



The Applied Research and Innovation Branch and Research Library are located on the CDOT Headquarters Campus in Denver, in the Shumate building east of the Headquarters building.

**RESEARCH
RESEARCH
RESEARCH**

Innovation Frontline

Applied Research and
Innovation Branch (ARIB)

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Research Implementation Council Meeting

Gateway to Innovative Ideas

Research projects are selected and prioritized annually by the Research Implementation Council (RIC). The RIC is composed of CDOT senior managers and representative(s) from FHWA. The RIC reviews, discusses, evaluates, and ranks potential research projects based on a number of factors including cost, benefit, value, and research need. This process is meant to ensure that a broad array of research topics is funded and that CDOT's needs, mission, vision, and goals are addressed.

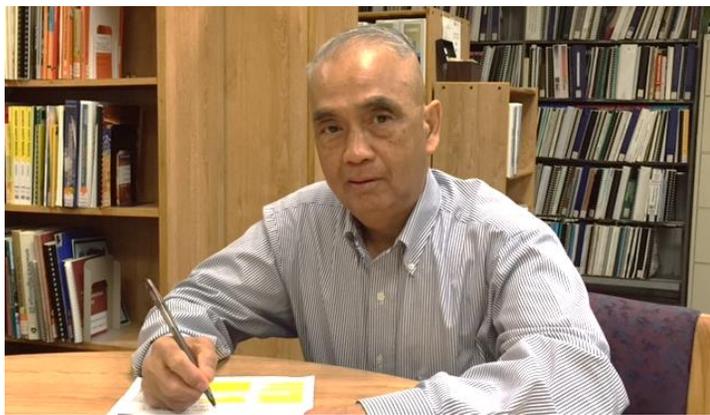
This year, 69 problem statements were submitted to the Applied Research and Innovation Branch (ARIB) for funding consideration. Problem statements are concise descriptions of a problem or innovative idea that needs to be addressed through research. They can be proposed

by any CDOT staff or any of CDOT's research partners such as universities and contractors.

These problem statements are first analyzed, critiqued, modified and prioritized by the ARIB Research Managers and Research Oversight Teams that are made up of CDOT subject matter experts. This evaluation process produced a list of the 29 strongest problem statements CDOT received. The ARIB presented these 29 problem statements to the RIC for their consideration on February 23, 2016. The main findings of this meeting should appear in the next ARIB news

Keeping all senior managers for a whole day to listen to the presentations and rating them is time consuming. We will be looking for iterative practical options.

Amanullah Mommandi, M.S., P.E.
Director of Applied Research and Innovation Branch



ROBERTO De DIOS, who retired in 2013, was recently rehired by the CDOT Applied Research and Innovation Branch for the second time to manage the Pavements and Materials Research Program. Mr. De Dios has a B.S. degree in Chemical Engineering and a M.S. degree in Environmental/Civil Engineering. He is a registered professional engineer in the state of Colorado. He currently manages at least six active research projects that encompass various topics in the areas of pavements and materials engineering.

News Corner

RESEARCH PROJECTS COMPLETED IN 2015

CDOT's Applied Research and Innovation Branch is continuously at work overseeing a number of innovative projects that add value to the field of transportation and engineering. Nearly a dozen reports were completed in 2015 and they can be accessed at:

<https://www.codot.gov/programs/research/pdfs/2015-research-reports>

The 2015 research project titles provide insight into the effort involved in the research. Projects include:

- Assessment and Placement of Living Snow Fences to Reduce Highway Maintenance Costs and Improve Safety
- Assessment of CDOT Revegetation Practices for Highway Construction Sites
- Life Cycle Cost Analysis Rehabilitation Costs
- Best Practices for Full-Depth Reclamation Using Asphalt Emulsions
- Monitoring Wildlife-Vehicle Collisions: Analysis and Cost-Benefit of Escape Ramps for Deer and Elk on U.S. Highway 550
- Feasibility Study of Developing and Creating a Standardized Subset of Bridge Plans
- Evaluating the Effects of Concrete Pavement Curling and Warping on Ride Quality
- Potential Impacts of Solar Arrays on Highway Environment, Safety and Operations
- Effectiveness of Two Reflection Crack Attenuation Techniques
- A Comparison of Freeway and Parallel Major Arterial Corridors: A Study of Safety Patterns in the Denver Metropolitan Area

Research Highlights

A Comparison of Freeway and Parallel Major Arterial Corridors: A Study of Safety Patterns in the Denver Metropolitan Area

Observations and initial examination of average daily traffic and peak-hour volume data on Denver regional arterials suggests questions as to if and why they are happening, and what the implications are on corridor travel and accident patterns? This research task investigated these trends and addressed questions to assist CDOT in better determining which improvements would more likely decrease accident experience while improving corridor capacity. The research focused on a selected freeway section and corresponding regional arterials corridors. The study addressed the effects of arterial traffic volume diversion patterns and the discontinuities on freeway versus arterial safety parameters. The research report provided conclusions as to what improvements would most likely improve safety and corridor thru-put on both the freeway and corresponding arterial corridors. *Short Elliot Hendrickson, Inc.:* **Ron Hensen**, PhD., PE; **Joe Miyaki**, EIT. *CDOT Research Project Manager:* **David Reeves**.

Best Practices for Full-Depth Reclamation Using Asphalt Emulsions

Full depth reclamation of asphalt pavements using asphalt emulsions (AEFDR) is a process that recycles and rejuvenates the existing asphalt pavement surface, base, and, sometimes, the subgrade, providing an improved underlying structure for the new asphalt pavement. This report provides design guidance, standardized plans and specifications, construction inspection best practices, materials testing procedures and frequencies, a performance evaluation process, and quality assurance and quality control protocols when constructing FDR projects. *CDOT Author:* **Scott Shuler**; *CDOT Research Acting Project Manager:* **Richard Griffin** and **Researcher Skip Outcalt**.

Effectiveness of Two Reflection Crack Attenuation Techniques

The purpose of this study was to evaluate two reflective crack mitigation techniques that include the use of either reflective cracking interlayer (RCI) or GlasGrid materials to prevent the propagation or migration of cracks from the underlying course to the surfacing course of asphalt pavement overlays. The CDOT Materials Advisory Committee (MAC) on its quarterly meeting on March 9, 2016 approved two separate resolutions regarding the application of RCI and GlasGrid in future CDOT projects. For RCI, the MAC recommended further investigation to include crack inventory of underlying pavement and at least three years of performance monitoring and cost effectiveness evaluation. For GlasGrid, the MAC recommended its use to mitigate distress in asphalt pavement overlays where: transverse cracking is the primary distress; fatigue cracking is minimal; and truck loading is moderate. *CDOT Author:* **Scott Shuler**; *CDOT Research Project Manager:* **Aziz Khan** and **Researcher Skip Outcalt**.

Paleoflood Investigations Improve Peak-Streamflow Regional-Regression Equations for Natural Streamflow in Eastern Colorado



By its very nature, the Plains hydrologic region in eastern Colorado has the largest flooding uncertainty of any hydrologic region in Colorado. The U.S. Geological Survey (USGS) and CDOT have known for years that *reliable* peak-streamflow information recorded by floodplain inundation maps is critical for the proper design of stream-related infrastructure, such as bridges, concrete box culverts (CBC), pipe culverts, and dams.

Sufficient long-term streamflow data have been collected at gaged sites and are kept in the USGS National Water Information (NWIS) database. But it has become apparent estimates have also been needed at ungaged sites where no site-specific streamflow data have been available.

This study's purpose provided an opportunity for the USGS and CDOT to cooperatively develop peak-streamflow regional-regression equations (PSRREs) for estimating the 50-,20-,10-,4-,2-,1-,0.5-,0.2- percent annual-exceedance probability discharge (AEPD) for natural streamflow in eastern Colorado. The PSRRE relate AEPDs to drainage basin size, topography, hydrology, and climatology.

Annual peak-discharge data from streamgages with a record of at least 10 years were compiled from USGS, Colorado Division of Water Resources (CDWR), and Nebraska Department of Natural Resources (NDNR) through water year 2013, as well as paleoflood data. A water year is the 12-month period from October 1 through September 30 designated by the calendar year in which it ends.

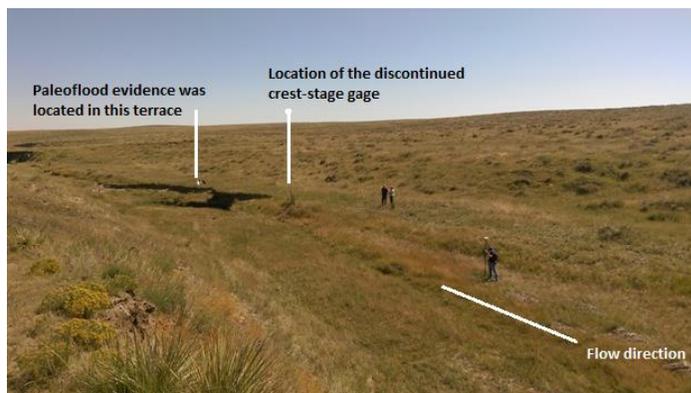
The limitations and accuracy of the PSRREs were presented in this study. The study area was extended 100 miles outside Colorado for the purpose of PSRRE development because the hydrology is not influenced by political borders. However, the PSRREs are only applicable in Colorado. The study also stipulated that the current PSRREs are only applicable to natural streamflow with drainage areas between 0.26 and 3,307 square miles. It clarified the PSRREs are based on analysis of peak-streamflow data at streams relatively unaffected by anthropogenic influences such as storage, regulation, and diversion or return streamflows from a municipality or mining operation, or urban development in a basin.

Methodology

A total of 188 streamgages, consisting of 6,536 years of record and an average of approximately 35 years of record per streamgage, were used to develop the peak-streamflow regional-regression equations. The estimated AEPDs for each streamgage were computed using the USG software program PeakFQ. The AEPDs

were determined using systematic data through water year 2013. Based on previous studies conducted in Colorado and neighboring States and on the availability of data, 72 characteristics (57 basin and 15 climatic characteristics) were evaluated as candidate explanatory variables in the regression analysis. Paleoflood and non-exceedance bound ages were established based on reconnaissance-level methods. The standard error of prediction (SEP) averaged for all AEPDs was reduced approximately 25 percent compared to the previous flood-frequency study. Generalized-Least Squares regression was used to compute the final peak-streamflow regional-regression equations for peak-streamflow.

Reconnaissance-level methods helped establish ages for paleoflood and non-exceedance bounds, as in this investigation at the Middle Bijou Creek Tributary near Deer Trail, Colorado.



Results

It was determined that dividing the Plains hydrologic region in eastern Colorado into two new individual regions at -104° longitude would result in peak-streamflow regional-regression equations with the smallest SEP. The new hydrologic region located between -104° longitude and the Kansas/Nebraska Stateline will be called the **Plains hydrologic region** and the hydrologic region comprising the rest of eastern Colorado located west of the -104° longitude and east of the Rocky Mountains and below 7,500 feet in the South Platte River basin and below 9,000 feet in the Arkansas River basin will be called the **Foothills hydrologic region**.

USGS Authors: Michael S. Kohn, Michael R. Stevens, Tessa M. Harden, Jeanne E. Godaire, and Ralph E. Klinger. CDOT Research Project Manager: Aziz Khan and co-author Amanullah Mommandi. Published 2015.

To determine the peak discharge of a paleoflood or non-exceedance bound, two different hydraulic models were used, which evaluated 72 characteristics (57 basin and 15 climatic characteristics) to potentially explain variables in the regression analysis.

Research Funding Sources

State Planning and Research Funds

The Applied Research and Innovation Branch finances a majority of its research ventures using **State Planning and Research (SP&R) Funds** with a 20 percent state match, and when FHWA approves proposed transportation pooled-fund studies, those are funded with 100 percent SP&R funds. Additionally, when there is limited scope, local interest, or a shortage of federal funds, the ARIB will finance certain studies with **State Funds** that are derived from the Colorado State Highway Users Tax Fund and approved through the State Transportation Commission review process.

Pooled Fund Sources

When significant or widespread interest is shown in solving transportation-related problems, research, planning, and technology transfer activities *may be jointly funded by several federal, state, regional, and local transportation agencies, academic institutions, foundations, or private firms as a Pooled Fund Study*. The **Transportation Pooled Fund (TPF)** Program allows federal, state, and local agencies and other organizations to combine resources to support transportation research studies. These studies must be sponsored by either a State DOT or the FHWA. For more information, visit: <http://www.pooledfund.org/Home/About>

Other Funding Sources

If deemed necessary, the ARIB also pursues **Public-Private Partnership** ventures that comply with state and federal regulations to leverage research funding and enhance implementation opportunities for the benefit of the transportation program. A couple of **Other Funding Sources** are detailed below.

University Transportation Center Resources

Several universities in Colorado participate in the University Transportation Center (UTC) program, which provides research grants to universities with students enrolled in surface transportation programs. There are presently 35 UTCs: 5 National, 10 Regional, and 20 Tier 1. All UTCs work with regional, state and local transportation agencies to help find solutions to challenges that affect the efficiency of the nation's transportation system.

Currently, several Colorado universities (CSU/DU/UCD) are participating in only one Regional UTC, the Mountain Plains Consortium (MPC), led by the North Dakota State University. The Colorado Department of Transportation is coordinating the potential establishment of a UTC in Colorado with CSU, DU, UCD, CU, CSM, and UNC and is also exploring participation by Colorado universities in other established UTCs. With these efforts and CDOT's continued

support, Colorado's eligible nonprofit universities may be able to benefit over the next five years from the nationally-authorized \$377.5 million in research grants recently announced by the Secretary of Transportation, in accordance with the FAST Act. For more information from the Research and Innovation Technology Administration, visit: <http://www.rita.dot.gov/utc/home>

STIC Provides Additional Resources

The State Transportation Innovation Council (STIC) is able to provide funding to offset some of the costs of innovative projects. In FY15, \$100,000 in funding was available. The 2016 application schedule is:

- April 22 – Application deadline
- May 15 – Agreement from Council on funded projects
- August 1 – Final approved projects submitted to FHWA

The types of proposals, which must be submitted by public-sector organizations, could include a wide range of activities such as:

- Providing training and other deployment efforts
- Conducting internal assessments
- Developing guidance, standards and specifications
- Implementing system process changes
- Organizing peer exchanges
- Sharing innovation technologies

Public sector organizations include city, county, tribal or state government organizations or federal agencies operating in Colorado. The STIC proposals may include partners from non-public-sector organizations. For more information, visit:

<https://www.codot.gov/business/process-improvement/colorado-state-transportation-innovation-council-stic>

Do you have ideas for Research? The CDOT Applied Research and Innovation Branch encourages you to submit your ideas to any ARIB staff member. It could be well worth it in the eyes of our experts. For more program information, visit www.codot.gov/programs/research

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