

# September 2013 Flood Event

- September 9-15<sup>th</sup> - A cold front stalled over Colorado and clashed with monsoonal air from the south
- 2380 square miles affected, many areas receiving their typical annual rain fall within this short time period
- 17 counties affected, State and Federal emergency declarations declared
- 8 deaths and over 3,000 military evacuations
- Over 468 miles of Federal-aid roads closed
- Over 150 miles of Federal-Aid roads damaged
- Over 200 bridges and culverts damaged
- 37 emergency repair projects, 54 permanent repair projects (32 CDOT and 22 LPA's)
- Total cost to ER program = ~ \$700 M

# **FHWA interest in resilience**

## **– why is it important?**

- **Saves the FHWA emergency relief program money over time**
  - in some circumstances, restoring the facility to its pre-disaster condition would leave it vulnerable to repeat damage, costing the FHWA emergency relief program more than if the facility had been rebuilt with protective features.

# Defining Risk and Resilience

- For management and decision making purposes **risk** is best reflected as a annualized monetary expected loss from threats based on asset design, characteristics and vulnerability
  - Simplifies decision making
  - Allows for assets to be analyzed/assessed with similar metric
  - Easy for non-technical staff and decision makers to understand
- **Resilience** is reflected as a measure of loss of service
  - For example, potential number of vehicles affected by threats in a given year (loss of essential traffic).

# Risk and Resiliency Calculations

Analysis Objectives	Formulas
<b>Risk from Natural Threats</b>	$Risk = C \times V \times T$ <p>Where:</p> <p>R = annual monetary risk due to natural threats (\$)</p> <p>C = consequences (\$)</p> <p>V = vulnerability to identified consequences under a specific threat (probability)</p> <p>T = specific threat likelihood (probability)</p>
<b>Resilience from Natural Threats</b>	$Resilience = AADT \times \%AADT \text{ Not Serviced} \times Days \text{ Out of Service} \times V \times T$
<b>Benefit to Cost Ratios</b>	B/C Risk - Reflects the reduced annualized monetary risk to the asset only as compared to the annualized cost of the design
	B/C RnR – Reflects the reduced risk as well as the resilience of the design provided to the overall CDOT system

# Economic Justification of Resilient Design Alternatives

- Assess risk of assets to natural threats
- Assess vulnerability of assets to natural threats
- Estimate consequences of future natural threats to CDOT assets
- Reduced annualized risk for design alternatives are compared to “Restore-in-Kind” designs to natural threats

# Colorado Resiliency Framework & Definition of Resilience



*Resilience is the ability of communities to rebound, positively adapt to, or thrive amidst changing conditions or challenges – including disasters and climate change – and maintain quality of life, healthy growth, durable systems, and conservation of resources for present and future generations*

**- Definition of Resilience by the State of Colorado**



# River always picks it's own path

## Example 1

US 34 East of Greeley



# Need for a Resilient solution





# Resilient solution

## Betterment through R&R analysis

Replaced the blown out roadway with a bridge to pass future flows in that area.



# **It worked!!!**

## US 34 East of Greeley in the 2015 Event





# River always picks it's own path

## Example 2

- SH 71 on the eastern plains of Colorado



# Resilient solution

## Replace to current standards

Utilized larger rock for the reconstructed road base to allow for water to pass through the roadway relieving pressure that would ultimately blow out the entire roadway in the future.





# River always picks it's own path

## Example 3

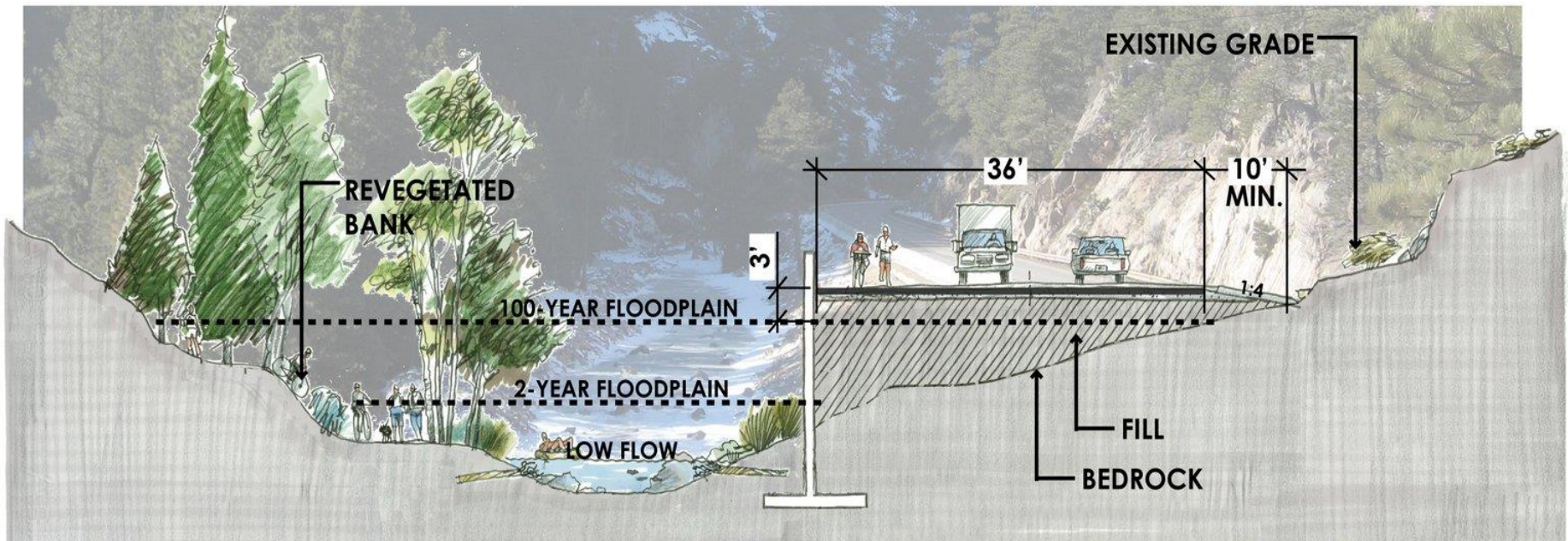
US 36 – Boulder to Estes Park – Similar damage to road in multiple locations.





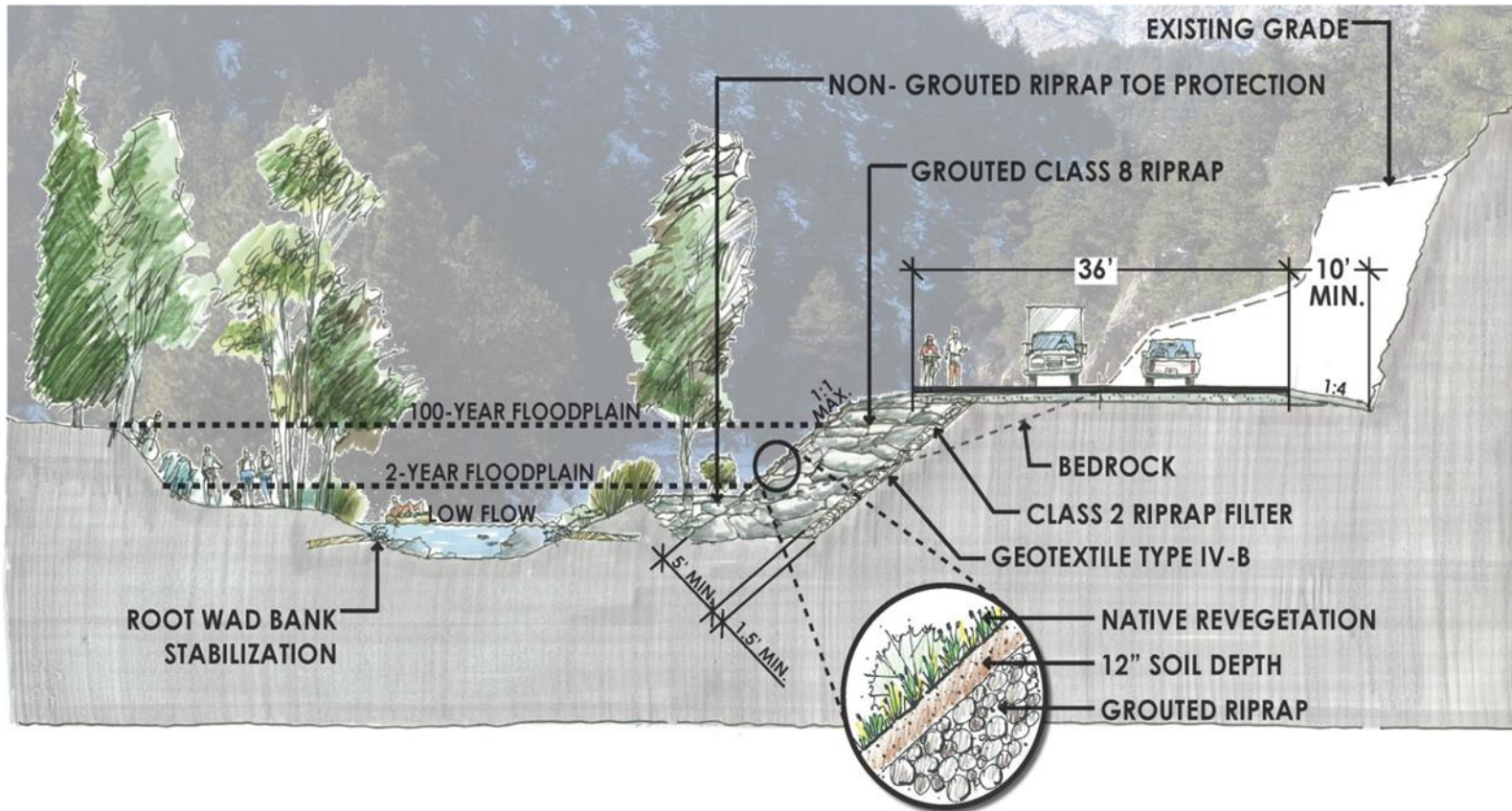
# Typical design to restore a facility to its pre-disaster condition

## CONVENTIONAL REPAIR TYPICAL SECTION



# CFL designed a Resilient solution

## PROPOSED REPAIR TYPICAL SECTION



Design makes room for the water, restores riparian habitat and attenuates flood impacts and risks of slope failures by building its own bedrock.



# Constructing the resilient design option. Replace to current geometric standards





# Constructing the resilient design option.





# Road today





# FINAL COMMENTS

- CDOT has an established process to analyze incorporating resilient features into projects (R&R)
- CDOT has incorporated this same process into their daily project selection and resource allocation.
- Part of their Asset Management program
- Have started incorporating resilience into PEL's

# Contracting methods

- Emergency contracting following State procedures
- Force Account (labor, equipment , materials)
- D/B/B
- CM/GC
- SATOC - CFL