COLORADO
Department of Transportation

Infrastructure Resiliency Strategies to Accommodate Future Disasters

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Contributors, Thank You!

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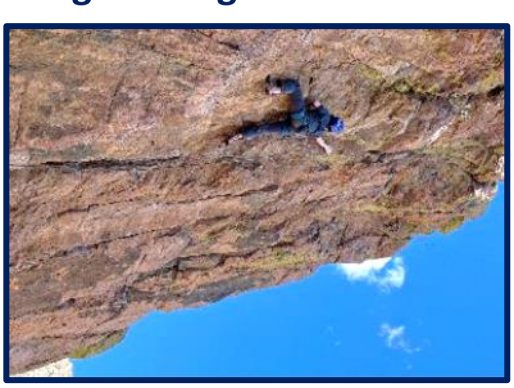
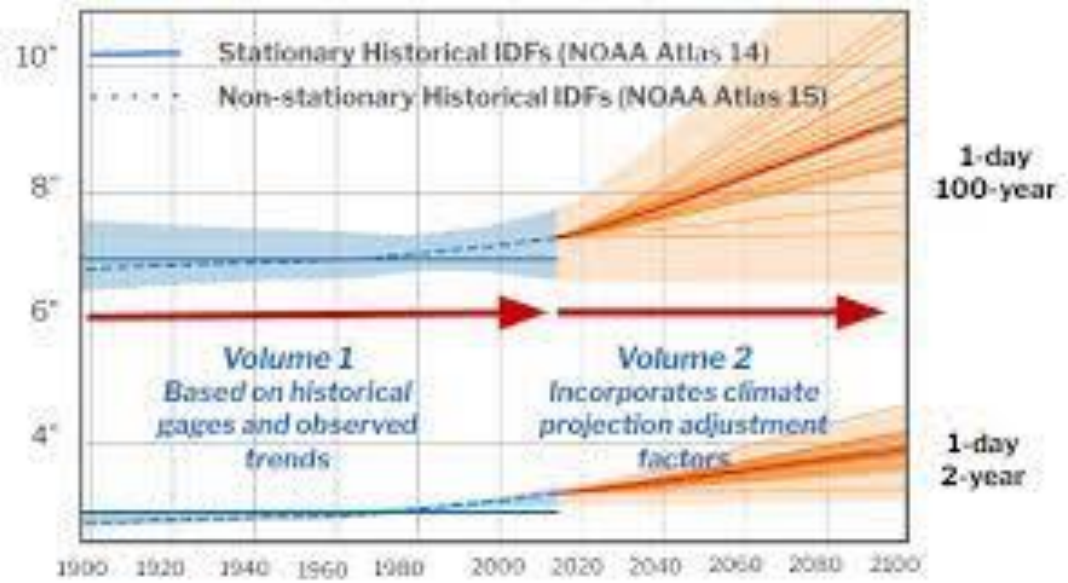
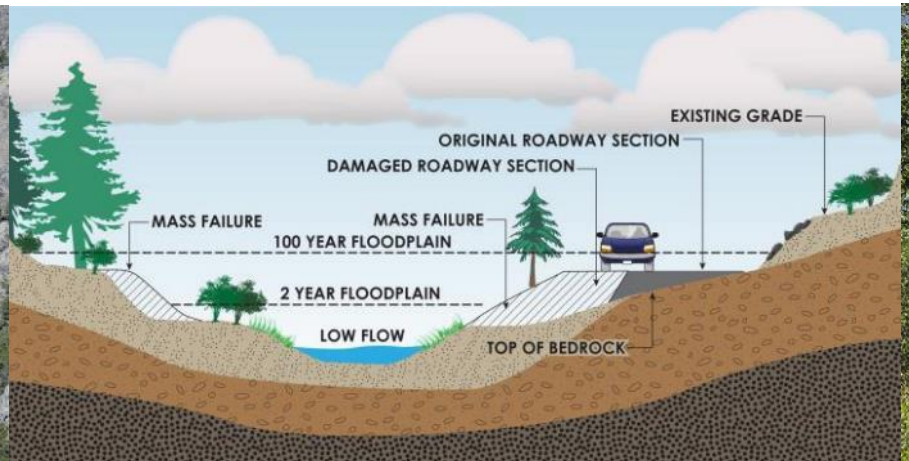


Discussion Agenda

1. Infrastructure Snapshot (NE Colorado)
2. Disaster Trends; Today's Challenge
3. CDOT Resiliency Measures
4. Tomorrow's Solutions
5. Discussion





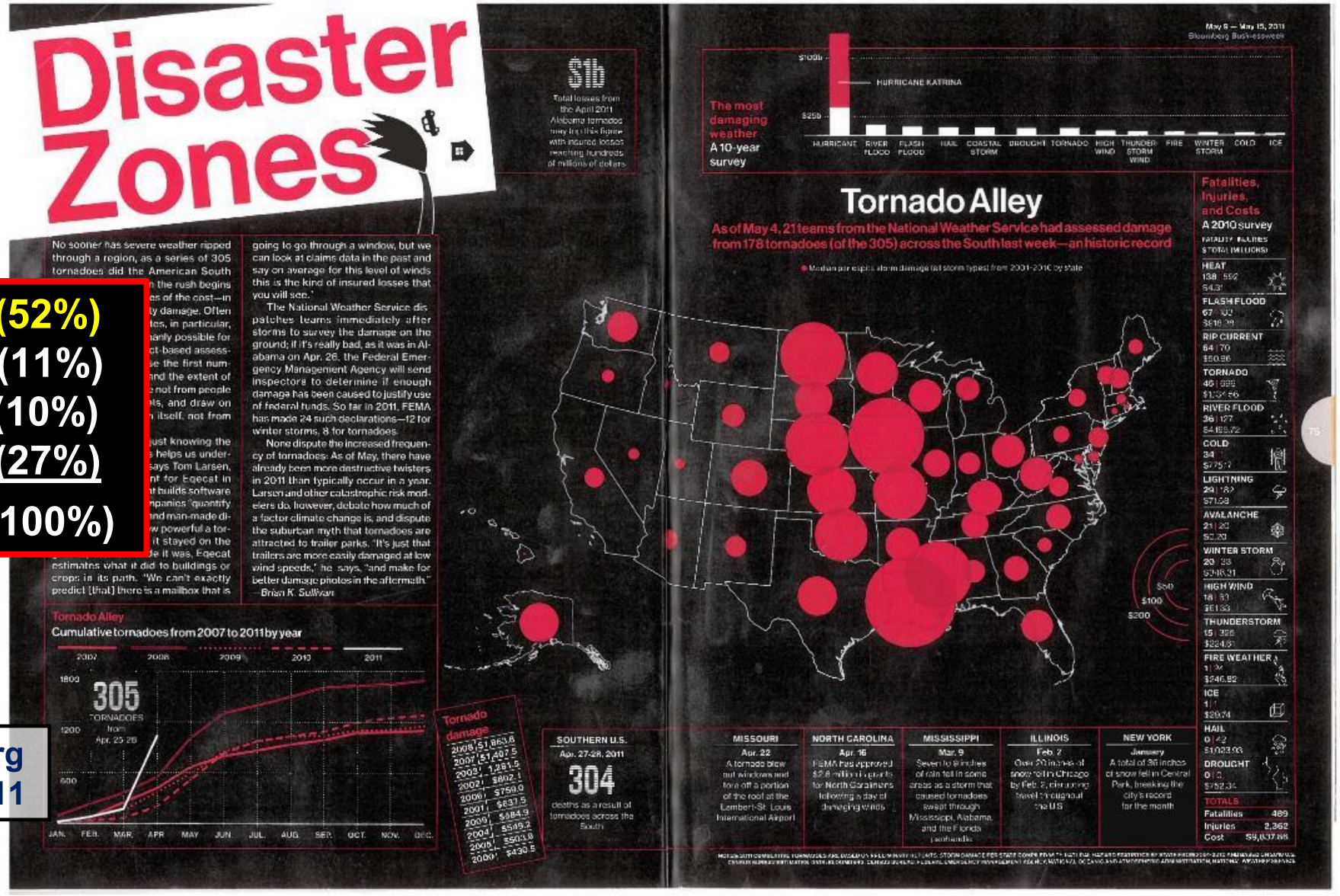
Order of Precedence; Problems & Solutions

"What is the problem we are trying to solve?"

-- Dave Bauer, PE, CFM
Weld Co. Public Works Director

2010 Natural Disaster Costs

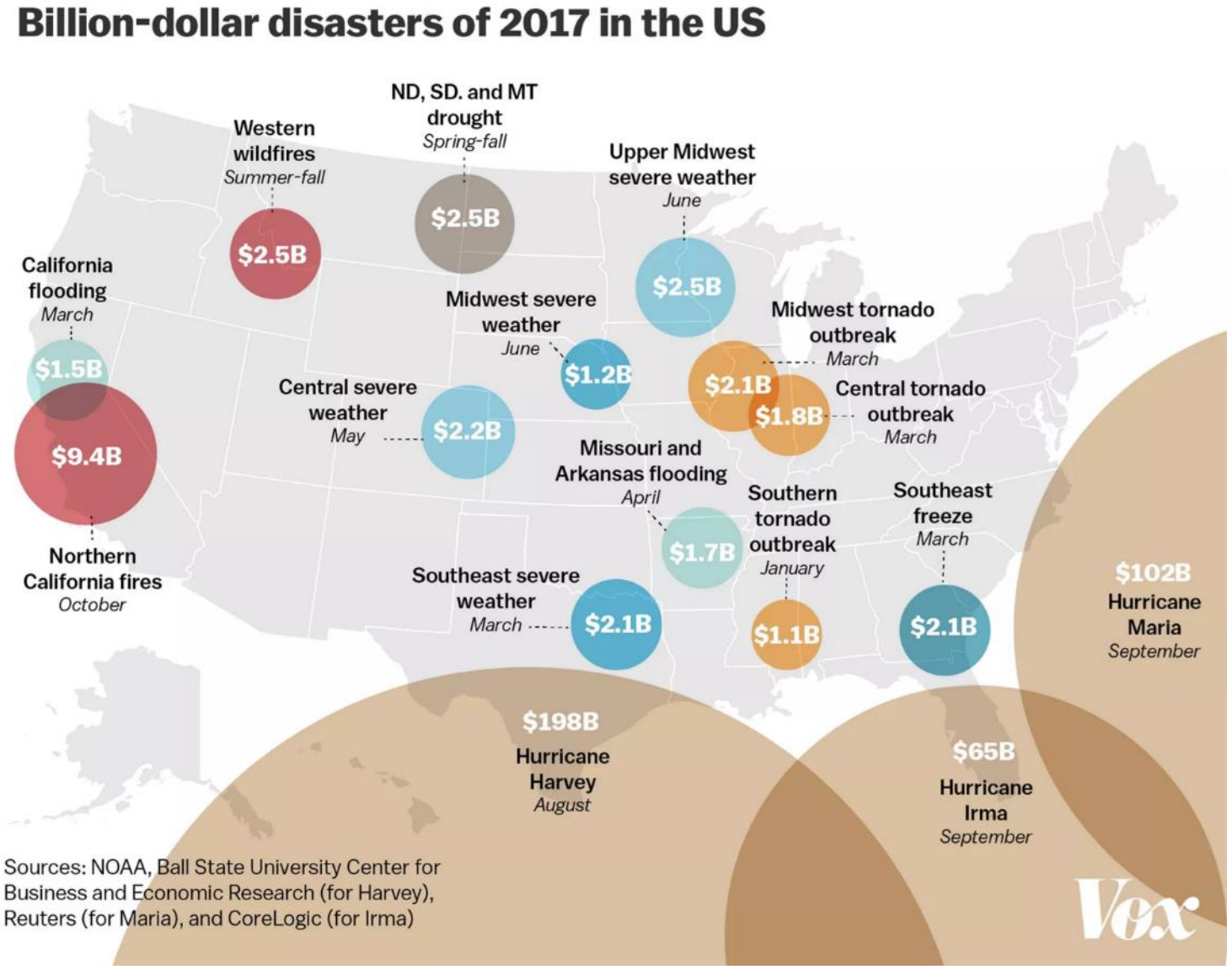
Flooding	=	**$5.1 Billion**	**(52%)**
Tornados	=	$1.1 Billion	(11%)
Hail Storm	=	$1.0 Billion	(10%)
All Others	=	$2.6 Billion	(27%)
TOTALS	=	$9.8 Billion	(100%)



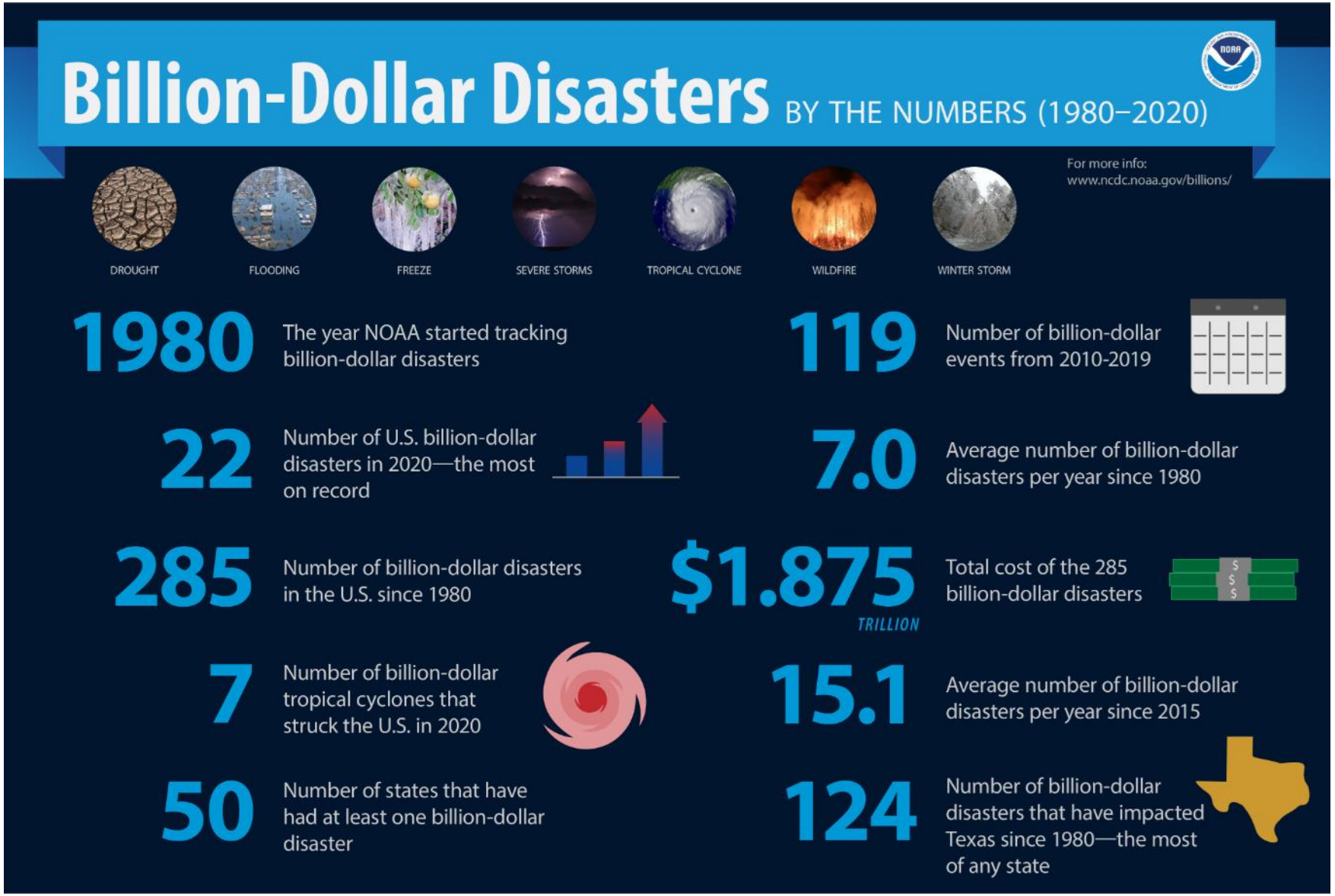
Source: Bloomberg Businessweek, 2011

2017 Natural Disaster Costs

Hurricane	=	$365 Billion	(92%)
Flooding	=	$3 Billion	(1%)
Tornados	=	$5 Billion	(1%)
Wildfires	=	$12 Billion	(3%)
All Others	=	$13 Billion	(3%)
TOTALS	=	$398 Billion	(100%)



Billion-Dollar Disasters, 1980-2020



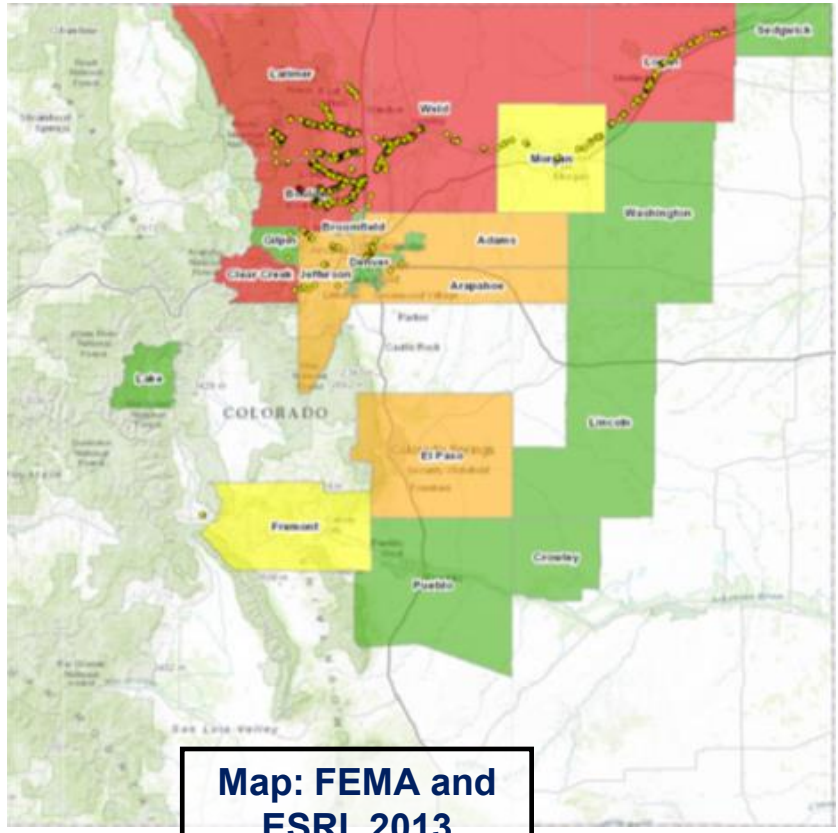
Source: NOAA's National Centers for Environmental Information (NCEI), https://www.ncei.noaa.gov/ (2023)

Colorado 2013 Regional Flood Disaster

Photo: Brian Varrella, 2013

*A **Human** Disaster*

- ***10 lives lost***
- ***28,000 people displaced***
- ***2nd largest airlift in U.S. history***
- ***$3.9 billion in total damages***
- ***2,000 square mile area over 24 counties***
  - ***120 CDOT bridges damaged***
  - ***39 roadways closed***

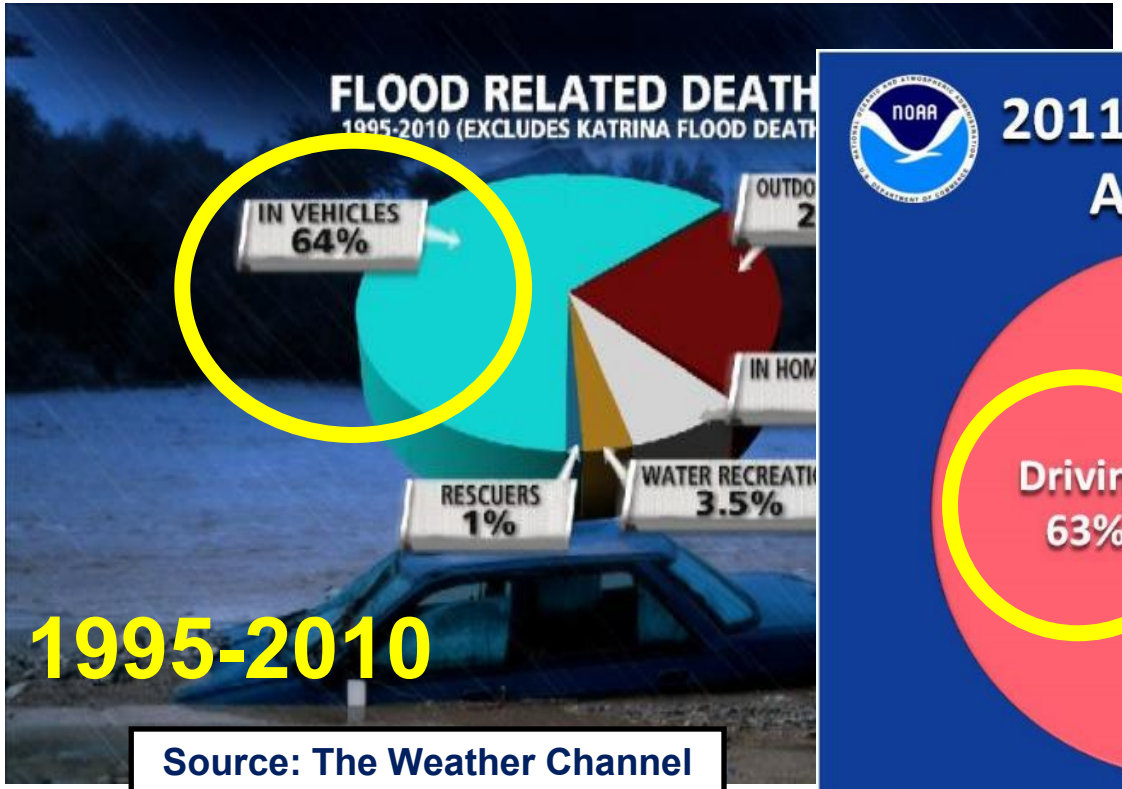


Map: FEMA and ESRI, 2013

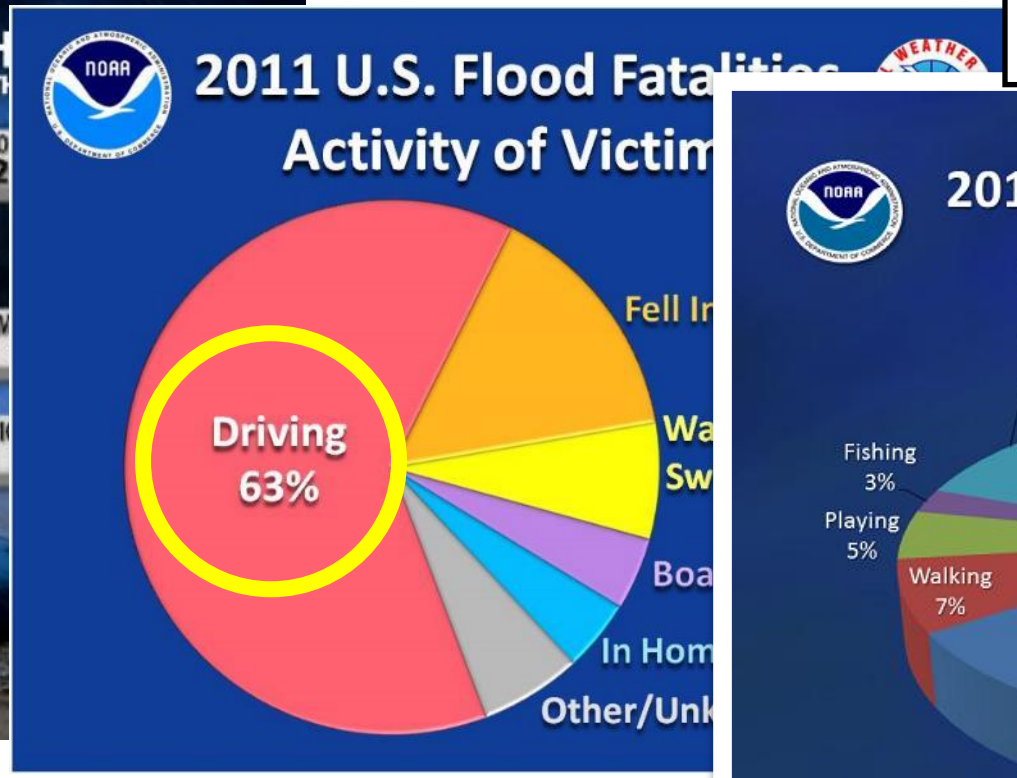
Infrastructure & Nature; the Price of Conflict

Why should transportation be concerned about Flooding?

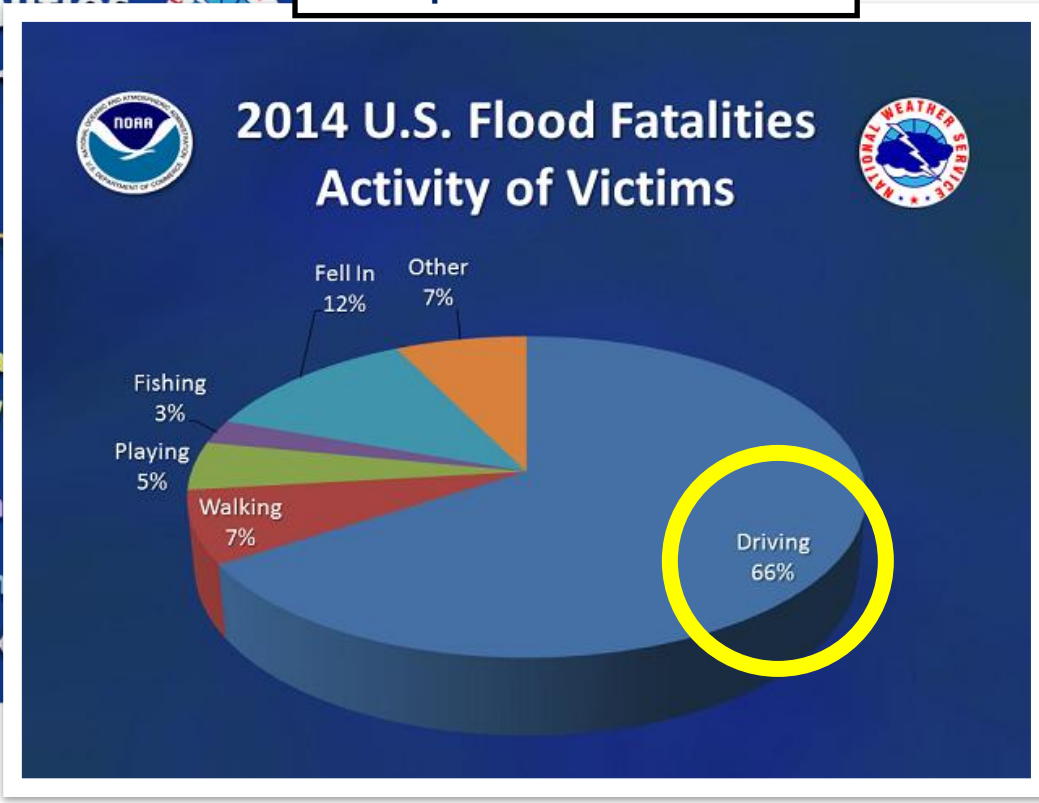
- #1 cause of death in floods = drowning in cars



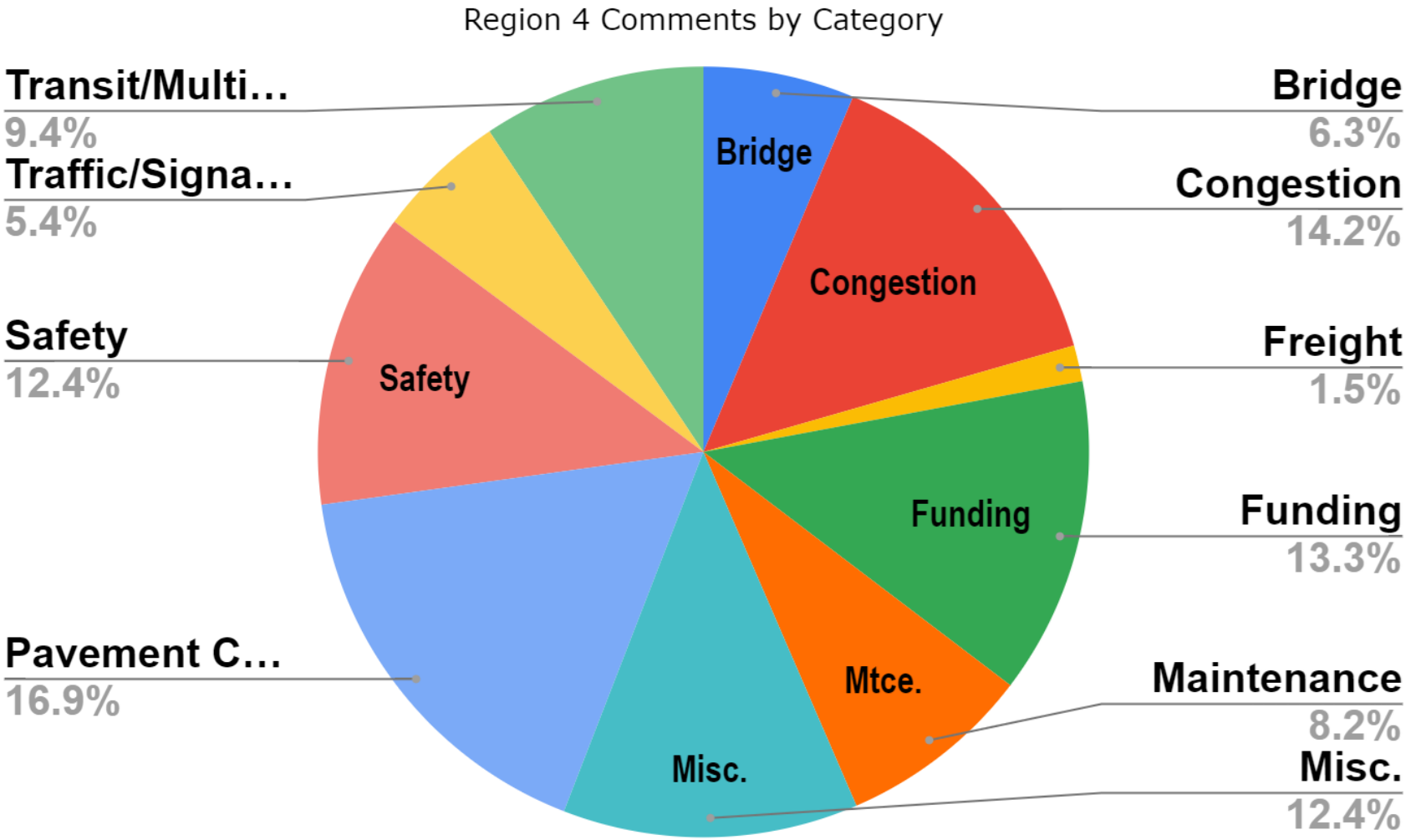
Source: The Weather Channel (www.weather.com)



Source: National Oceanic & Atmospheric Administration



CDOT Public Comments and Planning Priorities

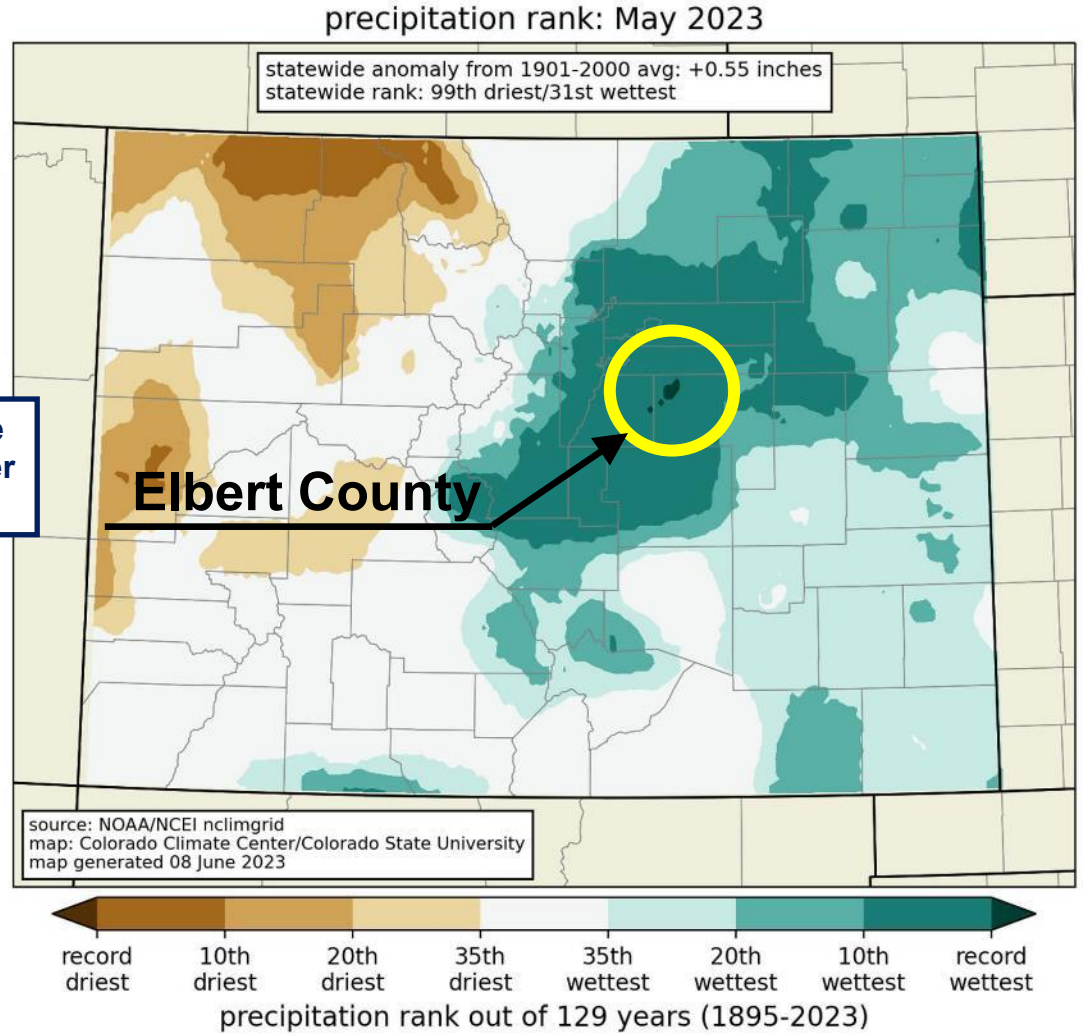


2023 Local Rainfall Disaster, 1 of 2

Colorado Climate Center (CSU):

- **June 2023** Report to the Colorado Water Conservation Board (CWCB)
- **May & June 2023** = rainy!

Images Courtesy of the Colorado Climate Center at CSU, and CWCB



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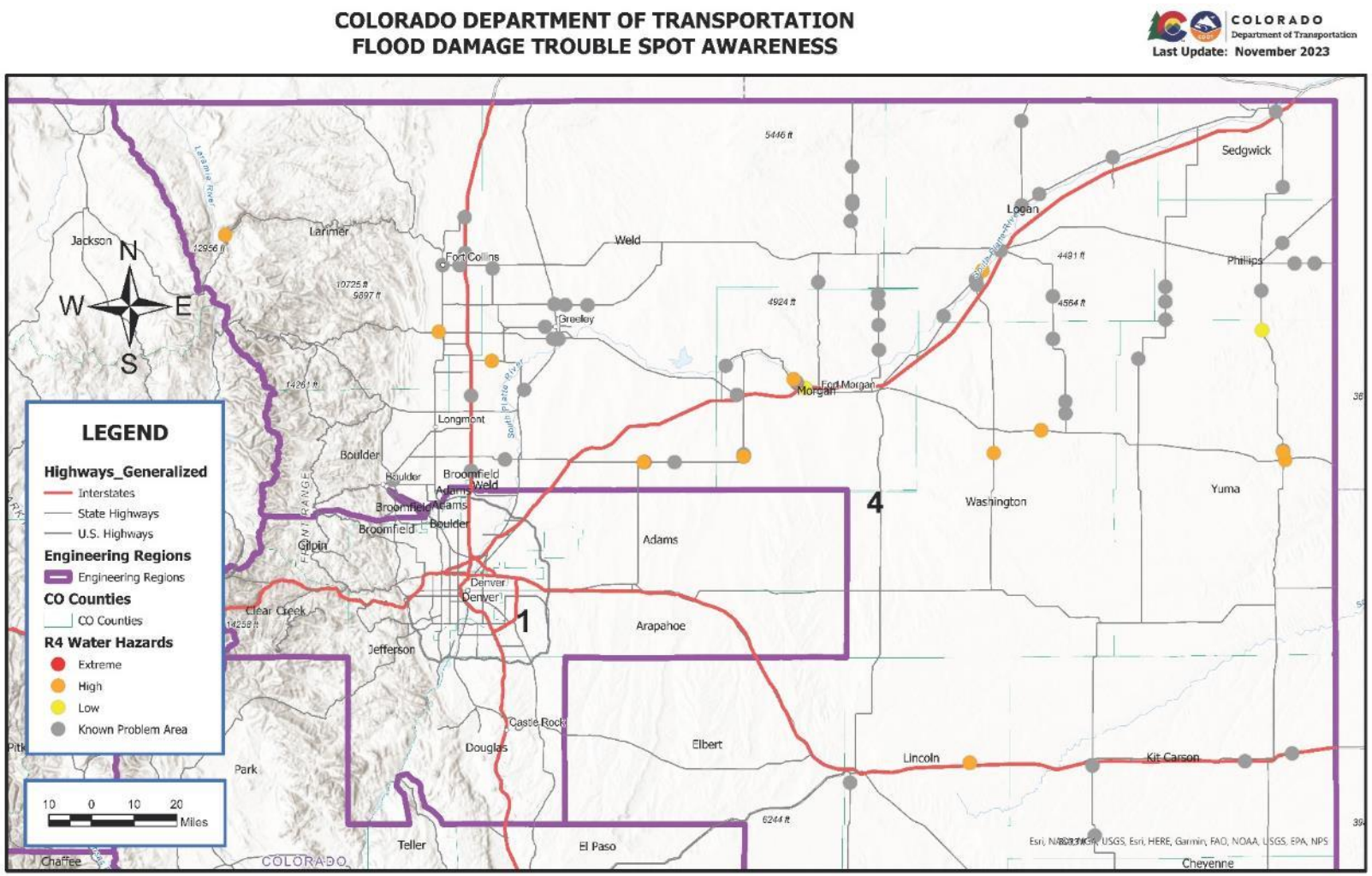
Lessons from 2023 Rainfall Disaster

2023 CDOT R4 Weather Trouble Spots:



- **Mapping trouble-spots**
  - GIS layer initiated
  - 81 reported incidents in May/June (*6 weeks*)
- **Records → *trends***
  - Minor rains are producing major floods
  - Most highways flooding is outside regulatory floodplains
  - Natural hazard mitigation is not a priority the 10-year plan of projects

The Future of Natural Hazards in Colorado

How Flooding Will Look Moving Forward

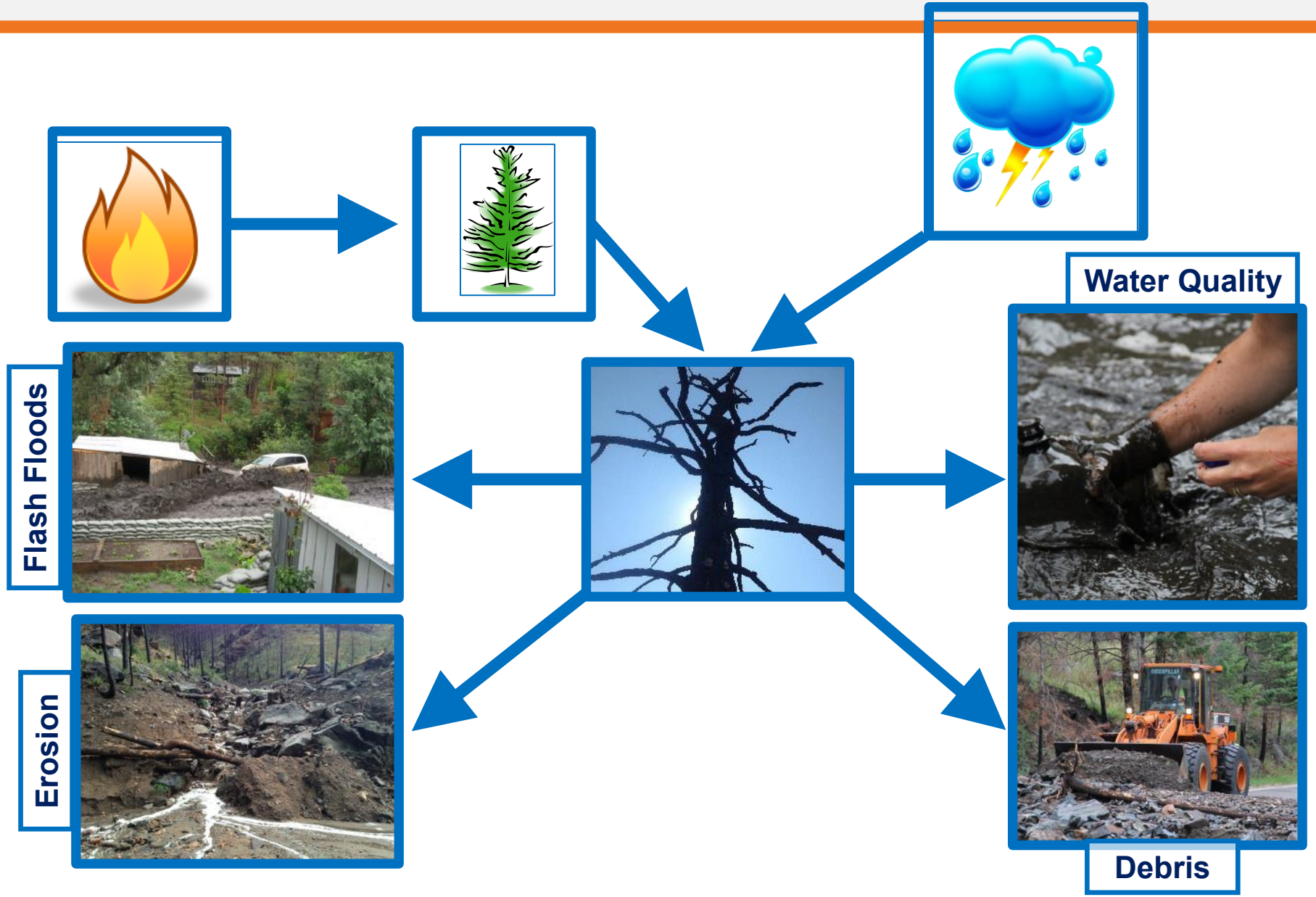
- The biggest floods in the future will still be traditional floods like 1997, 2013 & 2015
- Heavy snowpack always gets media attention, but rarely results in flooding
- On a frequent basis, the most common problem moving forward is post-wildfire flooding

Source: Kevin Houck, CWCB 2021

Colorado 2020 Wildfire Disasters

- Grizzly Creek Fire -- 33,000 acres, Glenwood Canyon
- East Troublesome Fire -- 194,000 acres, Grand & Larimer Counties
- Cameron Peak Fire -- 209,000 acres, Larimer County
- CalWood Fire -- 10,000 acres, Boulder County
- Total = 446,000 acres = 700 mi.^{2} (*Denver = 155 mi.^{2}*)

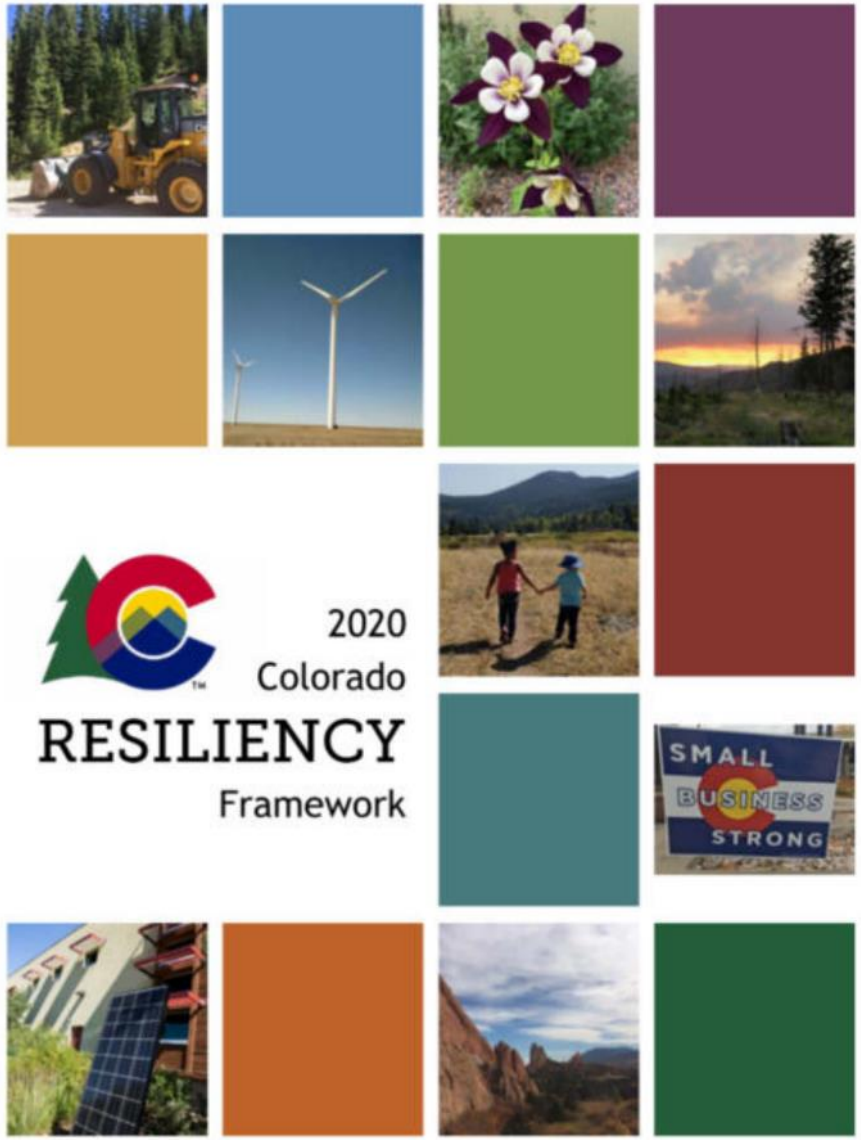
Compounding Hazards; One Disaster to Many



High Park Fire Flash Flood

48-second Video: Lucas Mouttet, 2013

The Colorado Resiliency Framework



Established 2015, Gov. Hickenlooper

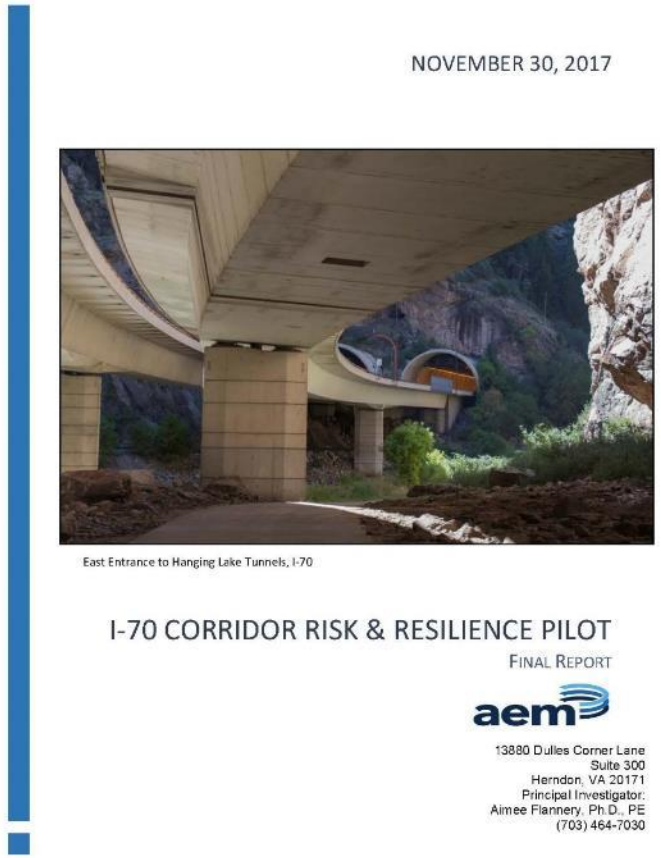
- **Managed by the Colorado Resiliency Office (CRO); *Anne Miller***
- **Outlines a structure for resilience**
- **Four themes of risk and vulnerability**
  - Adapt to climate change
  - Identify risks from all hazards
  - Address social inequities
  - Pursue economic diversity

Source: Colorado Dept. of Local Affairs at
https://www.coresiliency.com/colorado-resiliency-framework

First CDOT Resiliency Program Project

I-70 Corridor Risk & Resilience Pilot (*2017*):

- Analyze risk & review system resilience of I-70 from Kansas to Utah
- Proactive look at optimal investments
  - Develop pre-disaster mitigation strategies
  - Build system resilience over time
- Created from 7-step RAMCAP process used in flood recovery

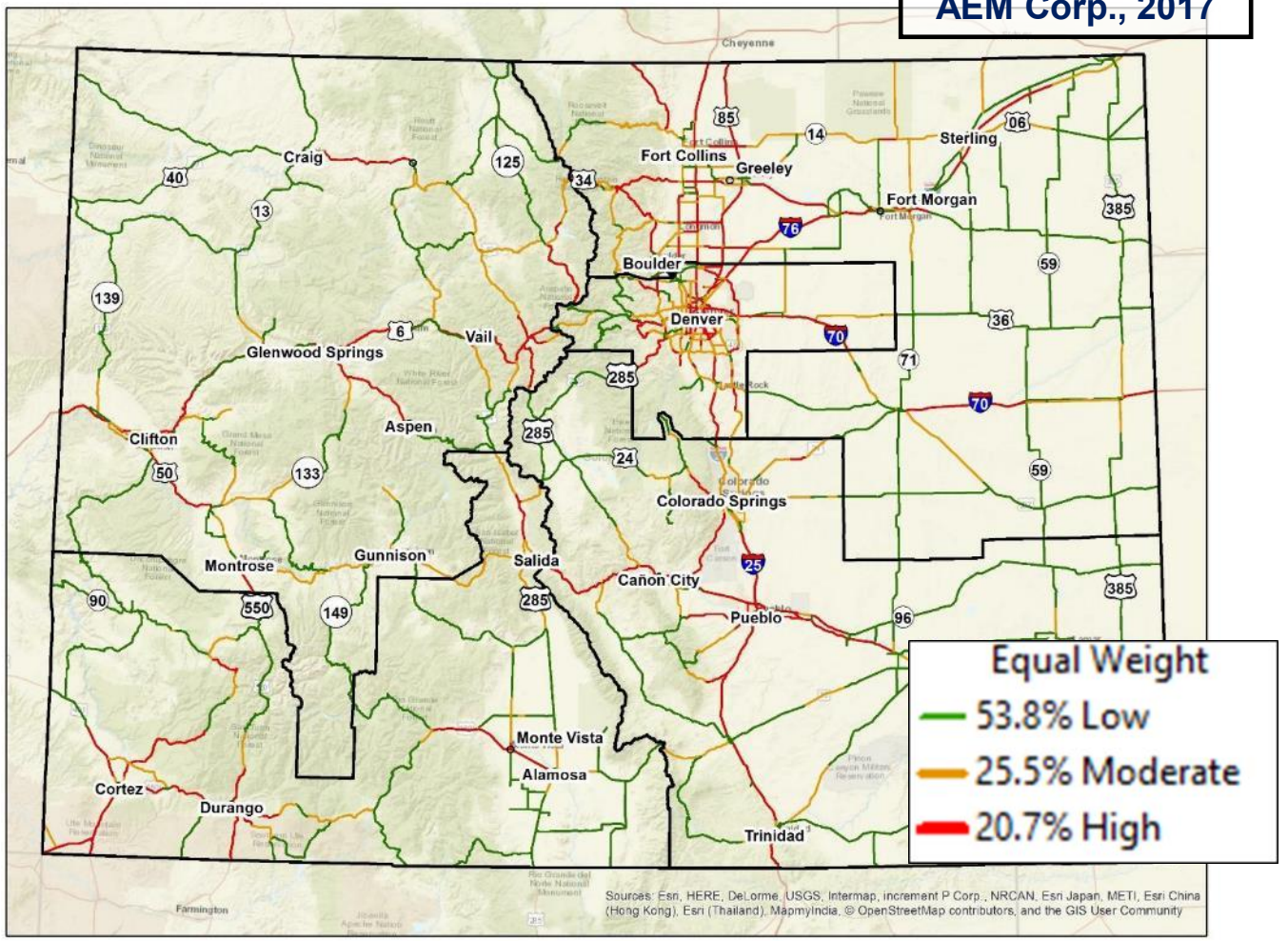


The CDOT Resilience Program

Statewide Highway Criticality Map:

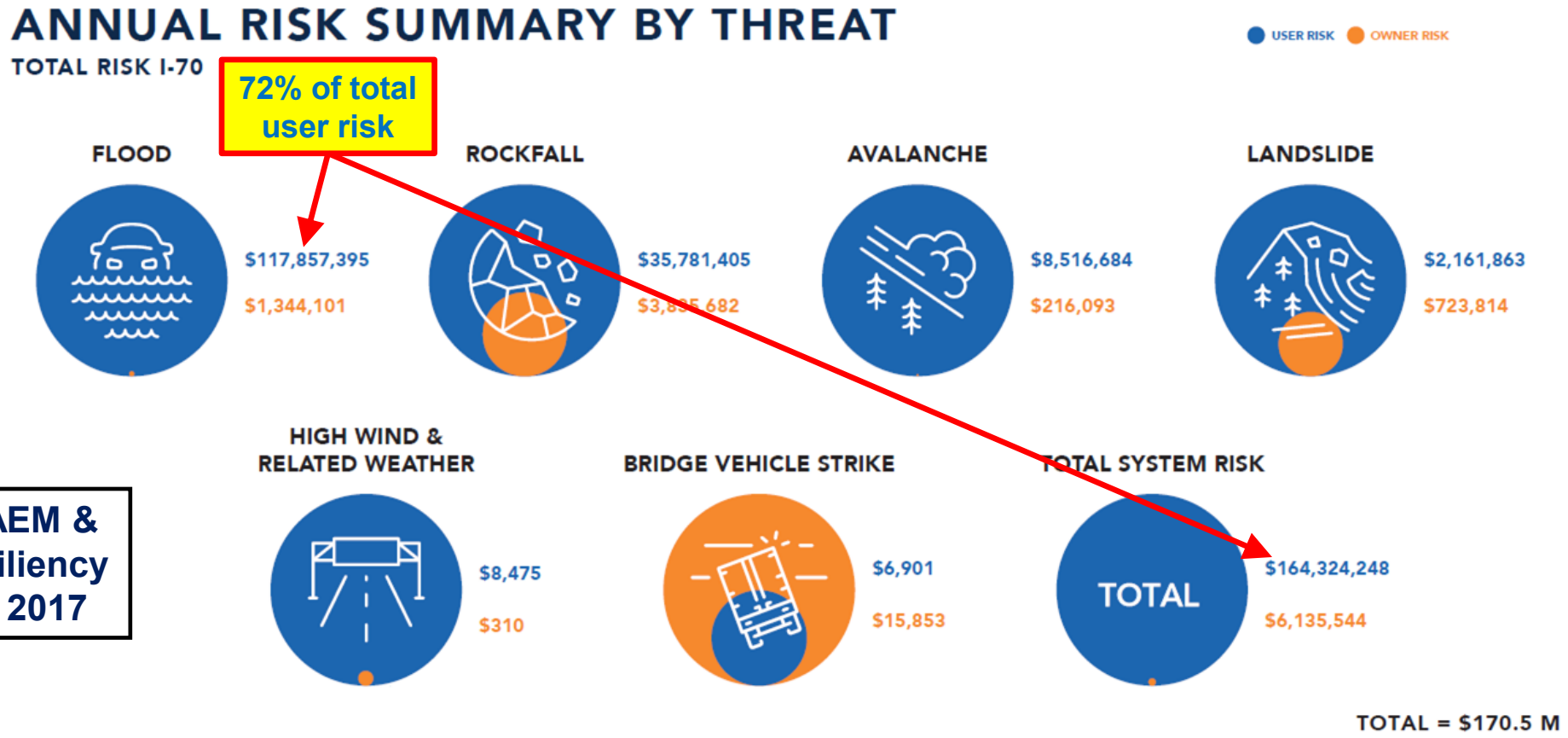
- **Threat Assessment**
  - Flood
  - Rockfall
  - Avalanche
  - Landslide
  - Wind
  - Vehicle Strike
- **Metrics**
  - AADT (Volume)
  - Social Vulnerability
  - Roadway Classification
  - System Redundancy
  - Freight (Economic)
  - Tourism (Economic)

Graphics:
AEM Corp., 2017



Who Covers the Cost of Risk?

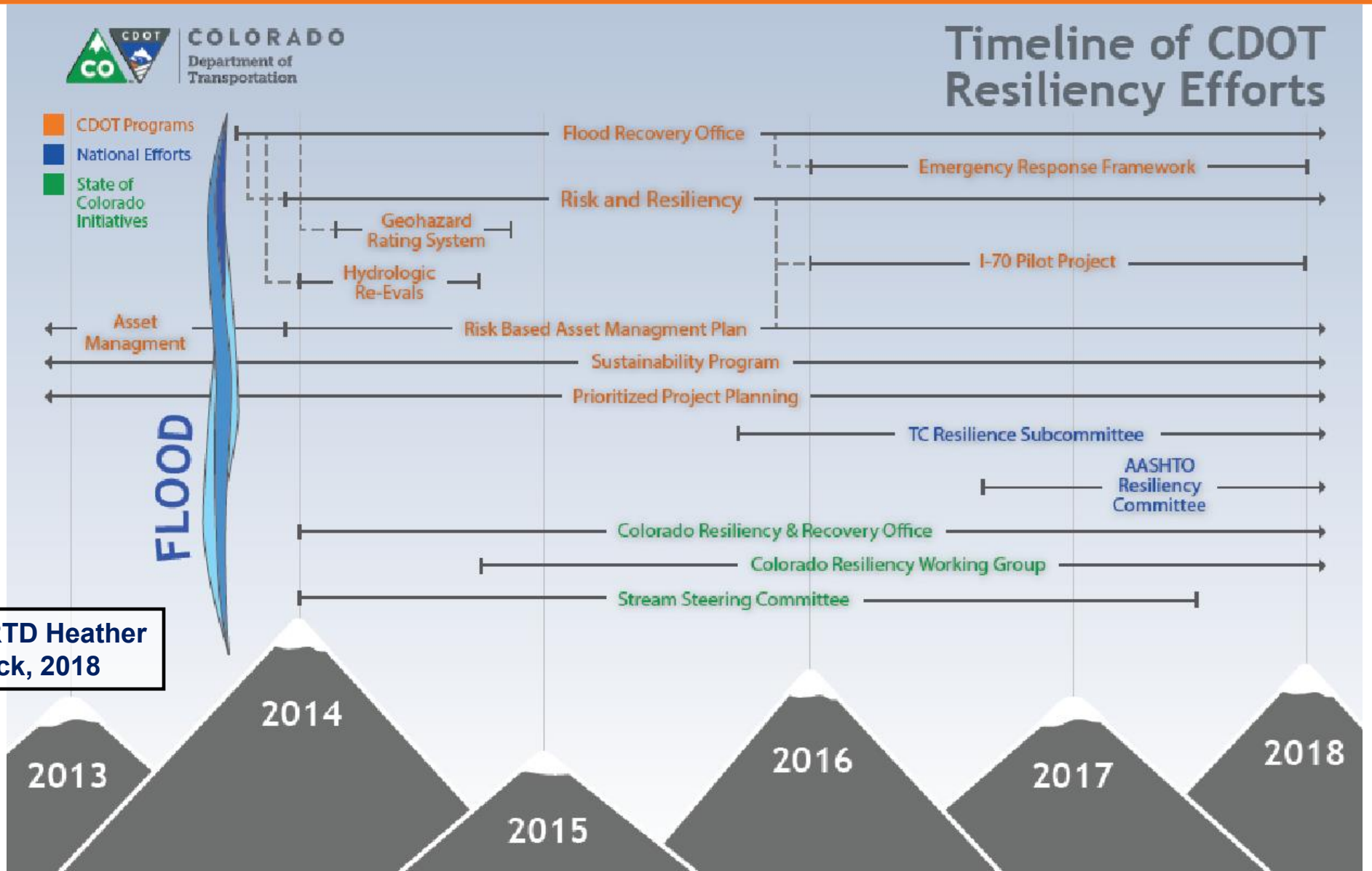
The costs of flooding are carried by the travelling public



Source: AEM & CDOT Resiliency Program, 2017

Mitigating Risk in Colorado Infrastructure

CDOT Evolution for Disaster Preparation



Source: RTD Heather Paddock, 2018

Graphics:
Muller Engineering
& JWO Engineering

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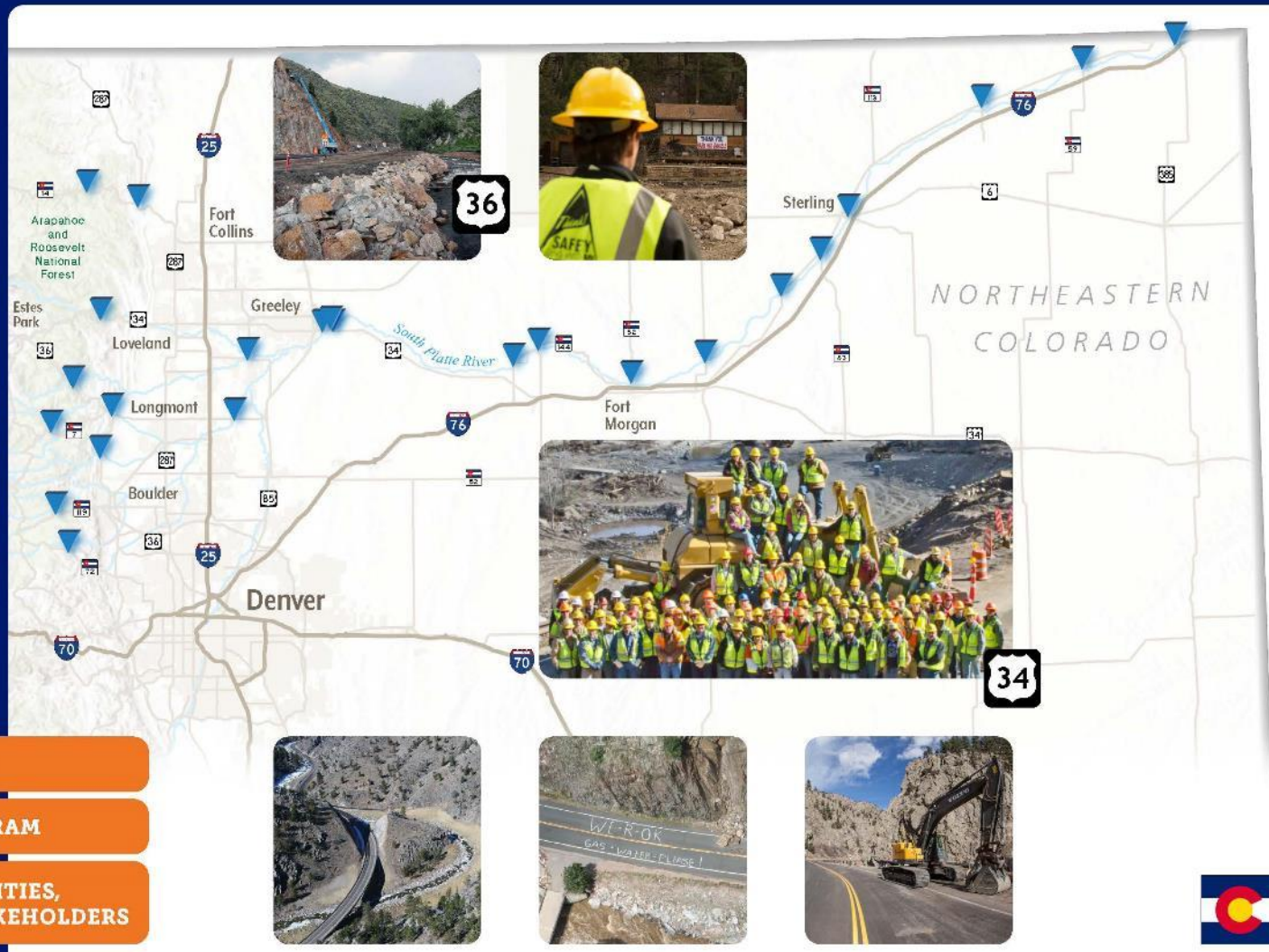
Flood Recovery Program

2013 - 2022

"We're not just going to build it back to what you had before we're going to build it back better than before."
— Gov. John Hickenlooper

On September 12, 2013 Colorado Governor John Hickenlooper declared a disaster emergency for large areas of the Northern Front Range and Northeastern Plains of the State. The disaster impact areas was unprecedented, affecting over 400 miles of roadways and impacting more than 120 bridges and structures. Permanent repair and recovery efforts continue to this day.

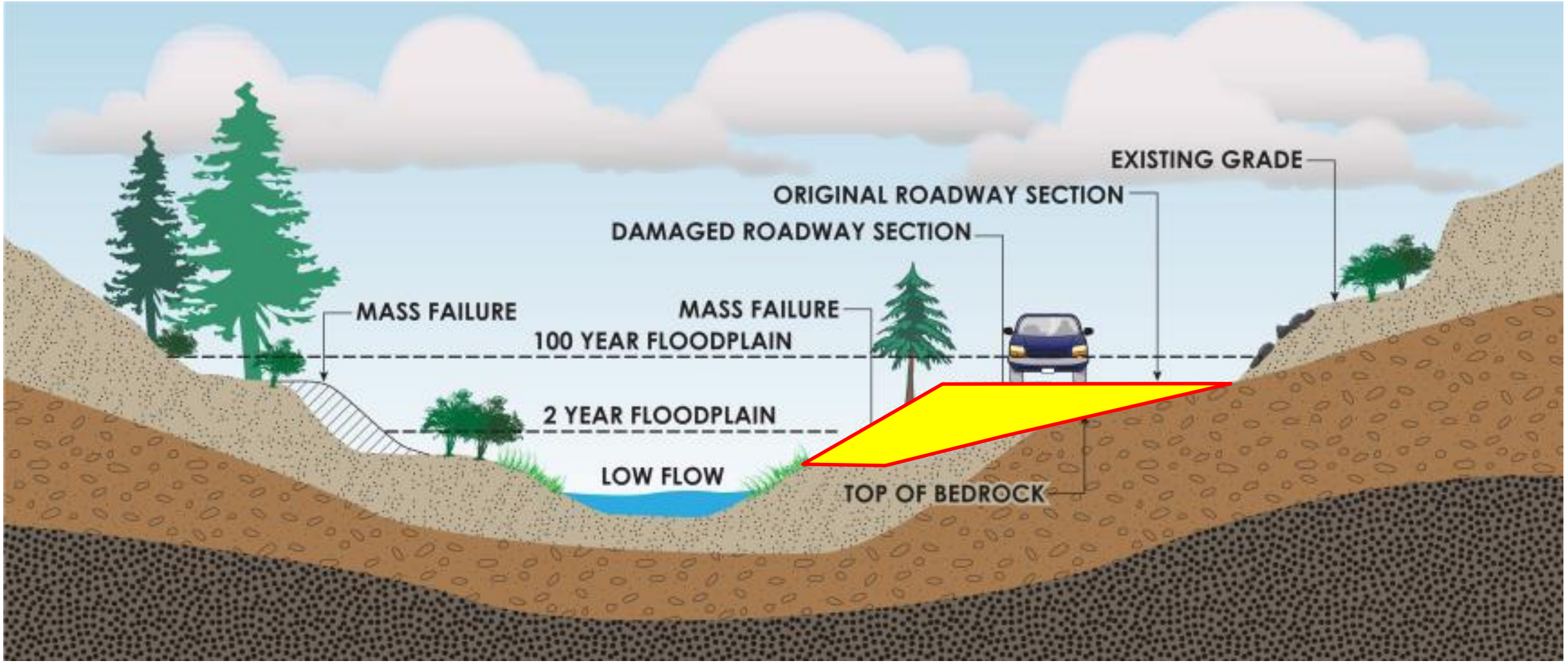


OVER 200 PROJECTS

$750 MILLION PROGRAM

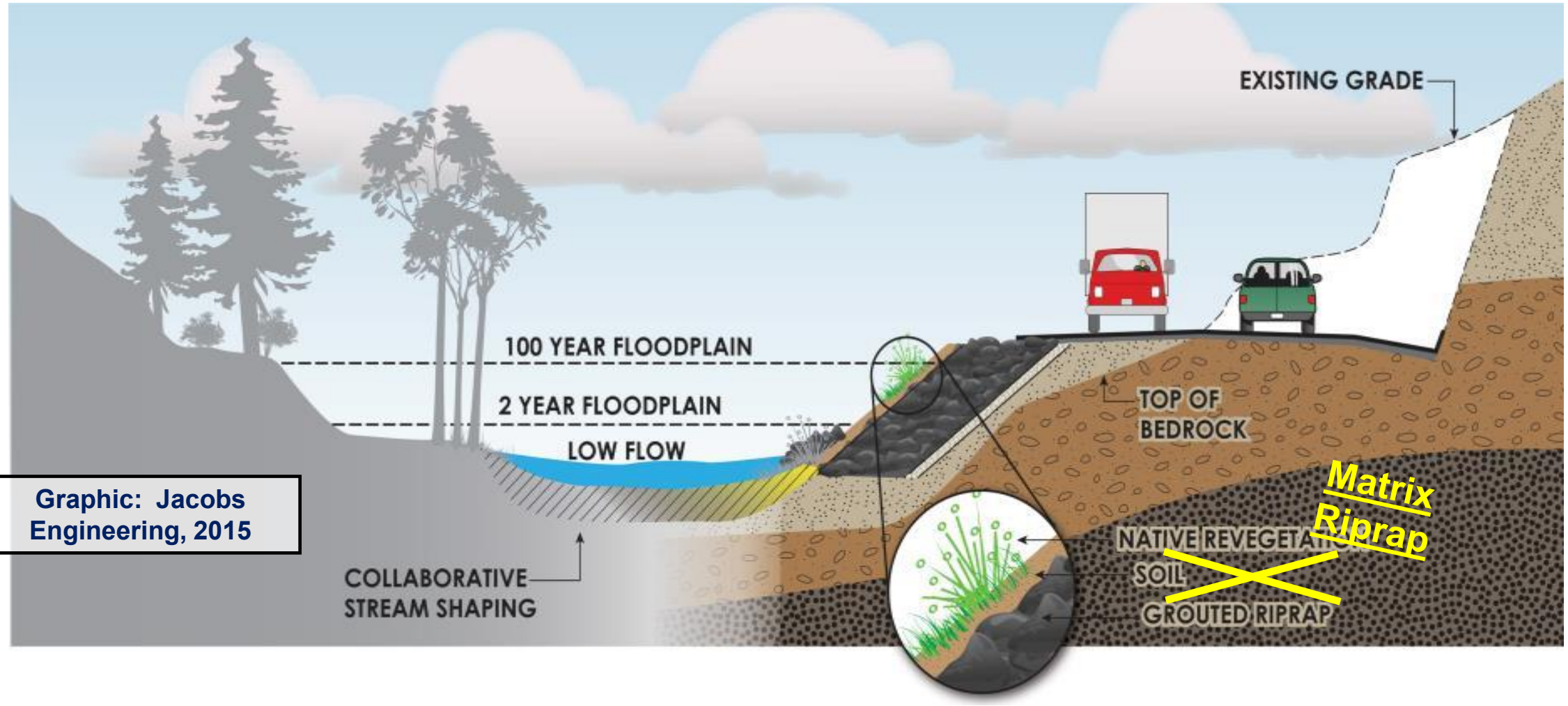
OVER 30 MUNICIPALITIES, COUNTIES, AND STAKEHOLDERS

Pre-2013 River Corridor Roadway Standard



Resilience by Backup Planning

Work with nature instead of against it (*planned failure*)



Graphic: Jacobs Engineering, 2015

Resilience by Retreat

Graphics: Jacobs team, 2015-2018

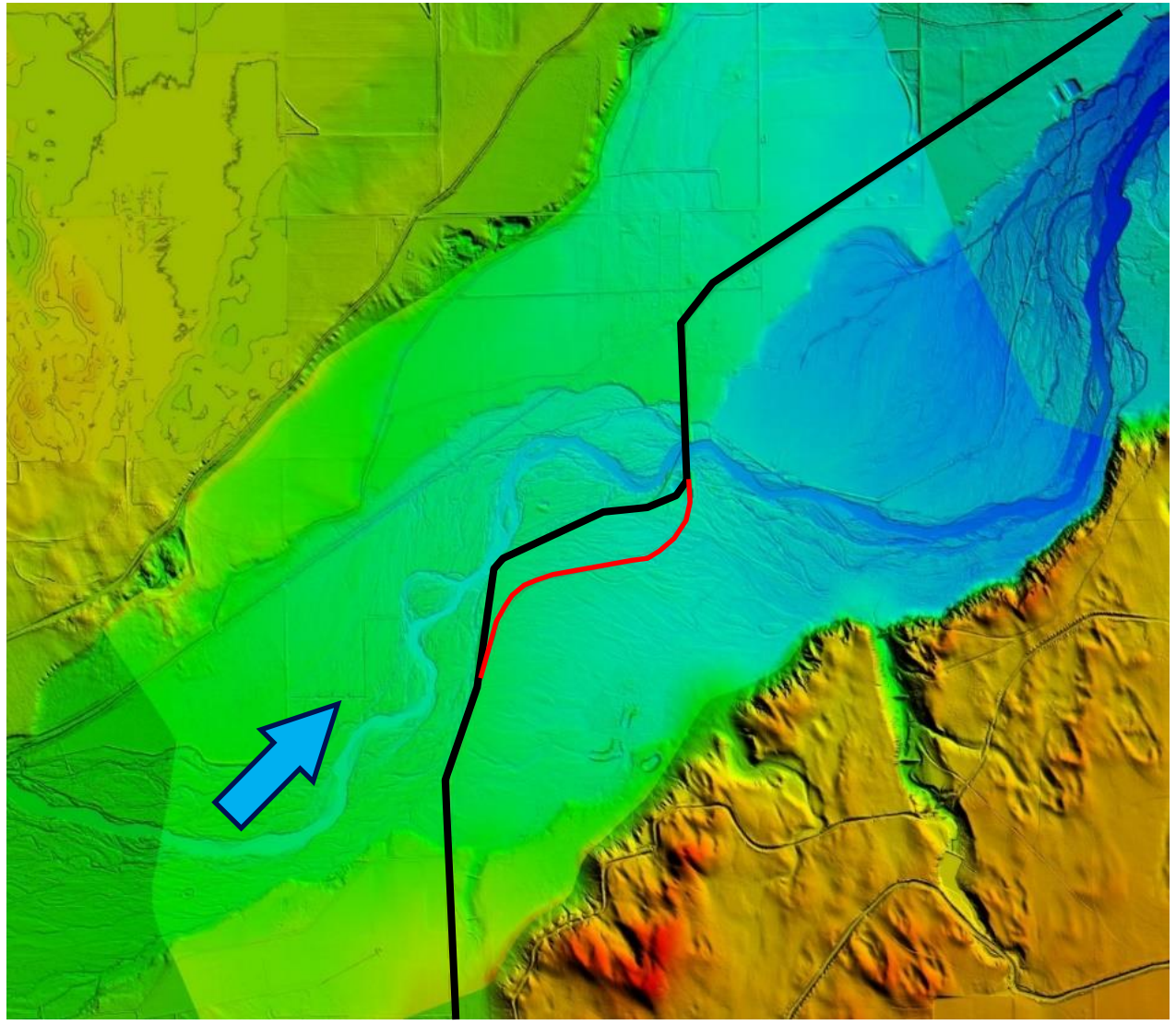
Resilience by Design Iteration

Continuous improvement; *test, review, revise, try again*

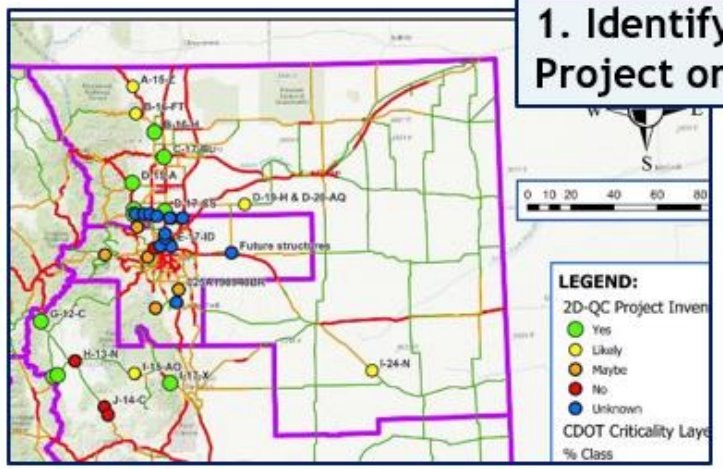
2dQC, Resilience by Technology, 1 of 3

2-D Quick Check (2dQC) Practice at CDOT:

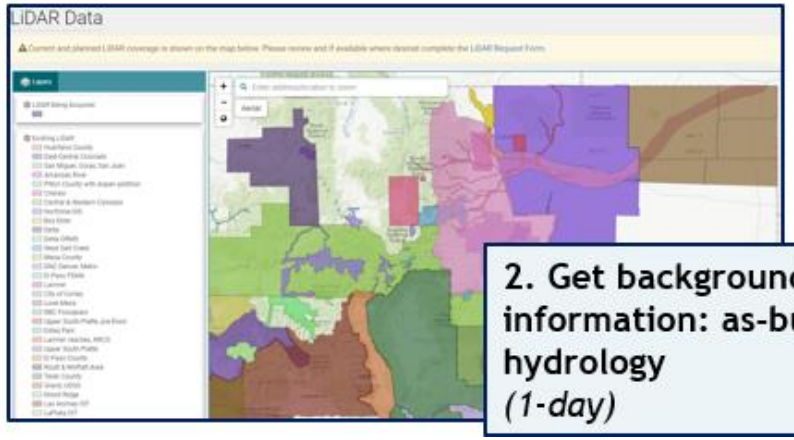
- Back-of envelope hydrologic and hydraulic analysis
- Requires 10-20 hours of analysis
- Informs project decisions after planning and before design
- Identifies fatal flaws and new value or benefits before a scope of work is complete



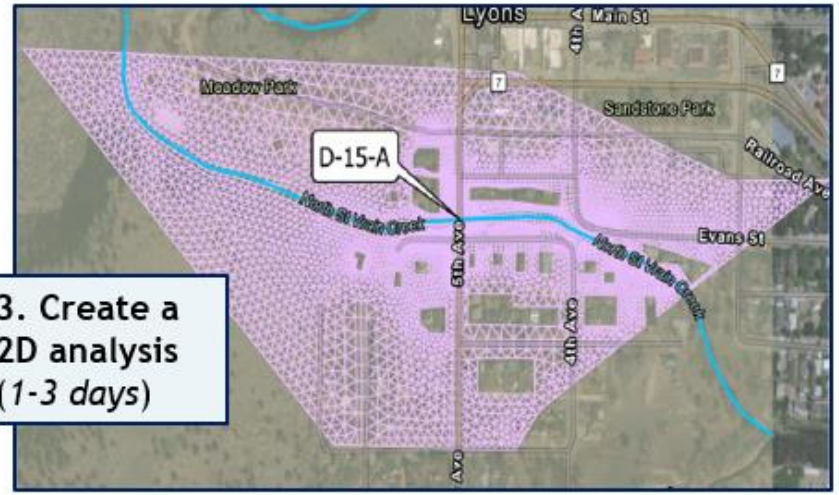
2dQC, Resilience by Technology, 2 of 3



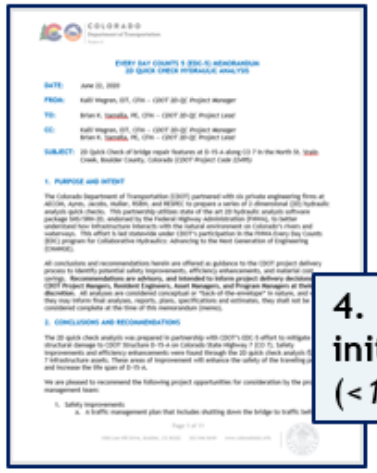
1. Identify the Project or Asset



2. Get background information: as-builts, topo, hydrology *(1-day)*



3. Create a 2D analysis *(1-3 days)*

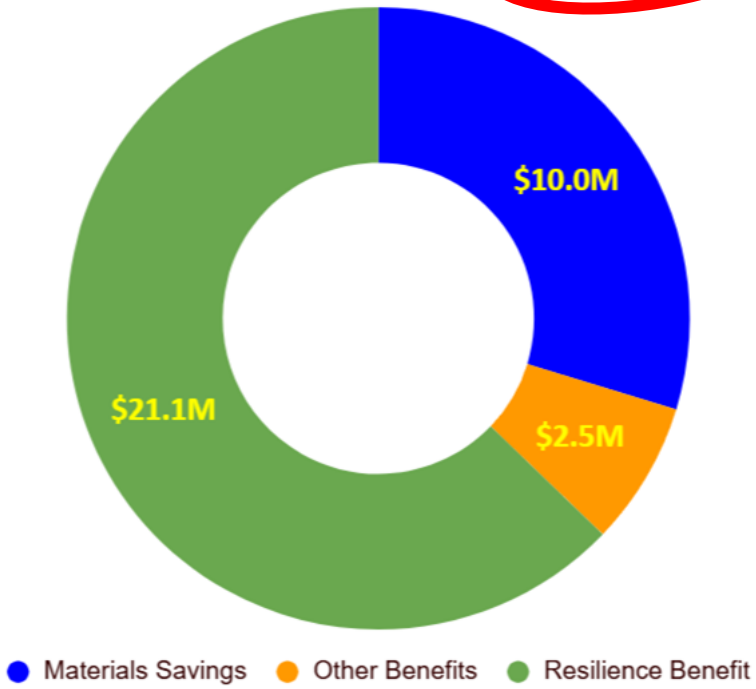


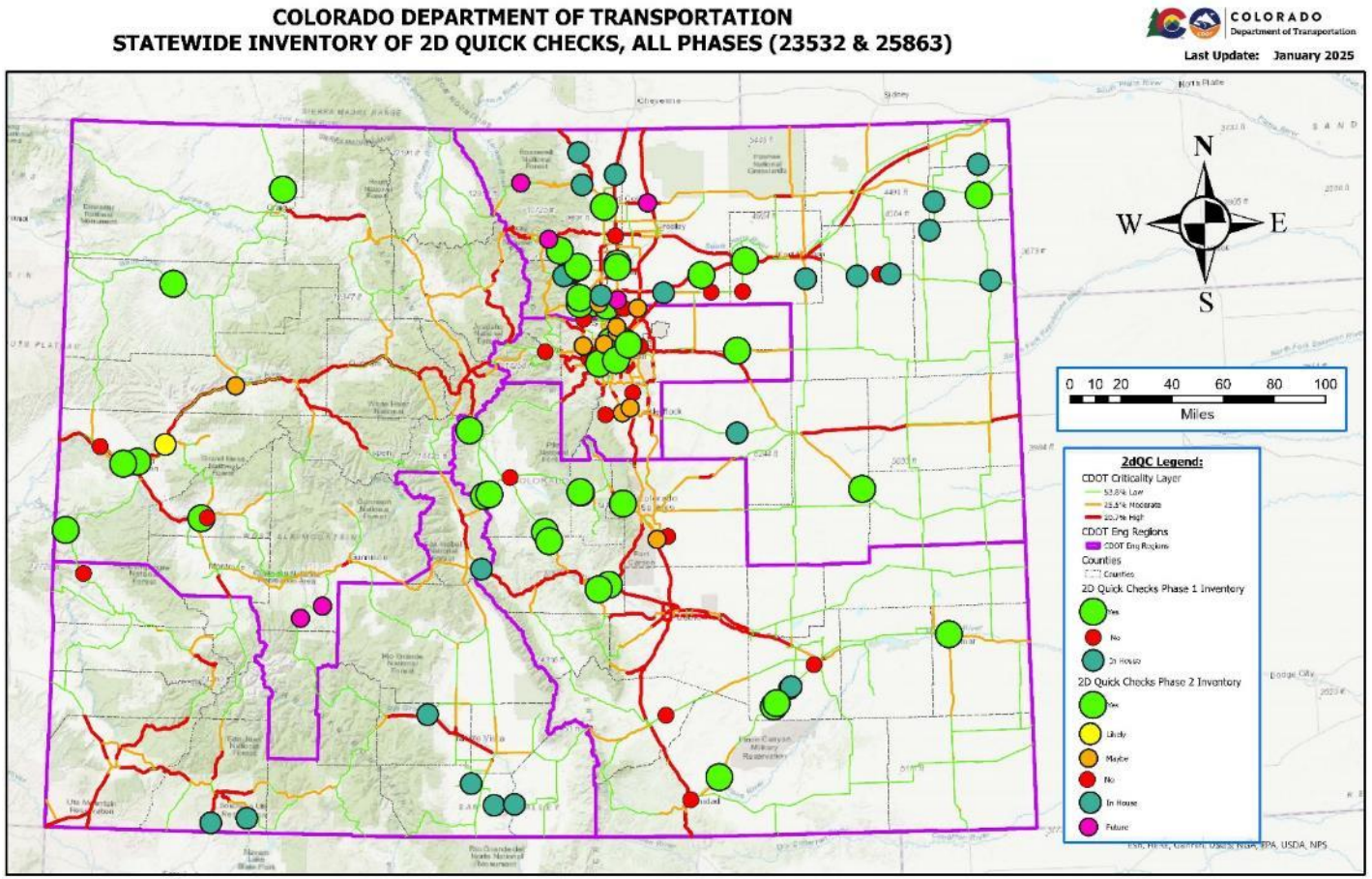
4. Summarize initial findings *(<1 day)*

2dQC, Resilience by Technology, 3 of 3

2dQC, All Phases, 1 and 2 (2020-2025) 68 of 125 Project Sites

Calculated All-Phase Benefits = $33.6M
68 Projects ROI = 100:1

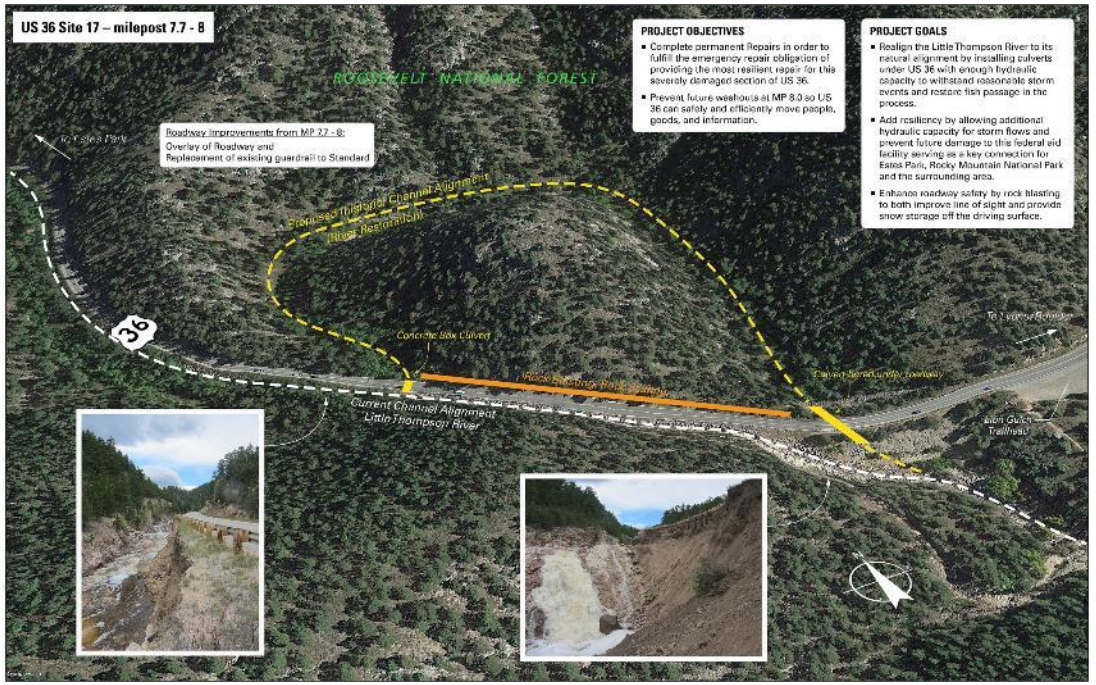




Project Example: US36 Mile 8, Muggins Gulch

Little Thompson River headwaters:

- Prevent a third major washout
- Return river to pre-1938 oxbow channel
- Reduce wildlife strikes
- Reduce head-on vehicle accidents



US36 Mile 8, Muggins Gulch Results, 1 of 2

Little Thompson River headwaters:

2022

2023

2024

s, 2 of 2

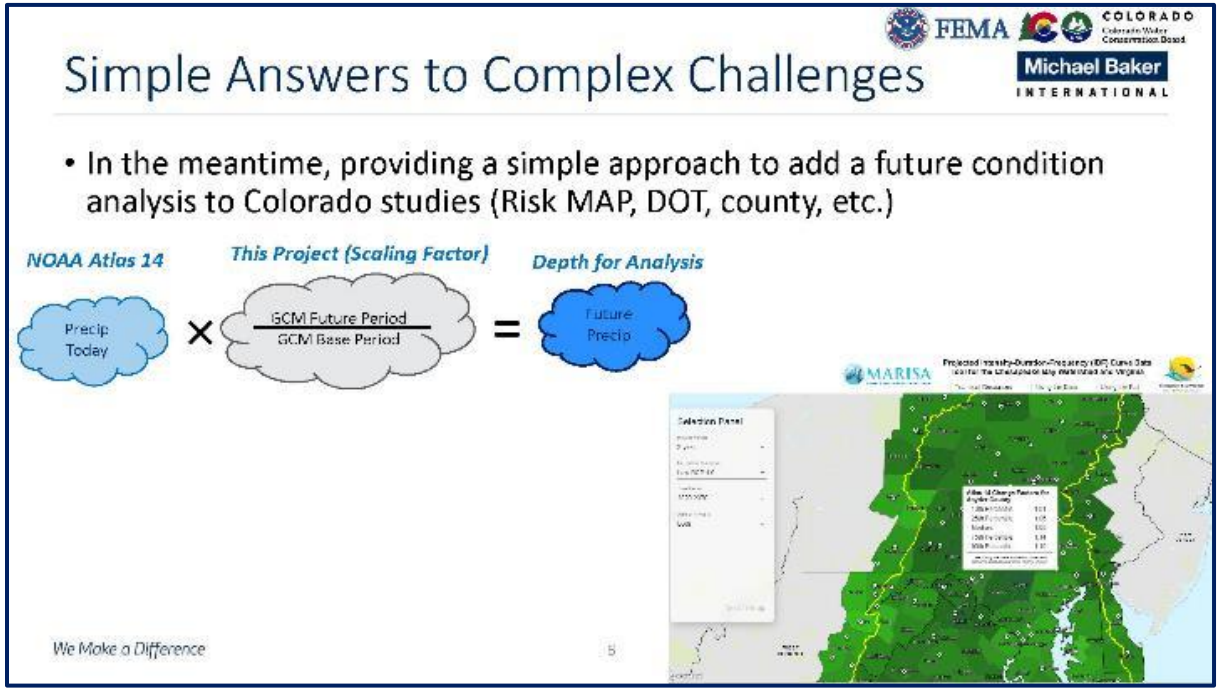
Little Th

Mitigating Risk in Colorado Infrastructure

Climate-Informed Design Standards, 1 of 2

Colorado Offers a CISA Solution for Hydrology

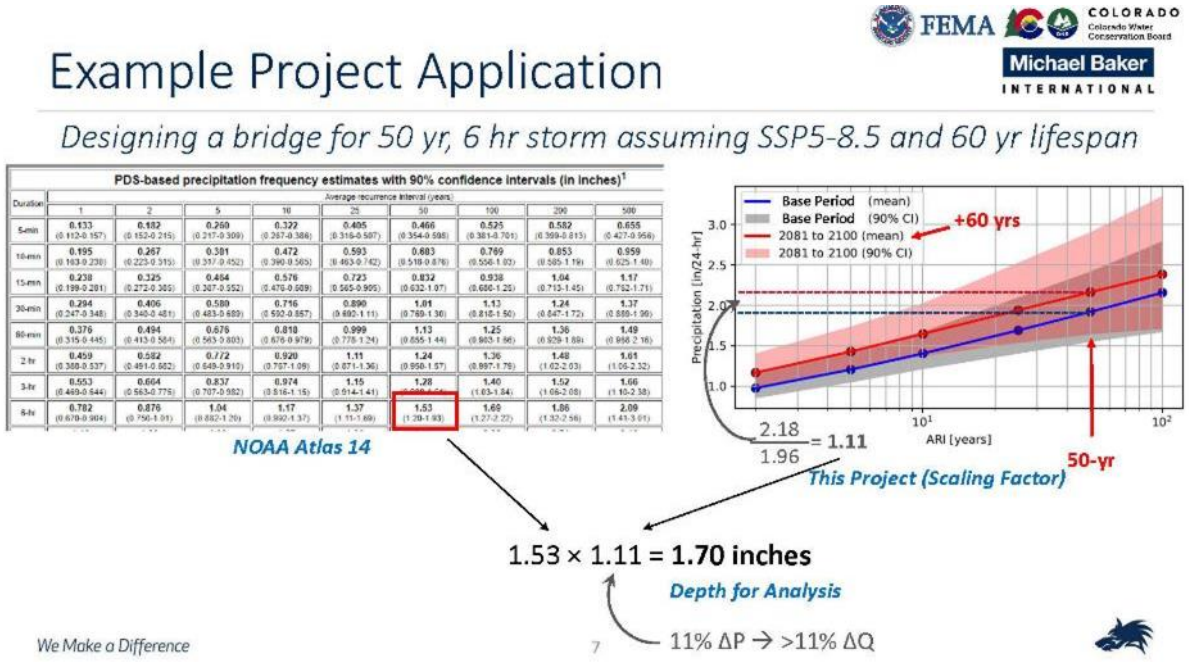
- Michael Baker, CWCB and FEMA Region VIII partnership
- Uses the Coupled Model Intercomparison Project Phase 6 (CMIP-6) data

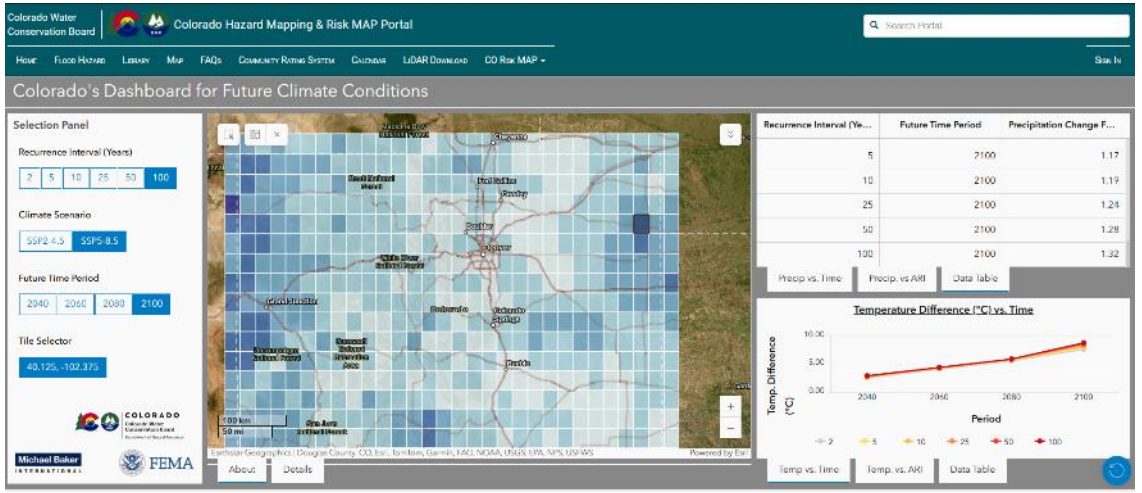


Climate-Informed Design Standards, 2 of 2

Uses Existing National Oceanic & Atmospheric Administration (NOAA) Data

- Collect multiplier from Colorado Hazard Mapping website
- Apply multiplier to NOAA Atlas 14 data to adjust rainfall to future conditions

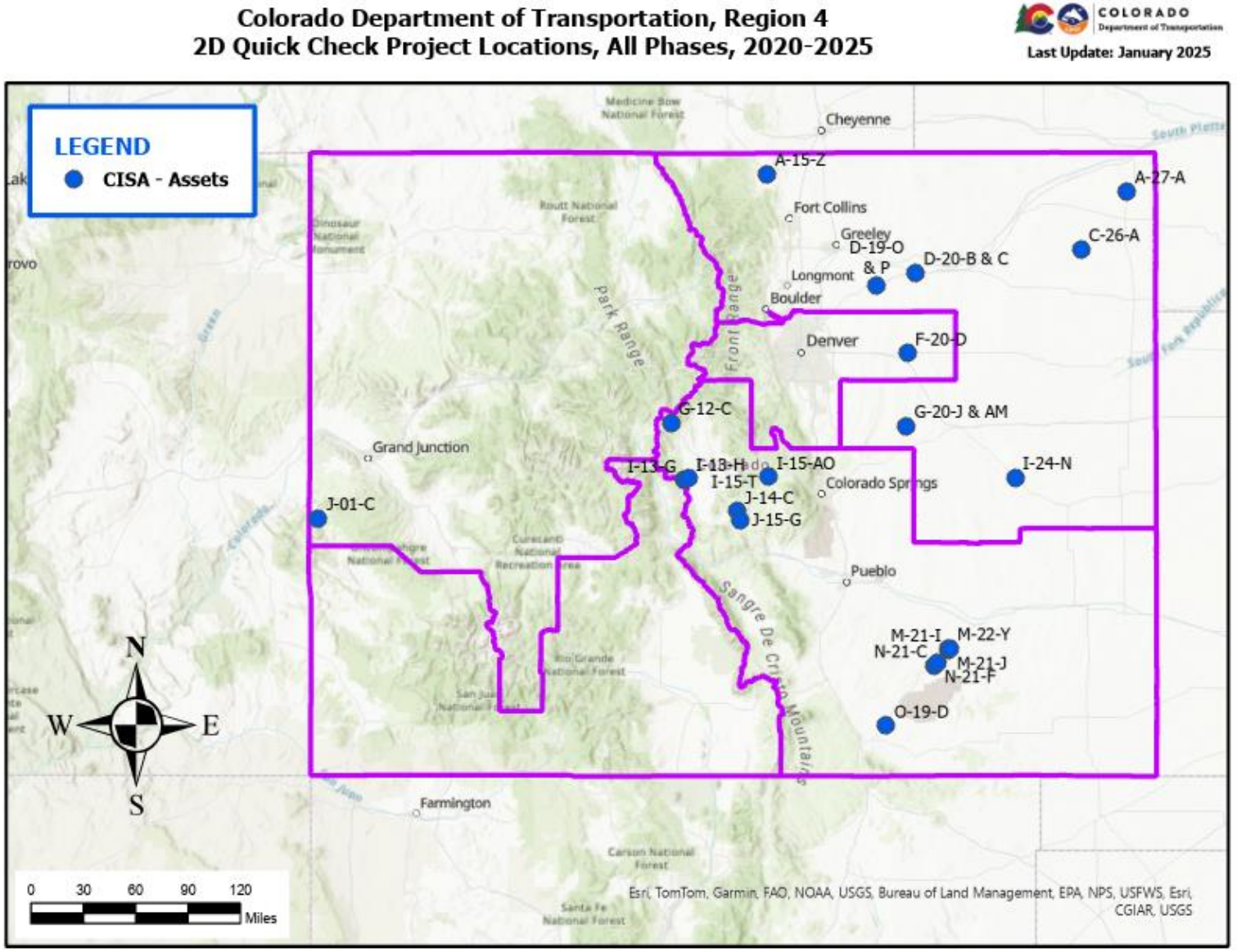




CISA Pilot Project Locations

CISA Investigation Framework

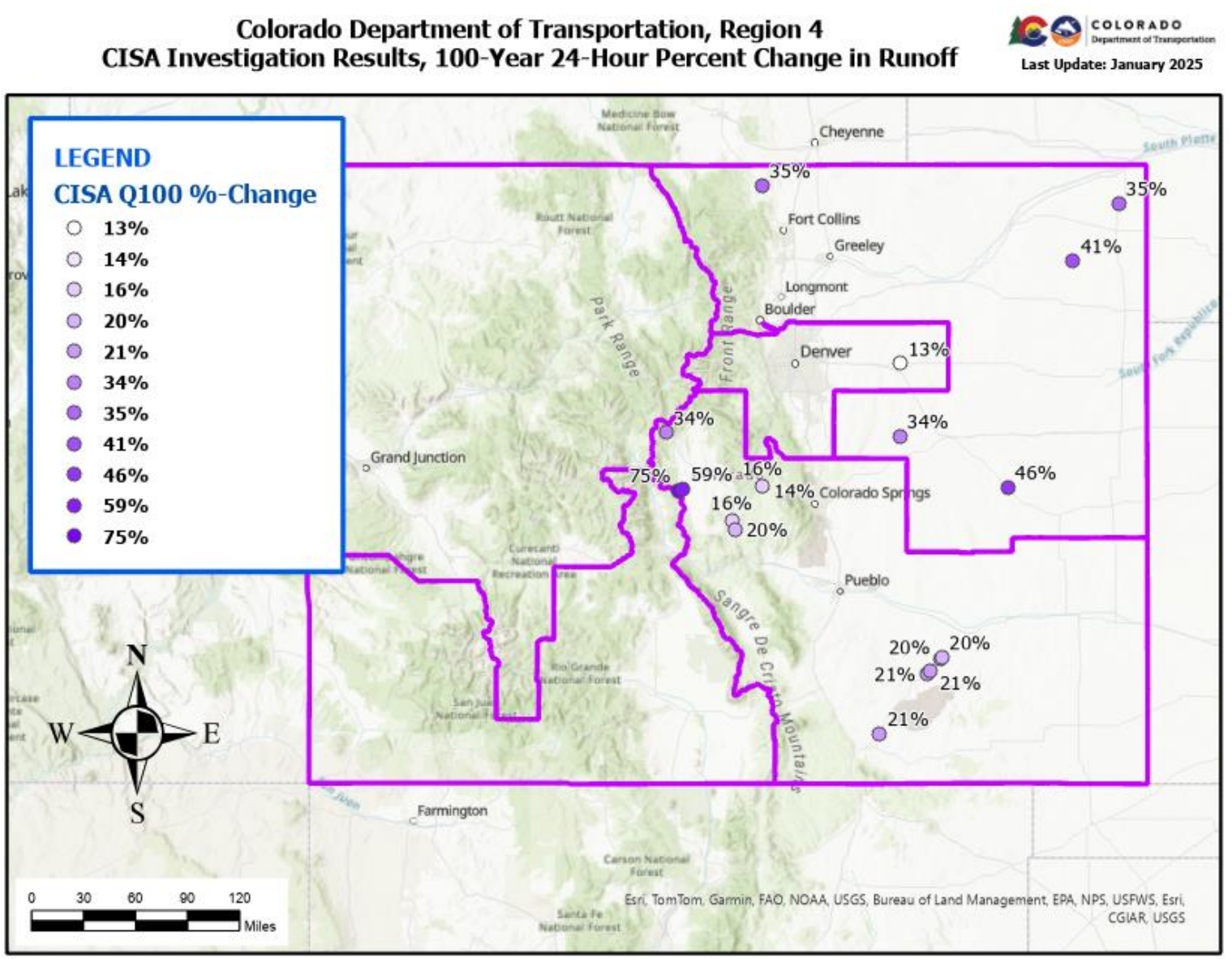
- 22 locations reviewed for modified hydrology
  - Calculated new hydrology for 10-, 25-, 50- and 100-year 24-hour storms
- 16 CISA-informed structure size analyses with 2dQC
  - Iterate on new structure sizes by changing width of openings
  - No other variables were tested



CISA Hydrologic Response to Precipitation

Initial CISA Hydrology Results at 18 CDOT Structures

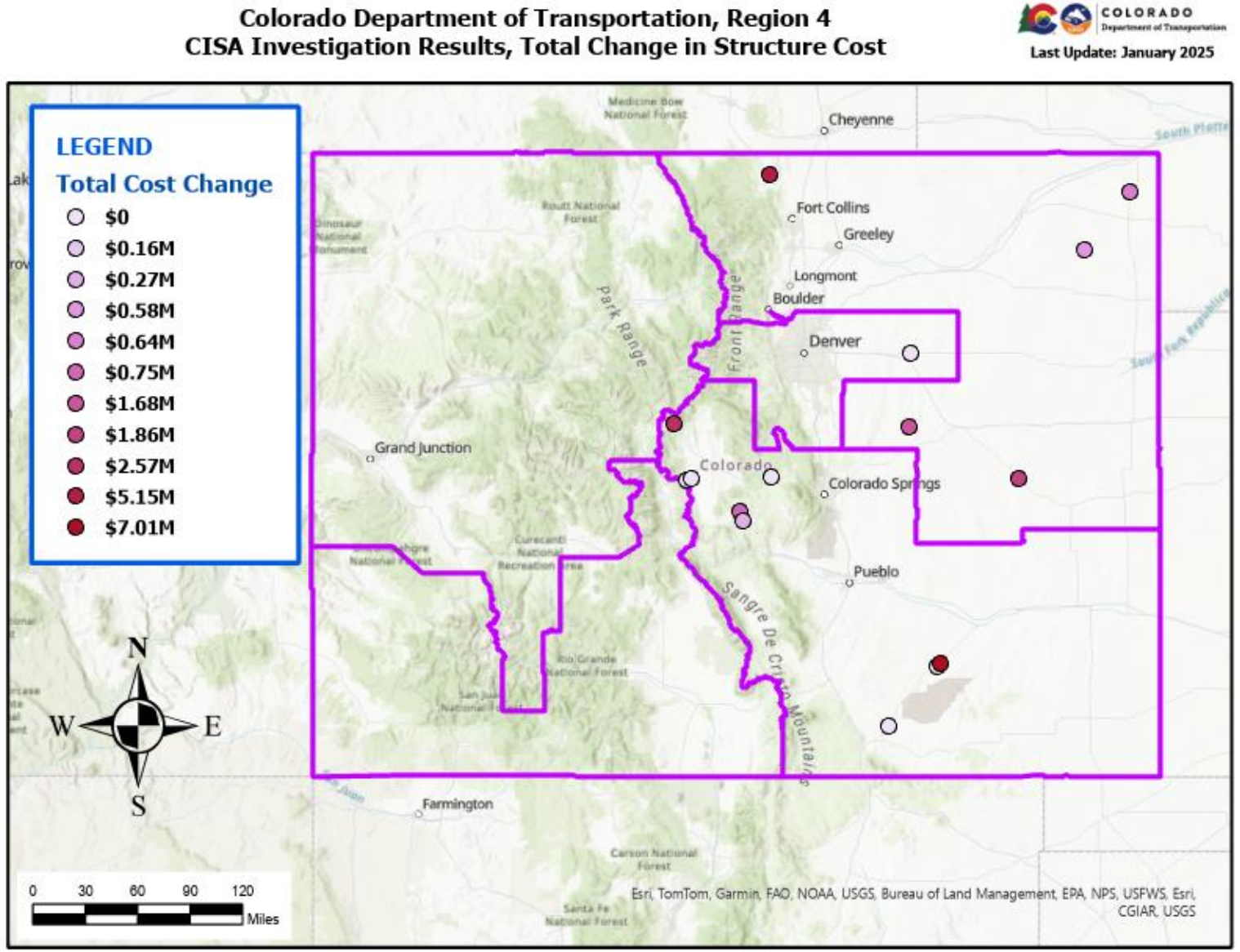
- 100-yr hydrology (runoff) response
  - Range = +13% to +75%
  - Average = +30%
- Other runoff intervals were calculated but are not reported here



Climate-Adjusted Bridge Design Impacts

Initial CISA Structure Size Change in Cost ($) at 16 CDOT Structures

- Total change in cost for a CISA-ready structure as compared to existing
  - Range = $0 to $7.0M
  - Average = $1.3M
- Analyses did not consider roadway profile changes, taller structures, extra bridge piers, grading, or temporary structures



Tomorrow's Solutions; Team Up

1. Keep Making Friends – *team up outside your industry*

- **Develop relationships like neighbors (*like Watershed Coalitions*)**
- **(*Diverse Workforce*) + (*Mutual Goals*) = *Your Goals Become Achievable***

CASFM Newsletter Summer 2014

"In your personal and professional lives you will face a crisis and you relationships will get you through them."

-- Michael D. Brown, 2012

2. Prepare for All Hazards – *keep disasters from being disastrous*

- **Factor in climate change-affected hydrology, drought, wildfires…**
- **Wildfire = a prelude to other disasters**
  - "I say fire, you say flood" (*Varrella, 2014 ASFPM Plenary*)

Photo: RJ Sangosti, published in the Denver Post, 2012

Photo: Lucas Mouttet, Poudre Canyon, 2012

Photo: Varrella, St. Vrain Creek, 2013

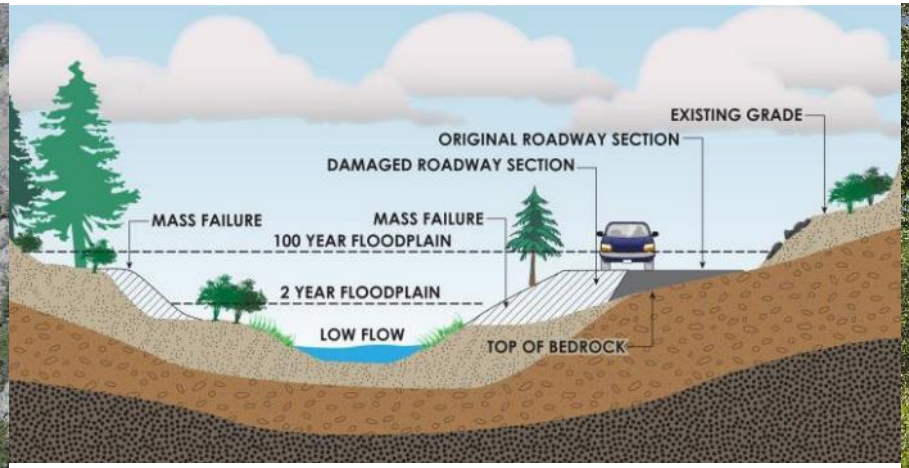
Tomorrow's Solutions; Event vs. Disaster

2. Prepare for All Hazards – *keep disasters from being disastrous*

Tomorrow's Solutions; Use All Plans

3. Update Your Plans – *know your risks & menu of solutions*

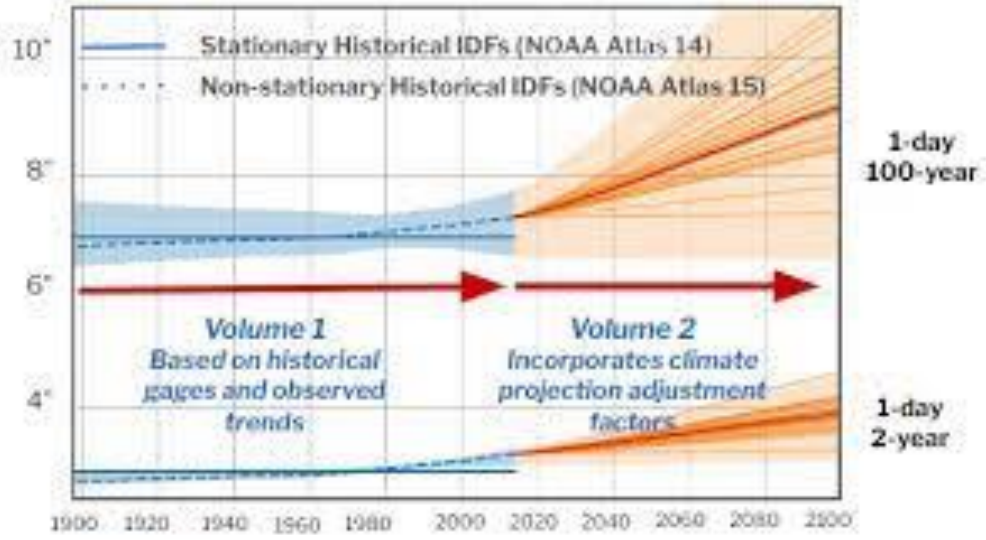
- **Multi-disciplined, multi-objective & adaptable**
- **(Current Needs) * (Future Conditions) = Innovation Needed**
  - "*Build Back Better*"
  - Risk & Resiliency Measures
  - Strategic Failure
  - Watershed Scale Planning & Design
  - Nature-Based Design
  - "*Let It Grow*" *(Katie Jagt)*



Tomorrow's Solutions; Advance the Science

4. Support Better Practices – *new science, new change*

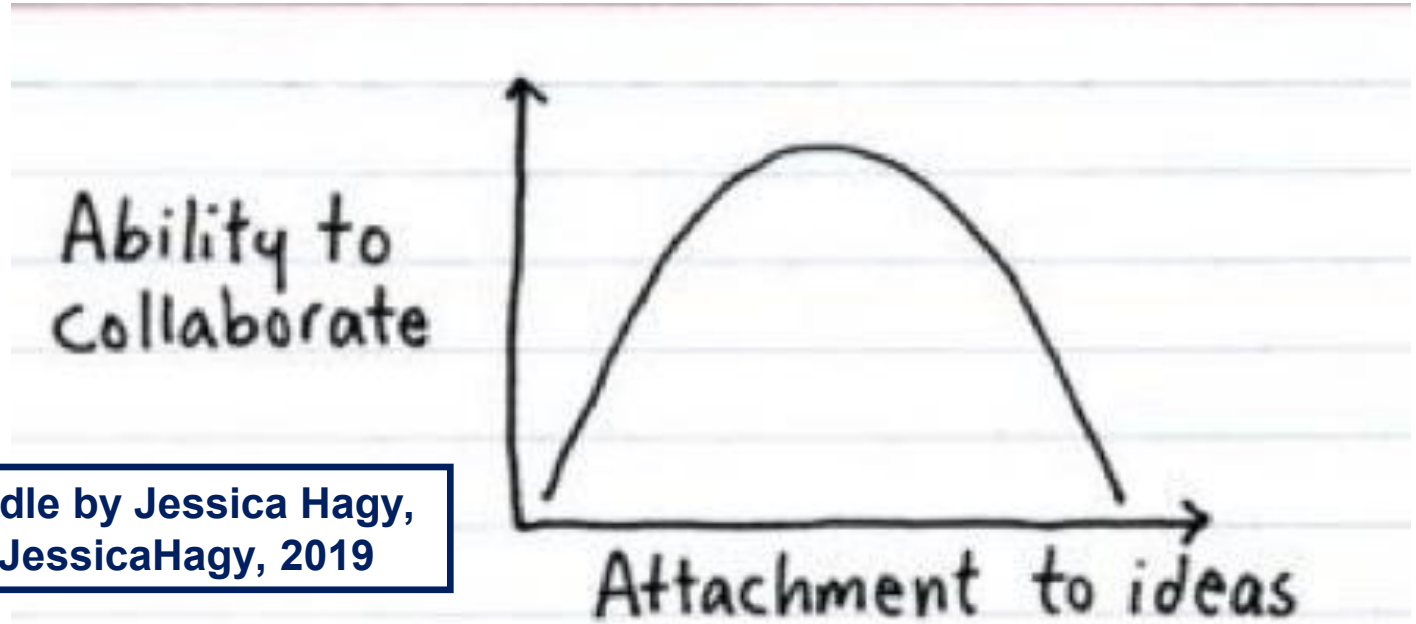
- **When the data changes, we change too**
  - Adapt → Innovate → Influence
- **Climate changes are changing the future of floods we manage**
  - Shift in rainfall intensity → new hydrology → new design targets
- **If roads <u>will</u> flood, close them**



Tomorrow's Solutions: Never Quit

5. Never Give Up – *run the marathon*

- **Do the right thing & don't look back**
- ***You will work in a collective of experts: trust and rely on one another daily***



Doodle by Jessica Hagy, @JessicaHagy, 2019

Thank You for Including CDOT!

Group Discussion

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