

### 4R Attributes

- Robustness: The strength of an asset or a system to withstand relevant threats
- Redundancy: The presence of a backup system or plan
- Resourcefulness: Ability to identify, diagnose, and treat problems with available resources
- Rapidity: Ability to restore functionality in a timely way

### Organizational Examples

- Post-fire debris flow is declared as a CDOT Research Area of Emphasis to enhance understanding and mitigation of the impact of this threat on the transportation system, which includes participation in state and federal research partnerships. (Resourcefulness)
- Adopted risk thresholds. Emergency road closure thresholds are triggered when rainfall exceeds a certain amounts on burn scar areas. (Redundancy)
- CDOT partners with other agencies including U.S. Forest Service (USFS), U.S. Geological Survey (USGS), and counties to construct projects that mitigate debris flow. (Resourcefulness)
- CDOT integrates real-time rainfall data from the National Weather Service (NWS) into its Colorado Early Warning System (EWS) to predict and alert to debris flows. (Resourcefulness)

### A Resilient Transportation Organization

- Has an organizational mindset of enthusiasm for challenges, problem solving, agility, flexibility, innovation, and taking opportunity.
- Understands interconnectedness and vulnerabilities across all aspects of agency function.
- Has established relationships, prearranged mutual aid arrangements, and regulatory partnerships.
- Has established response plans in place to mobilize when events occur.

## Post-Fire Debris Flow

Fast moving gravity-driven landslides containing mud, sand, soil, rock, water and air, and traveling down recently burned land. Slope failure is often triggered by intense rainfall. There is a risk that post-fire debris flow occurs, leading to asset/route damage that causes mobility and safety impacts, as well as increased asset management cost.



### A Resilient Transportation Asset

- Is safe to fail -- designed, where relevant, to allow controlled, planned failure during unpredicted conditions, recognizing that the possibility of failure can never be eliminated and can withstand and recover from unexpected events and challenges.
- Has parts, elements, systems, facilities, etc., that are substitutable, e.g., are capable of satisfying backup functional requirements in the event of disruption, degradation, or loss of functionality of the primary system. May involve system redundancy (i.e., maximizing use of frontage lanes, breakdown lanes, managed lanes), detour routes, or alternative modes.
- Includes equipment to monitor and alert to potential threats or failures before they occur. Sufficient materials are on hand to efficiently mobilize in case of emergency.
- Is designed in such a way that it is quick to restore functionality, containing losses and avoiding disruptions.

### Technical Examples

- CDOT evaluates the use of oversized culverts, debris catchment basins, and channel sizing in vulnerable areas, such as a 24-foot-wide concrete box culvert (CBC), along critical routes like US 24 near the Waldo Canyon burn scar. These systems allow for additional capacity and designed areas for debris to be collected during high-flow events. (Robustness)
- CDOT installs geotextile fabrics, soil nails, and wire mesh systems on fire-damaged slopes to prevent loose debris from triggering landslides during heavy rainfall. After the Grizzly Creek Fire, high-strength steel netting was used to stabilize the steep canyon walls along I-70 in Glenwood Canyon. A similar mitigation project in Waldo Canyon caught about eight feet of mud, sediment, and logs during flash flooding in 2013. (Robustness) Debris Encatchment Systems and an Emergency Gate Closure were installed in Waldo and Williams canyons. (Robustness)
- Rain monitoring equipment installed in high-risk areas. (Resourcefulness)
- CDOT works with USFS to implement Burned Area Emergency Response (BAER) to implement emergency soil stabilization measures, such as reseedling burn scars with fast-growing vegetation and installing erosion control measures to stabilize slopes above highways. (Robustness)
- Constructed catchment basins west of Cascade at Sand Gulch, Wellington Gulch, Cascade Basin, Rampart Terrace and Rainbow Falls (to be constructed), allowing additional debris to be collected "off-road" and away from the highway. (Robustness)
- A real-time video feed provides CDOT and USGS with the ability to see if a rain event is producing debris flow or just water. (Resourcefulness)