 flood, Weaver designed two training courses for National Weather Service forecasters and helped create a set of natural disaster guidance cards for E-911 dispatchers.