Amanullah Mommandi, M.S., P.E.
Colorado Department of Transportation (CDOT)
Director of Applied Research and Innovation Branch
Denver, Colorado
amanullah.mommandi@state.co.us
(303) 757-9044
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>CDOT and USGS funded research project for <em>Eastern Colorado</em>.</td>
</tr>
<tr>
<td>2009</td>
<td>CDOT and USGS funded research for <em>Western Colorado</em>.</td>
</tr>
<tr>
<td>2009</td>
<td>Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado was published by USGS</td>
</tr>
<tr>
<td>2010</td>
<td>StreamStats Version 2 for Colorado was released by USGS to the public on <em>January 27, 2010</em></td>
</tr>
</tbody>
</table>
The StreamStats study divided Colorado into 5 Hydrologic Regions

Colorado StreamStats utilized stream flow data from gages located about 50 miles outside the Colorado border in Utah, Wyoming, Nebraska, Kansas, Oklahoma, New Mexico and Arizona.
In addition to web-based StreamStats, USGS Published this Scientific Investigation Report
These equations can be used without the internet

1. Peak Streamflow for *Mountain Hydrologic Region*

2. Peak Streamflow for *Northwest Hydrologic Region*

3. Peak Streamflow for *Rio Grande Hydrologic Region*

4. Peak Streamflow for *Southwest Hydrologic Region*

5. Peak Streamflow for *Plains Hydrologic Region*
StreamStats for Colorado Provided Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado for the following Four regions:

Mountain Hydrologic Region, Northwest Hydrologic Region, Rio Grande Hydrologic Region and Southwest Hydrologic Region, :

- Peak Stream Flow Equations
- Minimum Stream Flow Equations
- Maximum Stream Flow Equations
- Annual and Monthly Mean Streamflow Equations
- Flow Duration Curve
Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado

Peak Streamflow Equations for Mountain Hydrologic Region
Generalized least-squares (GLS) regression, 141 stations
Approximate range of predictor variables

\[ Q_2 = 10^{-2.05} A^{0.78} S^{0.17} P^{2.10} \]
\[ Q_5 = 10^{-1.51} A^{0.77} S^{0.16} P^{1.85} \]
\[ Q_{10} = 10^{-1.20} A^{0.77} S^{0.14} P^{1.71} \]
\[ Q_{25} = 10^{-0.90} A^{0.75} S^{0.16} P^{1.55} \]
\[ Q_{50} = 10^{-0.68} A^{0.75} S^{0.16} P^{1.45} \]
\[ Q_{100} = 10^{-0.46} A^{0.75} S^{0.14} P^{1.35} \]
\[ Q_{200} = 10^{-0.28} A^{0.75} S^{0.13} P^{1.26} \]
\[ Q_{500} = 10^{-0.06} A^{0.74} S^{0.15} P^{1.14} \]

\( SEP = 49, \quad \text{pseudo}R^2 = 83, \quad SME = 48, \)
\( SEP = 44, \quad \text{pseudo}R^2 = 86, \quad SME = 43, \)
\( SEP = 41, \quad \text{pseudo}R^2 = 87, \quad SME = 40, \)
\( SEP = 40, \quad \text{pseudo}R^2 = 88, \quad SME = 39, \)
\( SEP = 39, \quad \text{pseudo}R^2 = 88, \quad SME = 37, \)
\( SEP = 36, \quad \text{pseudo}R^2 = 90, \quad SME = 34, \)
\( SEP = 36, \quad \text{pseudo}R^2 = 90, \quad SME = 34, \) and
\( SEP = 33, \quad \text{pseudo}R^2 = 91, \quad SME = 31. \)

By Joseph P. Capesius and Verlin C. Stephens
StreamStats for Colorado

StreamStats Provide Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado

For the Plains Hydrologic Region it provide only:

- Peak Stream Flow Equations

It did not provide Regression Equations for:

- Minimum Stream Flow
- Maximum Stream Flow
- Annual and Monthly Mean Streamflow
- Flow Duration Curve

For other Four region it provided equations for all of the above
StreamStats Version 2 was released on January 7, 2010. In 2012 CO StreamStats had over 300,000 pageviews by CDOT, Federal Agencies, private sector, consultants, cities, counties and universities.

Colorado Pageview’s 2012 Total: 303,375
StreamStats Version 2 was released on January 7, 2010. StreamStats Version 3 was released on July 15, 2015.

- During the year consisting of April 1, 2015 to March 31, 2016, Colorado users had 5,874 StreamStats sessions
- Average CO use per workday was 23 people
- CO usage is 3-4 percent of national usage

StreamStats Version 4 was introduced on March 24, 2016. Following is the national usage through June 30:

- 6,203 basin delineations
- 2,903 basin characteristics computation, and
- 2,244 streamflow statistics estimates
StreamStats for Colorado Benefits

Following are benefits of StreamStats:

- Minimum self-training needed to learn StreamStats
- Can be accessed from anywhere and anytime where there is access to the internet
- If there is no internet, the Regression Equations
- It is free for everyone, CDOT, consultants, universities, students, cities, counties and towns
- The drainage basins. No matter how large or small can fit into 8.5 inch by 11 inch standard sheet size
- The delineated basins are in color and can be printed or sent by e-mail anywhere
In my over 45 years of work experience, I have used a few methods from simple Plainimeter to the advance WMS to delineate drainage basins.

I find out that StreamStats is the most efficient hydrological method to delineate drainage basins.

It delineates drainage basins in 5-10 minutes compared to 3-4 hours; sometimes 8 hours for larger basins.

Estimated cost savings of about $400 per bridge analysis.

The drainage basin developed by this method can be used for other Hydrological methods as well.
The September flooding along the Colorado's, Front Range from Colorado Springs to Fort Collins

- The flooding affected the following:
  - State highways: 486 lane miles of state highway, closed, damaged, or destroyed
  - Bridges: 120 bridges damaged and requiring repair
  - Right of Way: in places, creeks and rivers changed course, washing over and washing out highway approaches to bridges, while leaving the bridges undamaged
  - Culverts: several damaged or destroyed, filled with debris
StreamStats for Colorado Benefits

- CDOT Staff and Consultants used StreamStats for 243 On-System Bridges for Colorado Plan Of Action (POA) for Scour Critical Bridges and Bridges with Unknown Foundations
- CDOT Staff and Consultants would not have been able to meet the deadline for the 2013 flood recovery and opening the roads without the StreamStats application
The following Five research projects related to StreamStats put CDOT in a Nationwide leading status

- **2014** - Crest-Stage Gage Network Research Project. Installation of 10 Stream Gages for Plains (Eastern Colorado) Hydrological Region (1)
- **2015**
  - Paleo-Flood Studies Research Project for Plains Hydrologic Region (2)
  - Partial Basin Delineation Research Project for the entire state (3)
- **2016** - Additional Basin Characteristics added to StreamStats for the entire state (4)
- **2017** - Addition of Rational and Natural Conservation Service (formerly Soil Conservation Service) Hydrological Methods for the entire state (5)
Reasonable Standard Error of Prediction

Gauge Stations

Large Standard Error of Prediction

By Joseph P. Capesius and Verlin C. Stephens
In the Plains Hydrologic Region, the Standard Error of Prediction for Peak-Streamflow is approximately 300% more than the Mountain Region due to lack of active stream gages.

Additional streamflow data are needed to lower the error of prediction for the Plains Region peak-streamflow equations.

Many streams in Eastern Colorado are ephemeral, they flow only after rainfall.

Using pressure transducers at Crest-Stage Gages allows for measurement of continuous stage and calculation of continuous discharge via indirect methods.
2014 - CDOT and USGS funded the Eastern Colorado Crest-Stage Gage Network for installation of 10 Crest-Stage Gages for Eastern Colorado

More cost-effective compared to streamgage stations

Conventional Stream gages
- O&M cost = $16,000/site/year

Crest-Stage Gage Network
- O&M cost $8,000/site/year

Following the CDOT, in 2015, DOTs from 30 different states and the USGS cooperatively funded crest-stage gage networks.
A pressure transducer sits at the bottom of steel pipe which has slots to act like a well to mimic the stage in the channel.

Source: Anne Tillery
2015 - CDOT and USGS funded research for Plaeoflood studies for Eastern Colorado to improve the reliability of the regional-regression equations for Plains Hydrologic Region of Colorado.

- **Paleoflood study procedure:**
  - Visit streams in Plains Hydrologic Region.
  - Find stable sections along the streams and survey at least 2-4 cross sections.
  - Determine stream slope, Manning’s roughness values.
  - Calculate peak flows using water marks on the stream banks or in the trees.
  - Run flood frequencies analysis for all gage sites.
  - Update and calibrate the equation from the site inspection.
2- Paleoflood studies Research Project for Plains Hydrologic Region

Source: Bob Jarrett

Source: Bob Jarrett & John England
The current StreamStats is for natural uncontrolled streams in Colorado.

Colorado is a headwater state for many rivers and has many dams upstream from CDOT’s bridges and culverts.

There is a need to delineate partial basins located between the highway structures and the upstream control structures / dams.

StreamStats interface would require the user to edit the basin delineation to remove the area upstream of the reservoirs which needs skill and more time.
2015 - CDOT and USGS funded the *Partial Basin* research project for the entire state

- The partial basin research has enabled designers to estimate peak flows for the area upstream of road crossings and downstream of reservoirs
- A “*partial-basin*” tool was created to allow users to define up- and down-stream limits of basin
- The StreamStats interface is more robust and useful
- This research project is the first of its kind update for StreamStats in the country
3- Partial Basin Delineation Research Project for Colorado

- Delineated basin for SH 9 Bridge – 439 sqmi
- Need the area downstream from Dillon Reservoir for Bridge Hydraulic analysis
- StreamStats Check Upstream Regulation tool indicates that 76 percent of basin at SH9 is regulated by upstream dams (shaded orange area) – 334 sq. mi
### 4- Additional Basin Characteristics Research Project

<table>
<thead>
<tr>
<th>Year</th>
<th>Funders</th>
<th>Characteristics Added to StreamStats</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>CDOT and USGS</td>
<td>Additional Basin Characteristics</td>
</tr>
</tbody>
</table>

The additional characteristics will be added to the easy-to-use StreamStats interface:

- Basin centroid and basin outlet locations
- Minimum and maximum elevation (feet)
- Elevation at outlet (feet) and Perimeter of the basin (miles)
- Stream 10-85 slope and Longest flow path in basin
- Potential watershed storage
The additional characteristics inclusion within the StreamStats interface will provide tools for users to use the following additional Hydrology Methods:

1. Natural Resources Conservation Service (NRCS) Hydrological Method
2. Rational Method

One stop for Three Hydrological Methods
Questions?