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Our Relationship with a Dynamic Landscape: Understanding the 2013 Northern Colorado Flood

The summer of 2013 was drier than normal along the Front Range, so when rain started falling on the northern end on September 9, 2013, some greeted it with enthusiasm. Others tempered their enthusiasm when the five-day forecast revealed an anomalous lineup of raincloud icons. In fact, a stationary low pressure system had developed over the Great Basin, to the west of the Rocky Mountains, and began to pull monsoonal tropical moisture from the Pacific Ocean as well as more moist air off the Gulf of Mexico. This circulation pattern directed and focused these moisture plumes toward the Front Range. The rain showers beginning on September 9th didn't let up until September 15th, falling most intensely between September 11th and 13th, 2013. According to the Colorado Climate Center, total rainfall for the week beginning Monday, September 9th measured 16.9" in Boulder, 9.3" in Estes Park, 5.9" in Loveland, and 6.0" in Fort Collins. Because the steep, rocky terrain in and around these communities channels water, the effects of precipitation can be greatly amplified and lead to rapid runoff. The sudden, huge influx led to extensive flooding that damaged infrastructure on the Arapaho and Roosevelt National Forests and devastated property, infrastructure, and lives in surrounding communities.

Water from the Big Thompson River washes through a wide landscape in Johnstown, CO. (Image credit: Jenny Sparks, Loveland Reporter-Herald)

The destruction and loss of life that resulted from the September 2013 flood were tremendous. The flood affected 14 counties, killed 10 people, damaged 26,000 homes, and entirely destroyed 2,000 homes. Preliminary figures suggest $2 billion in housing, road, and infrastructure damage to the flood-impacted northern Colorado communities of Boulder, Estes Park, Evans, Fort Collins, Longmont, Loveland, Lyons, Jamestown, and others. This includes an estimated $44 million in damage to the Arapaho and Roosevelt National Forests, where hiking trails and other recreation infrastructure were washed away. Many mountain roads were damaged and remain impassible, and access to public lands and private inholdings remains compromised. "Our preliminary flood impact assessment report, compiled in the weeks following the flood and subject to change – especially as we anticipate

spring run-off events – indicates that the floods caused over 250 debris slides and damaged at least 382 miles of roads, 236 miles of trails, several dozen recreational facilities [campgrounds, picnic areas, parking areas, fishing/boating access sites, etc.], and four bridges," says Glenn Casamassa, Forest Supervisor on the Arapaho and Roosevelt National Forests and Pawnee National Grassland (ARP). To put this in perspective, the miles of roads damaged on the forest is about the north-south length of the state of Colorado. The ARP preliminary flood impact assessment report evaluated 463,000 National Forest acres by helicopter; 230,000 of these acres are considered to be "most heavily impacted." In addition, 144,000 acres of private lands interspersed in patchwork fashion with public lands were not included in the estimate of "most heavily impacted" public lands. Many owners of these private land inholdings may have once relied on historic mining or timber roads minimally maintained by the National Forest to access their private lands; however, many of these roads were partially or fully washed away by the floods. According to Forest Supervisor Casamassa, "Working with the public and nearby communities, communicating about the changed landscape and the associated heightened risks, and making decisions about how, where, and to what extent to rebuild infrastructure will be a large part of our flood recovery efforts." As part of this, a better understanding of the future vulnerability to risk will help the Forest make some critical decisions about rebuilding.

UNDERSTANDING HOW *NOT* TO BE VULNERABLE

A degree of vulnerability may be desirable in some human relationships. However, when the topic relates to human communities and environmental risk, being vulnerable is not necessarily desirable. One way that scientists sometimes think about this "social-ecological" vulnerability is according to the following pieces:

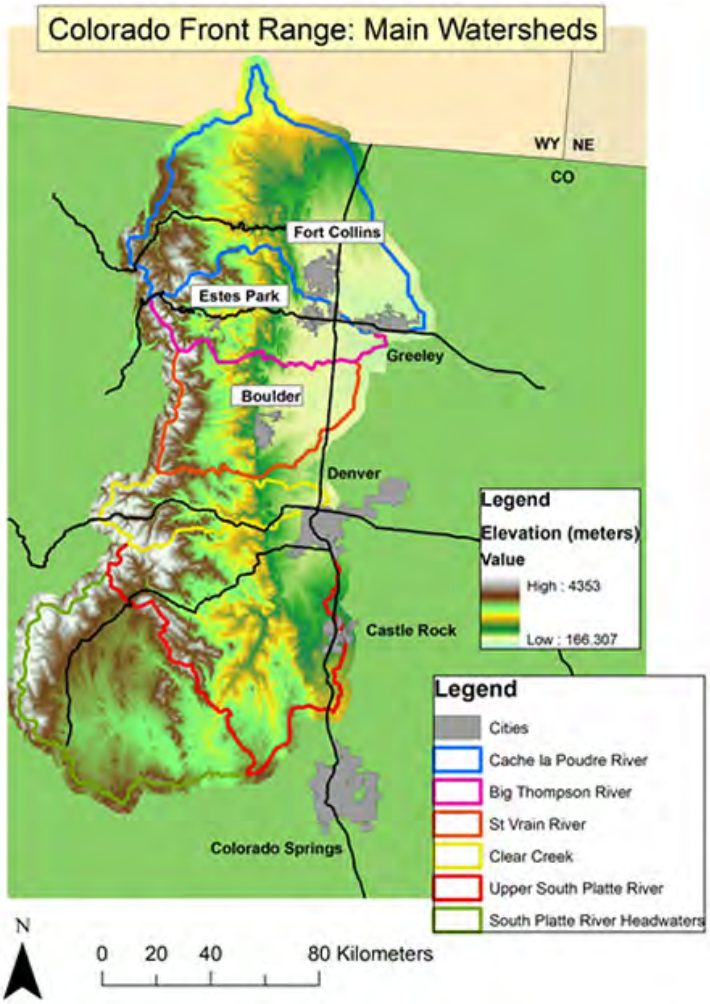
Exposure + Sensitivity + Adaptive Capacity = Vulnerability

In this equation, "exposure" is a measure of how much a system (e.g., a community) might be in contact with a threat. "Sensitivity" is a measure of whether and how a system is likely to be affected by the threat. "Adaptive capacity" refers to the opportunities that exist to reduce exposure or sensitivity, thereby mitigating – or reducing – the overall threat. Combined, these add up to overall vulnerability.

"Unfortunately, we've significantly increased our vulnerability to natural hazards, such as floods, in much of the Front Range over the past several decades," explains quantitative ecologist Linda Joyce, who lives in the affected area. "As the number of residents in many of these mountain and Front Range communities increases, our human footprint in the form of roads and buildings expands across the landscape, altering the hydrology of these systems and, over time, increasing our exposure to risk. In addition, when we build permanent infrastructure such as homes directly on the floodplain, we dramatically increase our sensitivity to these events," Joyce notes.

In some cases, the lessons learned from previous floods have helped to inform the third element – adaptive capacity. Prior to 1997, the City of Fort Collins had already taken many flood mitigation measures including regulation of floodplain development, design criteria for structures in the floodplain, land acquisition, and informational services. The lessons learned from the

These images highlight Colorado's Front Range, which runs north-south from Casper, WY to Pueblo, CO and has a total population approaching 4.5 million. Annual rainfall on the Front Range averages 16-20", while the annual number of days with sunshine averages about 300. (Image credits: Left, Colorado State University -Werner College of Natural Resource; Right, Wikipedia.)



The most significant flooding took place within the Big Thompson and St Vrain watersheds, though the Cache la Poudre and Clear Creek were also affected. (Image credit: Colorado State University, Werner College of Natural Resources.)

flooding in 1997 helped to initiate additional activities including stormwater management, flood-proofing, further land acquisitions, community education and outreach, and a fully functioning emergency notification system. As a result, much of the Cache la Poudre river corridor through Fort Collins now consists of open space that offers abundant opportunities for recreation; it also provides the land area for water, as in the 2013 flood, to spread out and slow down. This is an example of how exposure and sensitivity have been reduced, while adaptive capacity increased; as a result, overall vulnerability is far lower. Indeed, Fort Collins suffered comparatively little damage in the recent flooding and these decisions may have played a role. However, flooding along the Cache la Poudre River in 2013 was not as severe as along the Big Thompson and St. Vrain rivers, where peak flows were so large that optimal floodplain management may have done little to mitigate damage.

CHARACTERIZING THE RECOVERY ON NATIONAL FORESTS: ONE PART SOCIAL, ONE PART ECOLOGICAL

Unlike in Fort Collins, damage on the Arapaho and Roosevelt National Forests was substantial. Vulnerability of much of the built infrastructure – roads, bridges, trailheads, campgrounds – was relatively high. This is because peak flows in many streams on the Forest were comparatively larger, and infrastructure was primarily sited close to these rivers and streams.

Many of the roads and access points that were recently damaged on the Arapaho and Roosevelt National Forests were first constructed for mining and timber interests in the 19th and 20th centuries. In recent decades, as the Front Range communities of Boulder, Longmont, Loveland, Fort Collins, and others became more heavily populated and social values and planning processes shifted, timber and mining roads were repurposed to provide far-reaching access to a wide variety of recreation and other opportunities. Now, many of the 3.3 million people who live along the Northern Front Range have a favorite trail, hiking or camping spot on the Arapaho and Roosevelt National Forests or other adjacent public lands that may have been affected by the flood. This infrastructure damage has elicited a very emotional response from surrounding communities. Due to the scope and scale of the flood, many of the public's favorite places have been irreversibly changed or can no longer be accessed.

National Forests and the "Multiple-Use" Mandate

According to the Multiple Use Sustained Yield Act of 1960 (MUSYA), the National Forests and Grasslands are supposed to be managed for the "multiple use" and "sustained yield" of a range of renewable resources – including timber, range, water, recreation, and wildlife. For the Forest Service as an agency, this mandate translates into the need to both plan for and balance a wide variety of interests, needs, and objectives, and rarely – if ever – leaves all stakeholders completely satisfied. This is to be expected, however, since National Forest stakeholders – i.e., the American public – represent a broad and diverse group of over 300 million individuals, with correspondingly broad and diverse interests, values, and ideas. This "multiple use mandate", combined with collaborative processes and the use of best available science, have long been important in Forest Service planning, and these three elements will be important in flood recovery efforts.

"At this point, we need to ask, 'What is the appropriate amount of infrastructure and where should it be located? Where do we most need to focus our ecological restoration activities?'" explains ARP Forest Supervisor Glenn Casamassa.

The flood caused severe damage to bridges and roads on the Arapaho and Roosevelt National Forests. (Image credit: top and bottom, Arapaho and Roosevelt National Forests)

What might clinically be called a "changed condition" on the landscape can translate into a much more visceral sense of loss to the public. "Imagine having your favorite campground or fishing spot virtually wiped off the map," says Tammy Williams, Forest Public Affairs Specialist. "This is what many of our public is experiencing, because the floods changed the landscape so significantly." In other cases, members of the public may not yet realize that their favorite spots are gone since public access to the forest has been so limited (for reasons of safety and infrastructure loss) since the flooding took place. Forest Supervisor Glenn Casamassa explains, "What existed on the Arapaho and Roosevelt National Forests before the floods represented decades of infrastructure development – the accumulation of many infrastructure additions over a very long period of time. Now, much of the last one hundred years of infrastructure in the flood-impacted area is gone, and the landscape with which people identified has changed dramatically."

Many on the Arapaho and Roosevelt National Forests anticipate, and have already experienced, how challenging it can be for some people to process the change. "It's almost like going through the stages of a grieving process," says Casamassa, "both the ecological condition of the landscape and the infrastructure have changed so drastically." The Forest has plans to engage in ecological restoration and collaboratively identify and decide on infrastructure to rebuild and replace; however, the future infrastructure may not be identical to the past. Explains Casamassa, "At this point, we need to ask, 'What is the appropriate amount of infrastructure and where should it be located? Where do we most need to focus our ecological restoration activities? How should we balance our Multiple-Use mandate, our knowledge of this landscape and best available science, and our limited budgetary resources to rebuild and restore in an ecologically wise and sustainable manner?'"

The flood caused major washouts and erosion on the Arapaho and Roosevelt National Forests and in surrounding communities. (Image credit: Arapaho and Roosevelt National Forests)

which has allowed them to hire a portion of the extra capacity that they will need to collaborate with the public, plan specific recovery efforts, and implement management activities.

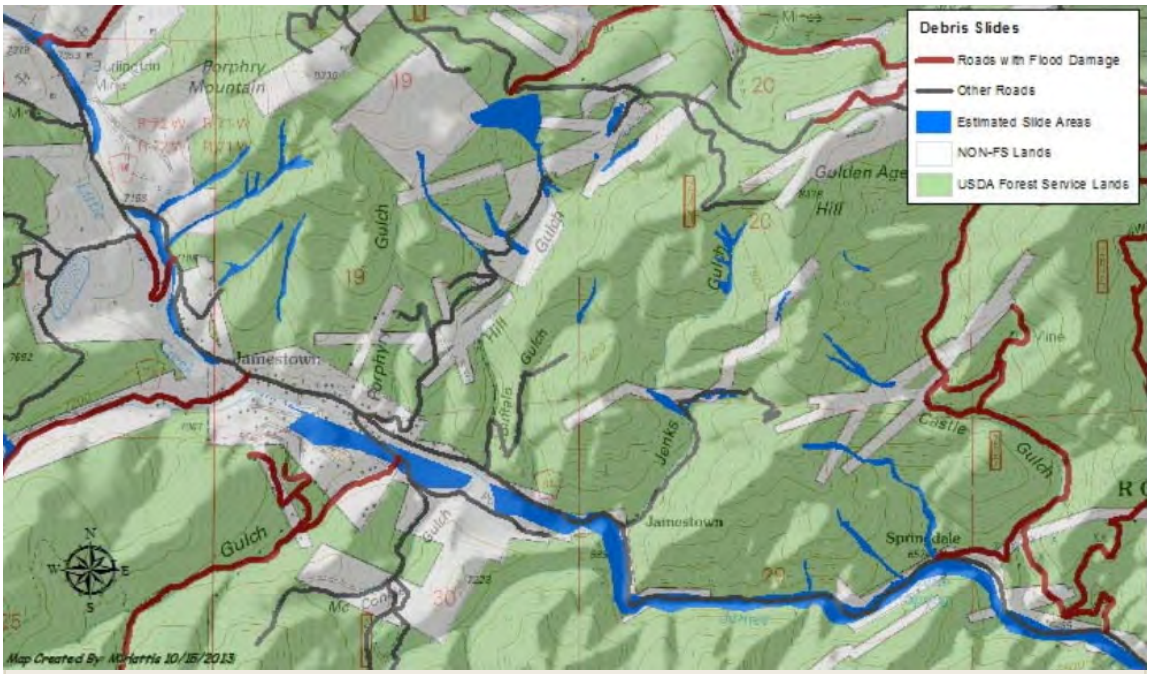
A key concern for the rapidly approaching snowmelt runoff is how sediment, large wood, and other debris in flood deposits may remobilize during potentially high spring flows. The ARP will be collaborating with research geomorphologist Sandra Ryan-Burkett at the Rocky Mountain Research Station in Fort Collins to assess stability and evaluate risk and management

"Some of these jams could be beneficial if stable or they could present a hazard if wood and debris are transported. Some might help trap remobilized sediment, but this may later cause the jam to break down. Much depends on where and how a particular jam sets up and what gets thrown at it next," says research geomorphologist Sandra Ryan-Burkett.

"There are going to be varied impacts across the landscape, and what we need to do is assess vulnerability and mitigate where possible, with no promise that future impacts won't still happen..." notes Boulder District Ranger Sylvia Clark.

There are also many scientific and technical aspects of recovery. How to deal with debris flows, large wood and debris jams, sustained water quality impacts, riparian habitat restoration, impacts to culverts, fisheries and other aquatic habitat – these issues need to be addressed by biologists, hydrologists, engineers, and other scientists and specialists on the ARP. So far, the ARP has received over $4.2 million dollars in special flood-related recovery funding,

Road damage in (L to R) Boulder, Big Thompson, and Coal Creek Canyons. (Image credit: Arapaho and Roosevelt National Forests)



A map of the significant road damage and multiple debris slides in one small area of the flood-impacted region. The map also displays the complex intermixed land ownership pattern common to the Boulder Ranger District. (Image credit: Arapaho and Roosevelt National Forests)

alternatives for the many in-channel debris jams on National Forest System lands. Says ARP hydrologist Carl Chambers: "We need to evaluate debris jam stability – some may be relatively stable and it would be ecologically beneficial to leave them alone. Others may be unstable, or contain detritus – such as housing materials, insulation, appliances, etc. – that was washed away in the flood, and we would want to remove those jams for safety or water quality concerns." However, the science of deciding which debris jams should stay and which should be removed, can be imprecise. Ryan-Burkett notes that "some of these jams could be beneficial if stable or they could present a hazard if wood and debris are transported. Some might help trap remobilized sediment, but this may later cause the jam to break down. Much depends on where and how a particular jam sets up and what gets thrown at it next."

The question of "what gets thrown at it [the debris jams and channels] next" is an important and very uncertain one. In the Rocky Mountains, like in other mountain ecosystems, winter snowpack determines spring and summer stream flows. As the snow begins to melt in early spring, it is channeled into streams and rivers. No one can predict, exactly, the timing, duration, and magnitude of the peak spring runoff , though hydrologists at the National Oceanographic and Atmospheric Administration (NOAA) and the Natural Resources Conservation Service (NRCS) use the winter snowpack and historical data to model and forecast, roughly, how much flow might occur. The fires and floods that have affected this landscape over the past several years add to the uncertainty. The recent High Park and Fourmile Canyon Fires, which affected parts of the Arapaho and Roosevelt National Forests subsequently impacted by flooding, burned so hot in some areas that they made the soils hydrophobic, or water-repellent, and charred the root systems that keep soil and sediment in place. Landslides commenced in several of the recently burned landscapes. In addition, the floods contributed to higher in-stream flows prior to the onset of freezing winter temperatures and snowfall; this raises the potential for additional flooding this spring. Moreover, many areas may yet experience rockfalls and landslides in this and subsequent springs, when the seasonal runoff begins. Boulder District Ranger Sylvia Clark notes that some people may be looking toward this year's spring runoff event, thinking that once that is over, things will be "safe" again. However, Clark warns that flood impacts and repercussions are likely to last years. Says Clark, "There are going to be varied impacts across the landscape, and what we need to do is assess vulnerability

"The environmental risk to users of the National Forests is now different; the September 2013 flood has substantially changed the landscape," notes quantitative ecologist Linda Joyce. "We must ask the public to be cognizant of the increased risk."

Miles of stream channels on National Forest System lands were scoured, widened, aggraded, or relocated as a result of the flooding, affecting fisheries, riparian areas, and roads. (Image credit: Sarah Hines)

and mitigate where possible, with no promise that future impacts won't still happen. The landscape will continue to be dynamic."

NOT-SO-INSTANT MESSAGING

Clark's message, that future impacts may still happen, is an important one. Indeed, there are a number of long-term messages and lessons that should be drawn from a disaster of this magnitude. To draw from the vulnerability framework: As more people seek out the beauty and adventure that comes with living in mountain communities, they increase both their own and societal exposure to natural hazards; as permanent infrastructure (such as homes) is built in these hazard-prone areas, sensitivity also increases. It is critically important for the Forest Service, other natural resource agencies, and towns and municipalities to communicate effectively with the public, helping individuals understand not just the benefits, but also the potential drawbacks, to living in and adjacent to the landscapes that they love. These messages can perhaps be summarized into three key takeaways, worth discussing not only in Colorado's Northern Front Range, but anywhere along the wildland-urban interface in the United States.

Key Takeaway #1 – National Forests and surrounding lands are dynamic, hazard-prone natural landscapes; community residents and policy makers should understand the risks inherent to people living and recreating in these landscapes.

The ecology and health of many forested landscapes in the West is driven by large-scale disturbance events such as fires, insect outbreaks, and floods. Throughout much of the 20th century, the Forest Service and other agencies suppressed fire on many landscapes. As our collective ecological knowledge has grown, we have come to understand the importance of these events in promoting ecosystem health and resilience; many ecosystems require some degree of fire at regular intervals to remain healthy. Today, many communities have been built in or near forested landscapes and it's important for us to recognize these landscapes as dynamic and hazard-prone – that is, subject to fires, floods, insect outbreaks, and more – when we choose to live there. In addition, if we increase the human footprint and amount of infrastructure in these landscapes, we need to be cognizant of how we change the dynamics (fire, hydrology) of these systems. Strategic development of the human footprint, wise land-use choices, and better community education are all important in this regard. However, even relatively wise expansion of our human footprint in these areas also increases our vulnerability and the potential costs of future disasters.

In addition, there is an important human element that must not be ignored, as many residents who live in flood-impacted communities have lived in these landscapes for years or decades. Reactions from the community may understandably range from questioning whether to leave,

According to Walker and others (2004), ecological resilience can be defined as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks." Walker, B., Holling, C. S., Carpenter, S. R., Kinzig, A. (2004). "Resilience, adaptability and transformability in social–ecological systems". Ecology and Society 9 (2): 5.

As a result of the 2013 flood, the current and future risk of hazards – landslides, rock slides, and debris flows – has increased across an area roughly three quarters the size of Rhode Island. Users of National Forest System lands will need to be cognizant of increased risk. (Image credit: Sarah Hines)

to resolving to rebuild what was lost. "In general, people who suffer direct impacts are more likely to implement self-protective action [such as rebuilding away from the floodplain], and those with affected family, friends, and neighbors are also more likely to engage in self-protective action than those whose social networks are unaffected by disasters. This offers an opportunity for community learning and adaptation," says University of Colorado sociologist Hannah Brenkert-Smith. "At the same time, any rebuilding efforts should account for the reality that the risk of natural disasters is never gone, or even reduced – that is the nature of living in these dynamic hazard-prone landscapes."

Beyond the risks to those who live in these mountain communities, there is also increased risk to those who recreate on flood-affected public lands. "The environmental risk to users of the National Forests is now different; the September 2013 flood has substantially changed the landscape," says quantitative ecologist Linda Joyce, explaining how the floods have increased the future risk of hazards – including rock slides, landslides, and debris flows – across an area three-quarters the size of Rhode Island. Mitigating risk across the entire changed landscape will be impossible. "We must ask the public to be cognizant of the increased risk," says Joyce.

Key Takeaway #2 –Recovery on National Forests will look different from, and occur on different timescales than, recovery along highways and in communities.

Our typical human response after a disaster is to rebuild, often as quickly as possible. We sometimes characterize rebuilding as "resilience," but these terms do not mean the same thing. To rebuild means to "build something again after it has been damaged or destroyed." In an example from the scientific literature, resilience is defined as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker and others 2004).

Landscapes are resilient, but ecological resilience occurs over long timescales, with sometimes unfamiliar metrics for success. While the landscape responds after a flood, nature's goal is not to rebuild what once was – rather, events such as flood and fire create opportunities for new landscapes, changed habitats, altered river channels, and stream beds. The ecosystem is still functioning, and these dynamic processes contribute to altered landscapes that, in time, may or may not resemble the past. As these landscape-altering processes play

"...[T]rusted community members, local organizations, and other partners and collaborators may be very effective communicators that can help spread information about what has just happened on the National Forests – why some roads are still closed, why access is limited, how risks to the public have increased," notes UC-Boulder researcher Hannah Brenkert-Smith.

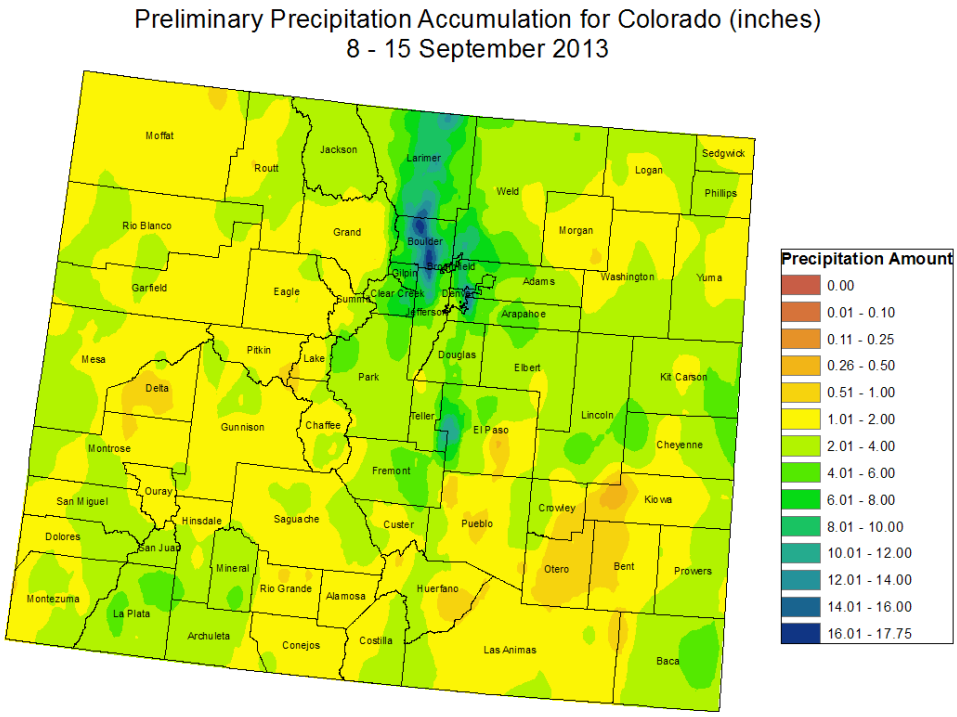
out, the Forest Service also strives to provide to the American public the many benefits that forests can provide: recreation, wildlife habitat, hunting and fishing opportunities, clean water, forest products, and more. As a result, the Forest Service strives to take a balanced and thoughtful approach to "restoring" the landscape that is rooted in the Multiple-Use mandate, and this may include elements of both rebuilding infrastructure and promoting ecological resilience. In some areas, the agency may rebuild infrastructure that is important to humans and human communities; in other areas, the agency may seek to restore ecosystem function where it has been compromised; in still other cases, the agency may favor a more hands-off approach.

Balancing these elements of rebuilding, a short- to medium-term endeavor, and promoting ecological resilience, a longer-term endeavor, may lead to some confusion about what "recovery" means on these landscapes. To some, a re-opened highway can signal that the flood is "over" and that the effects are gone. However, the flood impacted an area three-quarters the size of Rhode Island, and only a very small fraction of that consisted of highways. "Although the highways have reopened, the damage is not over, the effects on the landscape are not gone, and our recovery is not complete. We still have a lot of damage to infrastructure and local roads and resources, and we will have more impacts over time with this and future spring snow-melts and other events," notes Public Affairs Specialist Tammy Williams.

Key Takeaway #3 – Let's keep the conversation going.

In the days and weeks following a natural disaster, when attention is still focused on the event and its effects, there tends to be a great deal of dialogue about what might be done differently for the future. Over time, this dialogue may begin to dwindle, and the window of opportunity for continued dialogue may close. "When the first subsequent rain falls and if nothing happens, some may assume that they are in the clear," says research economist Patty Champ. However, in the case of the 2013 flood, the dialogue – at least so far – seems to be continuing. This is important, since impacts and effects are likely to be felt years into the future, and there is the potential for new fires or floods to continue to impact the landscape. Continued learning from the past can be a powerful tool in planning for the future.

In addition, research by Champ and Brenkert-Smith has demonstrated the importance of social interactions in conveying these messages. "In our research having to do with fire along the Front Range, we found that informal social interactions [e.g., talking amongst neighbors] were more important than institutional arrangements [e.g., insurance mandates] in terms of promoting mitigation actions," says Champ. Brenkert-Smith, Champ's research collaborator, continues: "Information from formal sources (e.g., the US Forest Service) is trusted, but individuals are not very likely to receive information from these sources.



This map of Colorado shows precipitation totals from data compiled from a variety of sources and monitoring stations for the week of September 8-15, 2013. On September 12, 2013, Colorado Governor John Hickenlooper declared a disaster emergency in 14 counties: *Adams, Arapahoe, Broomfield,* Boulder, *Denver, El Paso, Fremont, Jefferson, Larimer, Logan, Morgan, Pueblo, Washington* and *Weld. (Image credit: Colorado Climate Center.)*

Instead, they are more likely to receive information from more local or informal sources. This suggests that trusted community members, local organizations, and other partners and collaborators may be very effective communicators that can help spread information about what has just happened on the National Forests – why some roads are still closed, why access is limited, how risks to the public have increased."

A final piece of this takeaway message involves making efforts to convene the research and management communities for continued dialogue and learning. For example, convening technical sessions around ways that towns and municipalities can evaluate risk to inform future planning efforts would be important moving forward. "Understanding risk and planning to reduce it doesn't happen overnight. Reducing vulnerability is not a short-term, technical fix," says Linda Joyce, "but concrete examples – towns learning from other towns like Fort Collins, neighbors learning from neighbors, other forests learning from the Arapaho and Roosevelt National Forest – can be hugely helpful."

GOING FORWARD: THE ACTUAL AND FUTURE RISK OF 2013-TYPE FLOODS

Flooding on the northern Front Range is not uncommon, with floods affecting at least one drainage between I-70 and the Wyoming border every several years. Widespread, highly destructive floods such as in 2013 are much rarer; the most comparable flood events occurred in May-June 1894, September 1938, May 1969. In addition, the 1976 Big Thompson River flood was highly destructive, but it was much more concentrated and localized than the 2013 event. The 2013 event "may have exceeded those three floods [1894, 1938, and 1969] in terms of its combination of spatial extent and magnitude," says Jeff Lukas, senior research associate with CIRES Western Water Assessment at the University of Colorado, "but for the historic floods we have much sparser records of both the precipitation and the resulting peak runoff, so they are difficult to compare on the same basis with the extensively observed and documented 2013 flood."

The difficulty of placing the 2013 event in proper context is reflected in the claim, much repeated in the media, that it was a "1000-year" event. This number originated in a comparison of the observed rainfall (*not* the runoff) around Boulder with a pre-existing NOAA analysis of extreme precipitation—one based on a limited sampling of weather stations, and with acknowledged large uncertainties. Site-specific estimates of the likelihood of the observed peak runoff in the floods, made recently by the state of Colorado, range from an estimated 25-year event for Boulder Creek at Boulder, to a >500-year event for the Big Thompson River below Drake. But these estimates also carry large caveats, since they are based on comparisons with statistical models of peak runoff for each basin that may not have been updated for 30 years or more. The implication that events of this magnitude occur only once every 500 years (in the case of the Big Thompson), according to research geomorphologist Sandra Ryan-Burkett, may be very misleading. First, says Ryan-Burkett, "Many of the streams in the Front Range have not been gauged for very many years or decades, so we

"You haven't reduced the future risk [of another flood] just because you've already experienced an event," notes research economist Patty Champ.

MANAGEMENT IMPLICATIONS:

- National Forests and surrounding lands are dynamic, hazard-prone natural landscapes; community residents and policy makers should understand the risks inherent to people living and recreating in these landscapes.
- Recovery on National Forests will look different from, and occur on different timescales than, recovery along highways and in communities. The Forest Service strives to take a balanced and thoughtful approach to restoring the landscape that is rooted in the Multiple-Use mandate; therefore, recovery may include elements of both rebuilding infrastructure and promoting ecological resilience.
- Let's keep the conversation going. It will be important for both communities and the Forest Service to continue dialogue over time, communicating both about the impacts and effects likely to be felt years into the future, as well as the choices that society has for reducing future vulnerability to natural disasters.

lack information about the long-term historical range of variation in these streams." Also, says research economist Patty Champ, "the implication here is that, after having survived one '1000-year event,' you're off the hook for the next 1000 years. This is decidedly not the case: You haven't reduced the future risk just because you've already experienced an event." Flooding events along the Front Range are not nearly as rare as the more dramatic "x-year" figures would lead us to believe.

Finally, there's the potential for a warming climate to make extreme precipitation and flooding events worse, if not more frequent. Warmer air holds more moisture, and so warmer temperatures that are resulting from a changing climate may cause the largest precipitation events to be larger. The latest climate projections, however, do not clearly indicate whether flooding risk on the Front Range will increase in the future.

All of this means that while the 2013 northern Colorado flooding appears to have been unprecedented, it may only have been unprecedented in the degree of damage that it caused to communities and related infrastructure, not in terms of the underlying rainfall and runoff. Affected individuals and communities, the National Forest, and policymakers will have important decisions to make regarding recovery and planning into the future. Indeed, our response represents part of our ongoing relationship with this dynamic landscape. Just as in any enduring relationship, perhaps we might first seek to understand – the landscape, the ecology, and the consequences of our choices. Our collective understanding of these factors may influence social choices, policies, and management – thereby influencing our future vulnerability – for decades to come.

KEY FINDINGS:

- Human vulnerability to natural disasters has three principal components: exposure, sensitivity, and adaptive capacity.
  - As humans have more heavily settled and expanded communities in and along the Front Range, we've increased our exposure to potential natural disasters.
  - As we have built permanent infrastructure, such as homes, in the wildland-urban interface or along floodplains we've also increased our sensitivity.
  - Taking actions like promoting healthy riparian areas that can channel and absorb precipitation and slow flood waters, and promulgating flood plain development regulations and other adaptations, are examples of increasing our adaptive capacity. However, adaptive capacity also reflects our social capacity to make changes in anticipation of possible future events – these changes are only possible if there is political will and public support for such actions.
- Destructive floods are not uncommon on Colorado's Front Range. Although this event was unusual in terms of its footprint and magnitude, similar floods have occurred before and will continue to occur along the Front Range.
- There will continue to be varied impacts across the landscape, especially during this and future spring run-off events – including potential landslides, rockslides, debris flows, etc. While some of these may be identified and mitigated, the landscape will never become completely safe to a point where future impacts will not occur.
- The flooding affected an area roughly three-quarters the size of Rhode Island. While some highways and roads may be reopened, the effects and impacts of the floods are not over. Users of National Forest System lands and surrounding open space must be cognizant of the increased risk on these lands.
- The infrastructure that was washed away, practically overnight, on the Arapaho and Roosevelt National Forests represents decades-worth of decisions and investments. In addition, the ecological landscape has changed dramatically. The Forest Service will need to make difficult decisions, based on appropriate ecological considerations, a limited budget, and public consultations, about where, what, and how to rebuild infrastructure and promote ecological resilience on the landscape.

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