# Streamflow Completion, Naturalized and Unimpaired Flows

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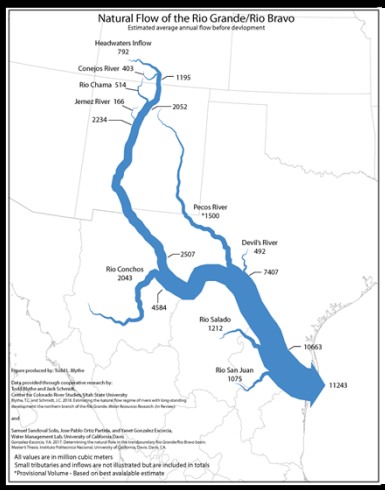
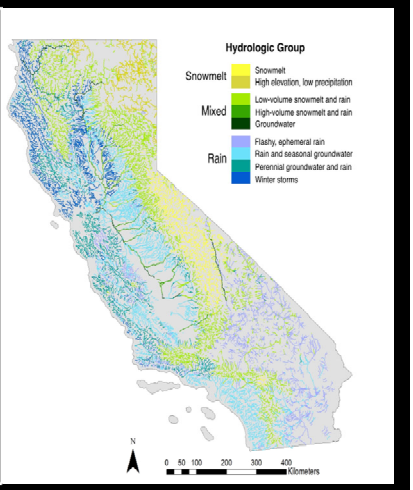
UCDAVIS WATER MANAGEMENT LAB

## Outline

UCDAVIS WATER MANAGEMENT LAB

- Data completion
- Observed flows
- Natural Flows
- Impaired flows
- Examples



# Hydrologic Foundation

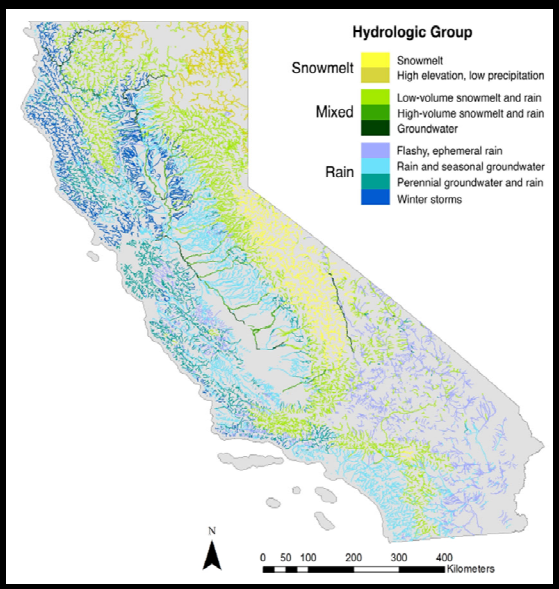
- Observed Data ($Q_t^{Impaired}$, $Q_t^{Observed}$): CDEC, GAGESII, USGS. Flow + Type of Alteration
- Unimpaired Data ($Q_t^{Unimpaired}$)

# Natural Streamflow Classification

**Catchment Properties**

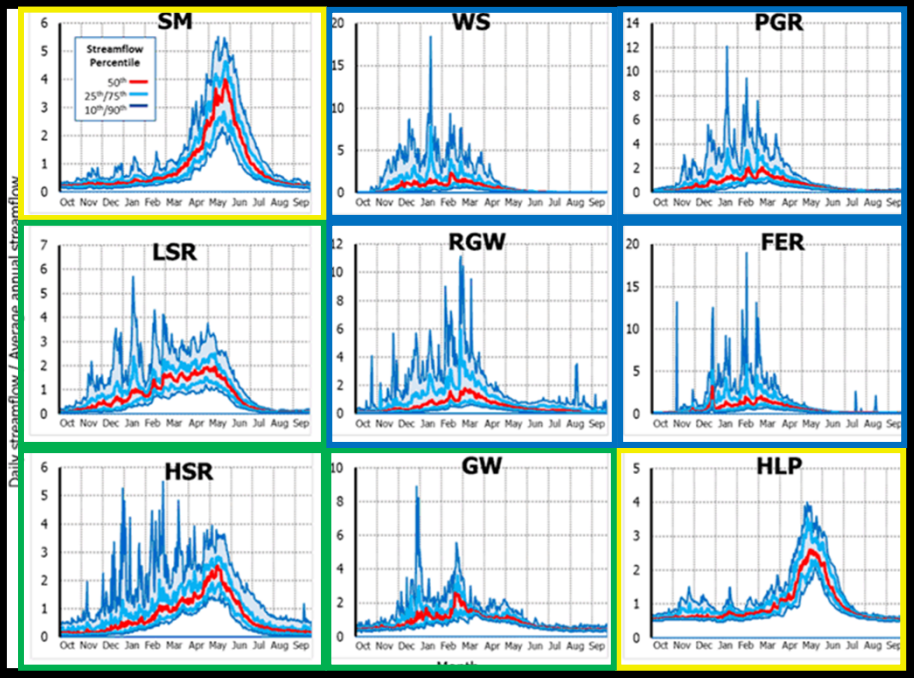
**Climate Patterns**

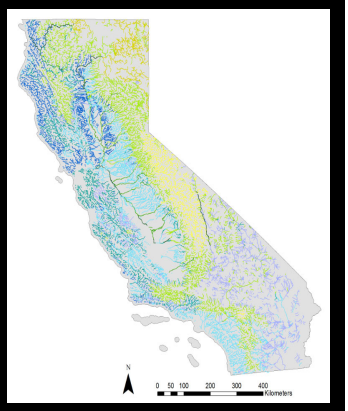
**Geology and Soils**




*eflows.ucdavis.edu*

Lane, B.A., Sandoval-Solis, S., Stein, E.D., Yarnell, S.H., Pasternack, G.B. and Dahlke, H.E. (2018). Beyond metrics? The role of hydrologic baseline archetypes in environmental water management. Journal of Environmental Management.



(**SM**) Snowmelt
(**HSR**) High-volume snowmelt and rain
(**LSR**) Low-volume snowmelt and rain
(**RSG**) Rain and seasonal groundwater
(**WS**) Winter storms
(**GW**) Groundwater
(**PGR**) Perennial groundwater and rain
(**FER**) Flashy, ephemeral rain
(**HLP**) High elevation, low precipitation

# Hydrologic Foundation

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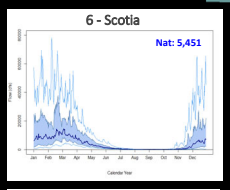
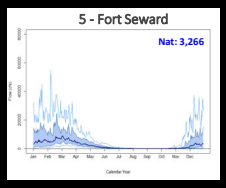
- Impaired Data ($Q_t^{Unimpaired}$):

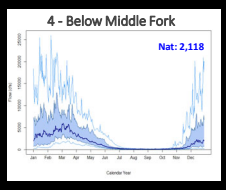
Mass Balance → Mass Balance $\Delta S_t = I_t - O_t$ → $Q_t^{Upstream}$, $Return_t$, $Import_t$, $Gains_t$, $Q_t^{Downstream}$, $Diver_t$, $Export_t$, $Losses_t$ → **Naturalized Flow** $Q_t^{Unimpaired} \rightarrow IF_t = O_t - I_t$

# Natural Flows
## Eel River Basin

Ph.D. Samuel Sandoval Solis
M.S. Laura Elisa Garza Díaz

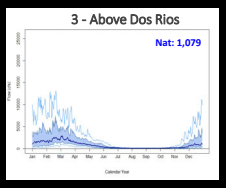


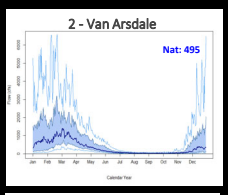



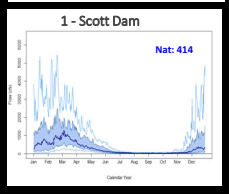





Average Volume in Thousand Acre-Ft / Year




# Natural Flows
## Eel River Basin

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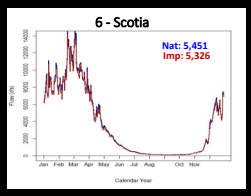
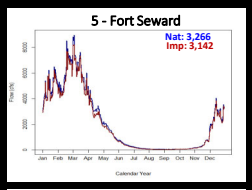
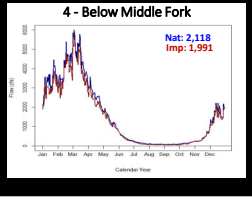
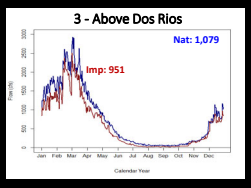


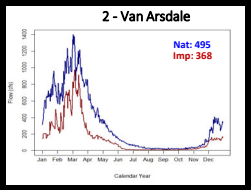



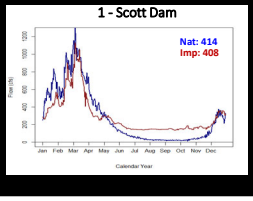





Average Volume in Thousand Acre-Ft / Year

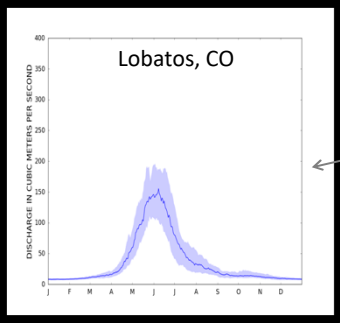


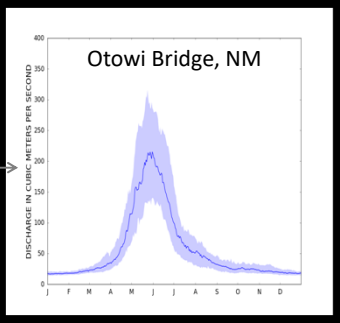



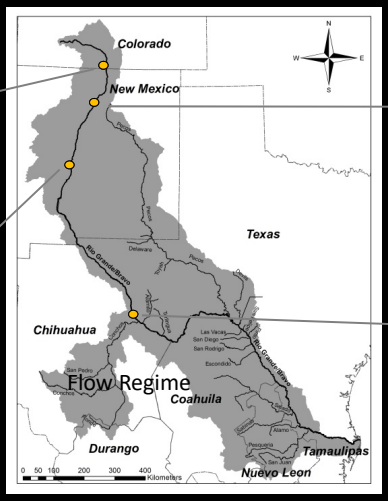



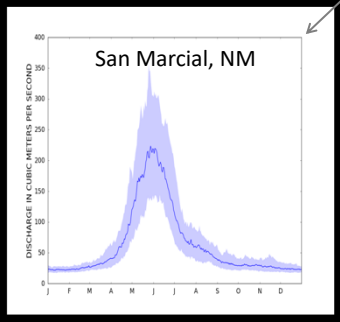
# Natural hydrology : Northern Branch

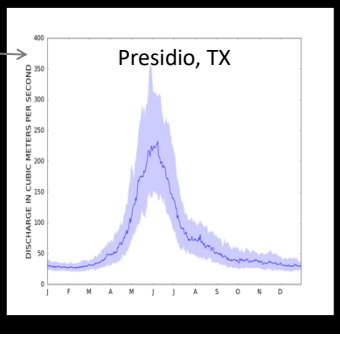
*Blythe, T., and Schmidt, J. (2017). Estimating the natural flow regime of rivers with long-standing development: the northern branch of the Rio Grande. J. Water Resources Research. Submitted*



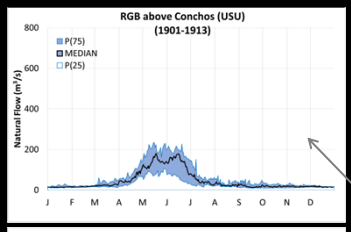



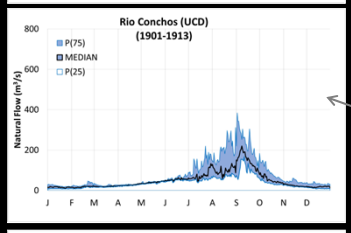



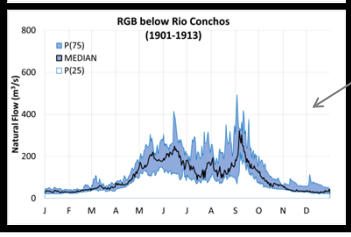



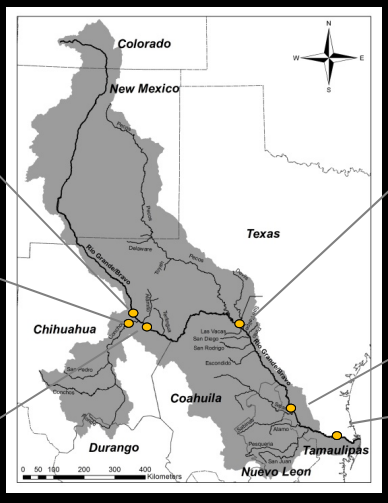

# Natural hydrology : Southern Branch

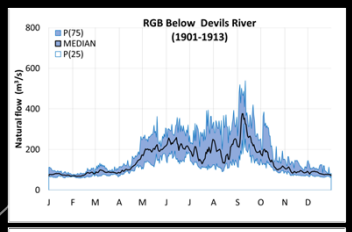
*Gonzalez-Escorcia, Y.A. (2017). Determining the Natural Flow in the Transboundary Rio grande/Bravo Basin. Master Thesis. Instituto Politecnico Nacional, University of California, Davis. Davis, CA.*

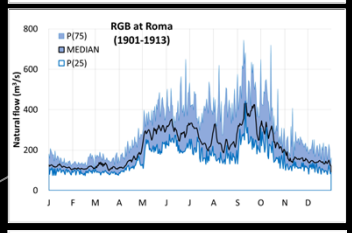


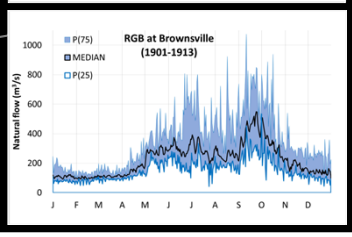



# Hydrologic Foundation

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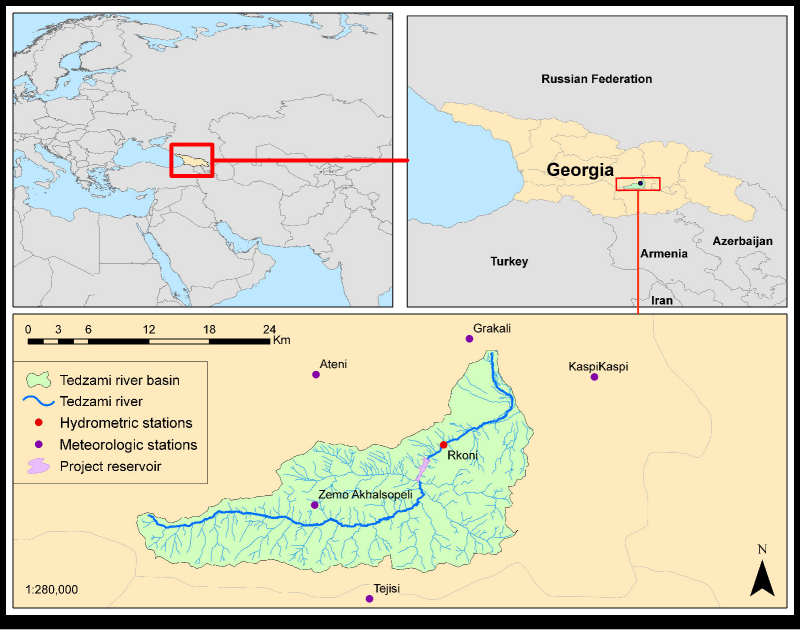
- Impaired Data ($Q_t^{Unimpaired}$):

Mass Balance → Mass Balance $\Delta S_t = I_t - O_t$ → $Q_t^{Upstream}$, $Return_t$, $Import_t$, $Gains_t$, $Q_t^{Downstream}$, $Diver_t$, $Export_t$, $Losses_t$ → **Naturalized Flow** $Q_t^{Unimpaired} \rightarrow IF_t = O_t - I_t$

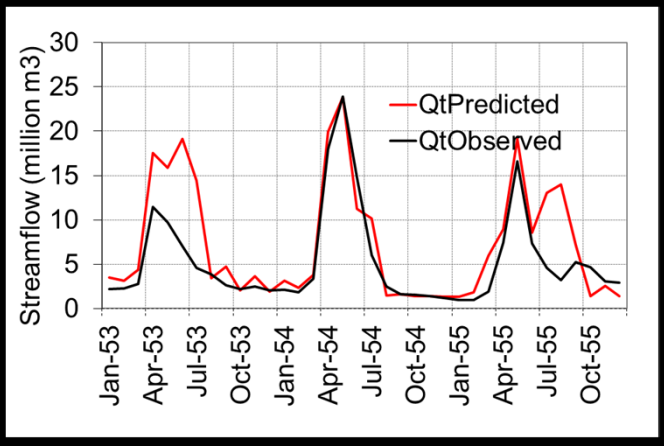
Hydrologic Modeling → Rainfall-Runoff Model → Climate: P, T, W, R, Land Use: Areas, Soil Charac., Crops Kc, Runoff: $Q_t^{Impaired}$, Calib., Valid. Change to Nat. Landscape = $Q_t^{Unimpaired}$ → **Unimpaired Flow** $Q_t^{Unimpaired}$

# Tedzami River



# Tedzami River

## Calibration (Jan/1953 – Dec/1955)




| | |
|---|---|
| $R^2$ | **0.706** |
| Index of Agreement (Willmott) | **0.504** |
| Coefficient of Efficiency (Nash) | **0.629** |

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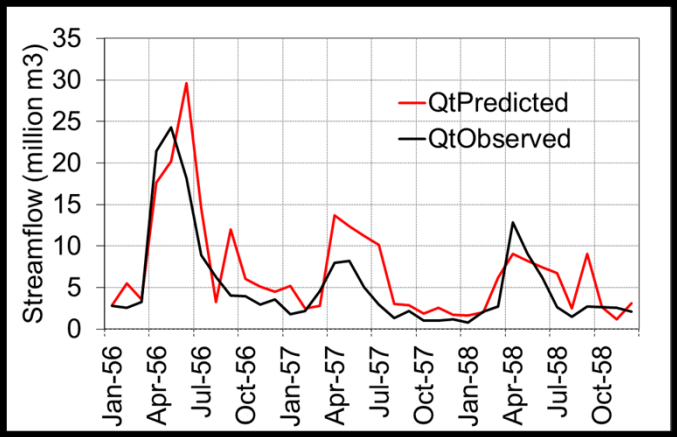
# Tedzami River

## Validation (Jan/1956 – Dec/1958)




| | |
|---|---|
| $R^2$ | **0.694** |
| Index of Agreement (Willmott) | **0.737** |
| Coefficient of Efficiency (Nash) | **0.644** |

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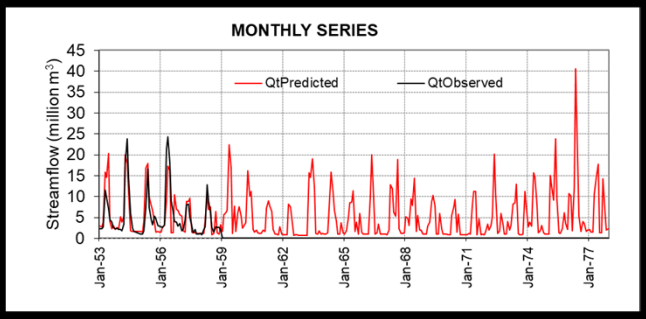
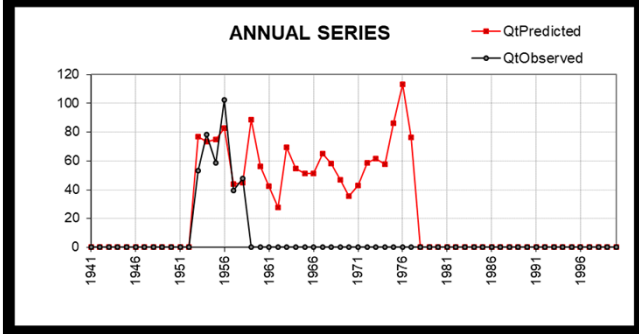
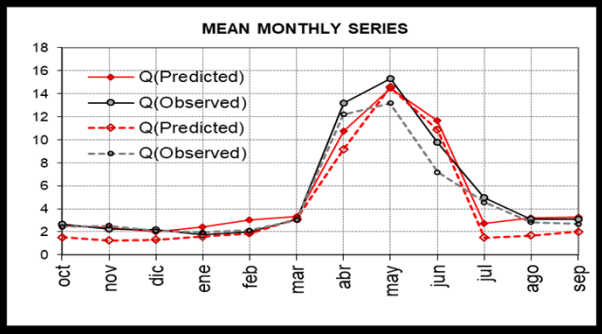
# Tedzami River

Prediction 30 Years
(Jan/1948 – Dec/1977)

**Predict: (Jan/1948 – Dec/1977)**




# Hydrologic Foundation

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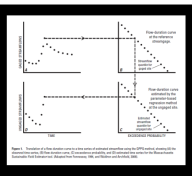
Hydrologic Modeling → Rainfall-Runoff Model → Climate: P, T, W, R, Land Use: Areas, Soil Charac., Crops Kc, Runoff: $Q_t^{Impaired}$, Calib., Valid. Change to Nat. Landscape = $Q_t^{Unimpaired}$ → Unimpaired Flow $Q_t^{Unimpaired}$

Percentile Method → QPPQ Method →  → **Unimpaired or Nat. Flow** $Q_t^{Unimpaired\ or\ Nat.}$

# QPPQ Massachusetts

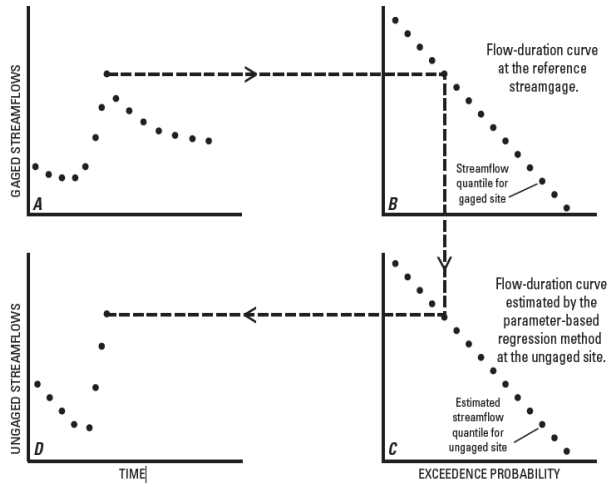
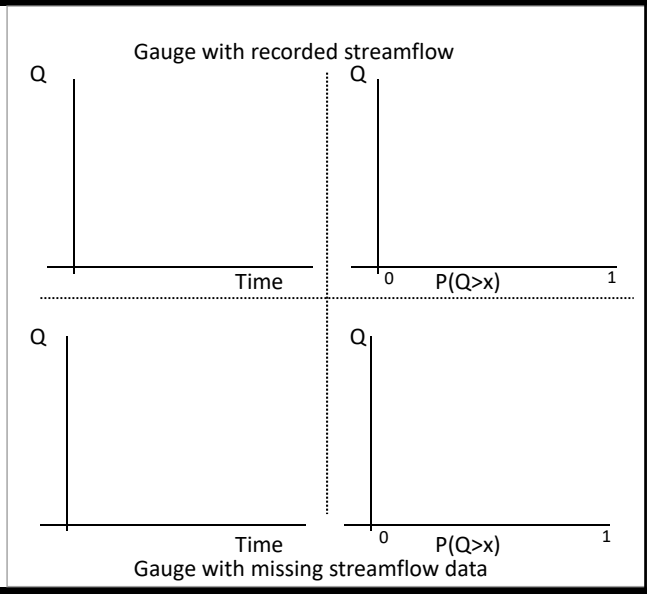



**Figure 1.** Translation of a flow-duration curve to a time series of estimated streamflow using the QPPQ method, showing (A) the observed time series, (B) flow-duration curve, (C) exceedence probability, and (D) estimated time series for the Massachusetts Sustainable-Yield Estimator tool. (Adapted from Fennessey, 1994, and Waldron and Archfield, 2006).




# QPPQ Massachusetts

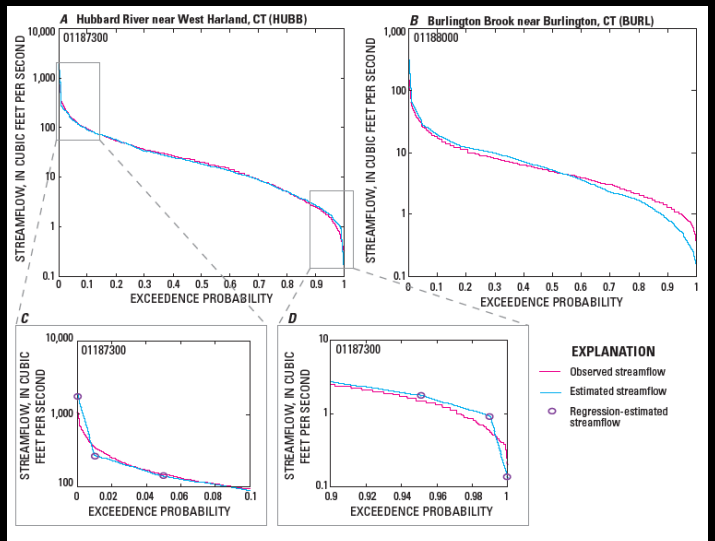



**Figure 8.** Observed and estimated streamflow quantiles by exceedence probability for U.S. Geological Survey streamgages (A, C, and D) 01187300, Hubbard River near West Harland, CT (HUBB) and (B) 01188000, Burlington Brook near Burlington, CT (BURL), southern New England study area.

# Tedzami River

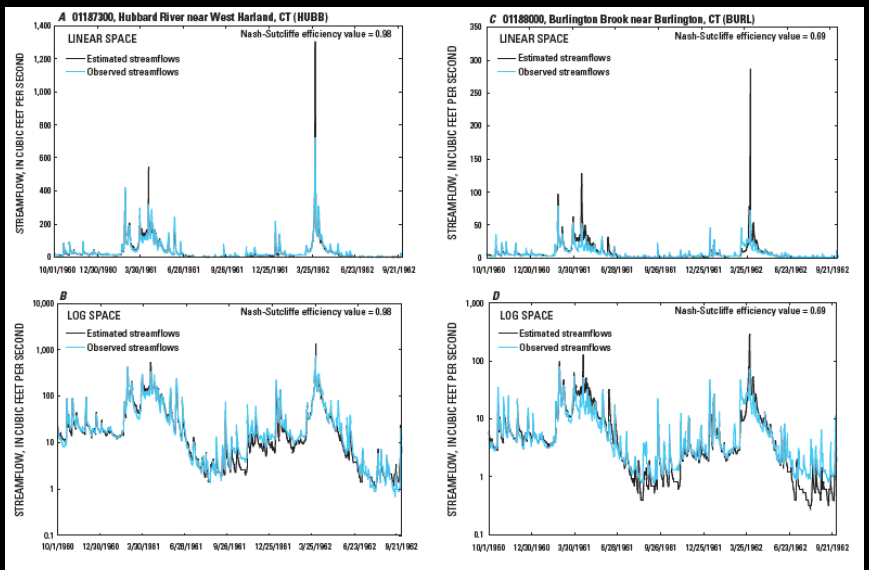



**Figure 9.** Observed and estimated streamflows for U.S. Geological Survey streamgages (A-B) 01187300, Hubbard River near West Harland, CT (HUBB) and (C-D) 01188000, Burlington Brook near Burlington, CT (BURL) showing the best (A-B) and worst (C-D) agreement between unregulated observed and estimated mean, daily streamflow, in linear space and log space, southern New England study area, 1960–62.

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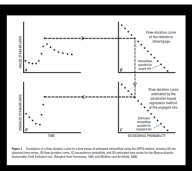
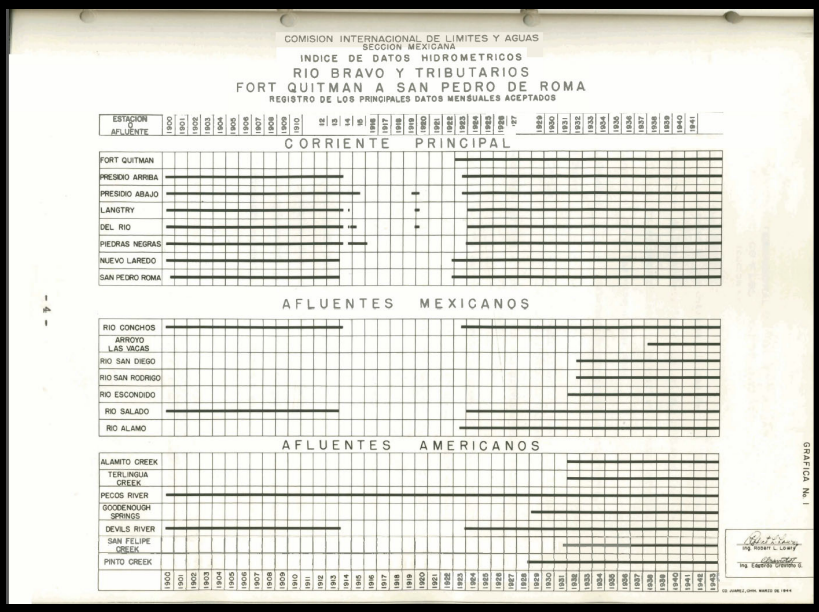
**Percentile Method** → QPPQ Method →  → **Unimpaired or Nat. Flow** $Q_t^{Unimpaired\ or\ Nat.}$

**Hydraulic Routing** → Muskingum →  → **Unimpaired or Nat. Flow** $Q_t^{Unimpaired\ or\ Nat.}$

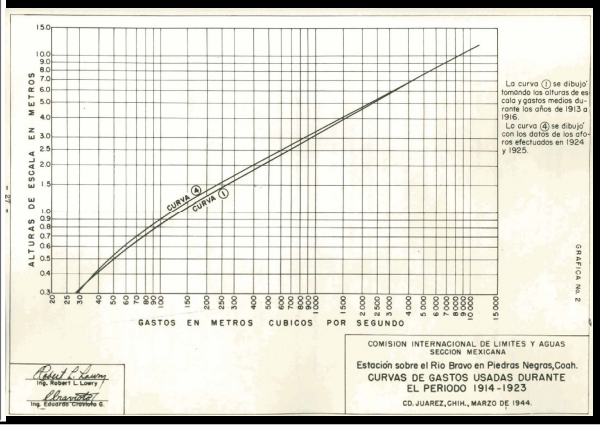
**Regression Analysis** → **Unimpaired or Nat. Flow** $Q_t^{Unimpaired\ or\ Nat.}$

# Data Analysis: Data Sources

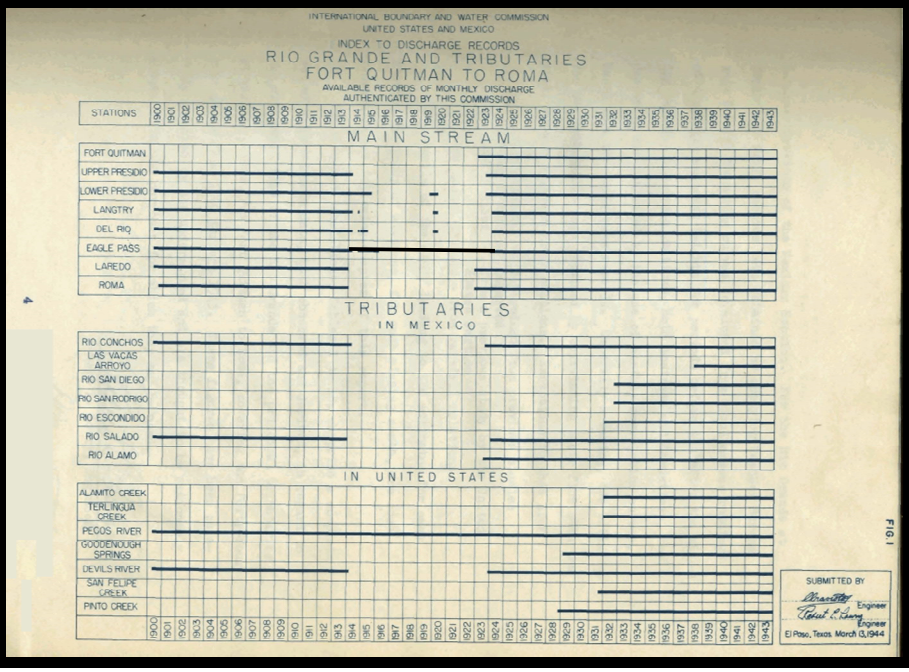



# Data Analysis: Estimating Missing Data


- Gage Height at Eagle Pass but not discharge
- Missing data for 2 years
- Using Laredo to fill missing data at Eagle Pass

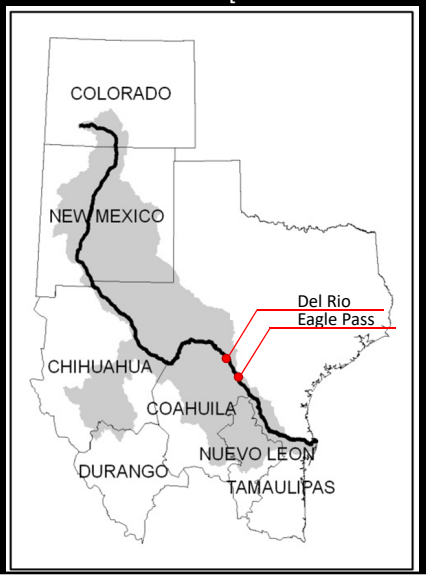


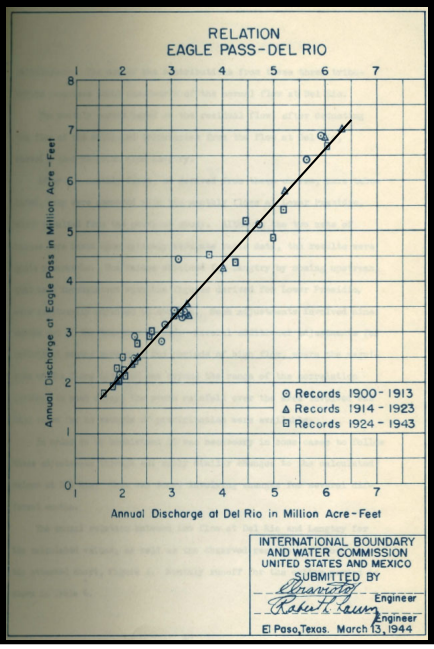
# Data Sources



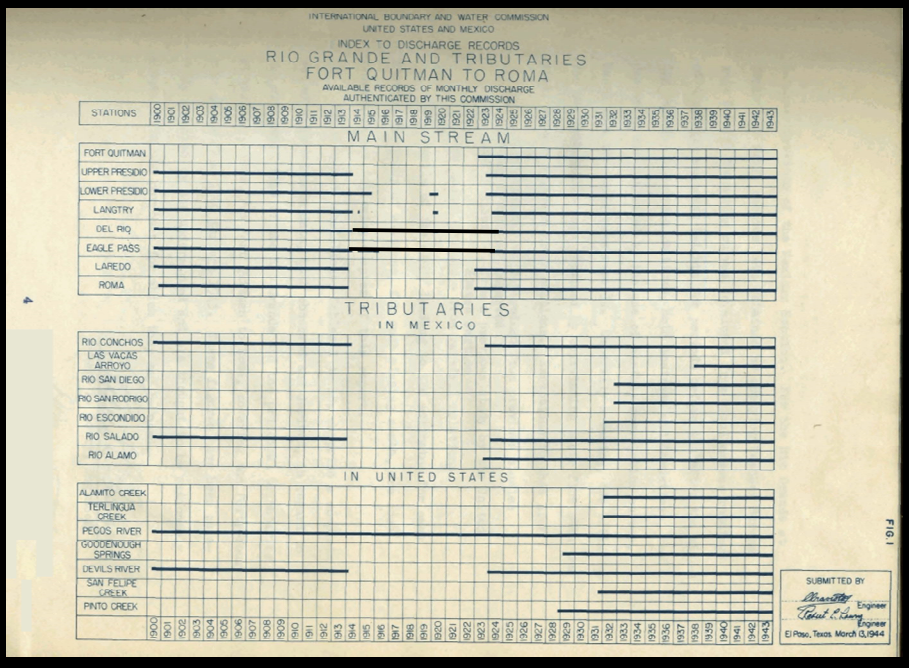

# Data Analysis: Estimating Missing Data

- Determined the relation between Eagle Pass and Del Rio [for each month!!!]



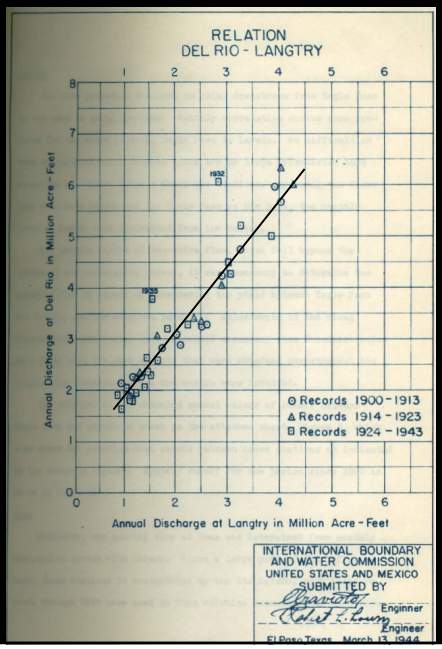



# Data Sources

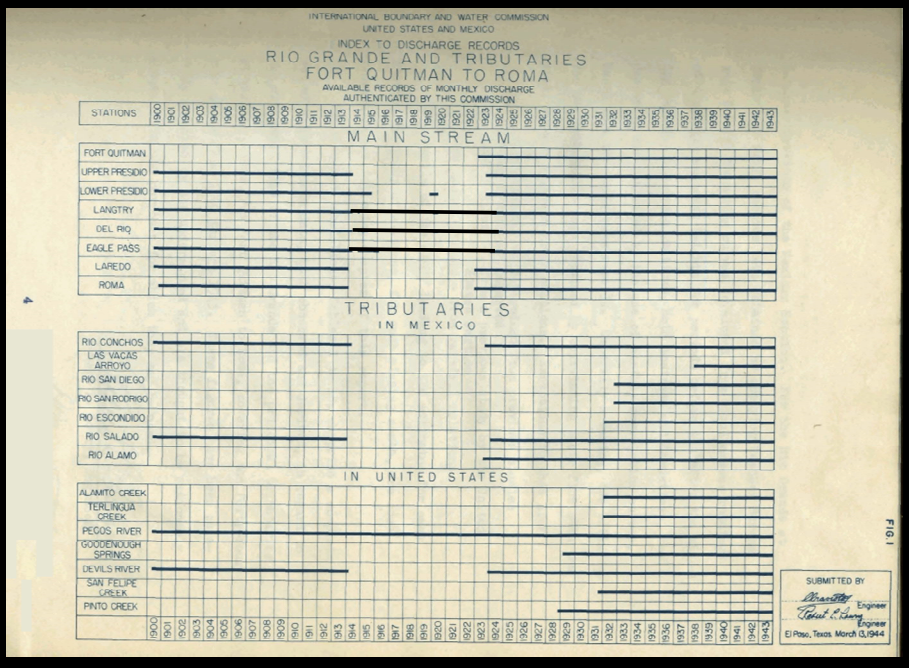



# Data Analysis: Estimating Missing Data

- Determined the relation between Eagle Pass and Del Rio [for each month!!!]

# Data Sources


INTERNATIONAL BOUNDARY AND WATER COMMISSION
UNITED STATES AND MEXICO
INDEX TO DISCHARGE RECORDS
RIO GRANDE AND TRIBUTARIES
FORT QUITMAN TO ROMA
AVAILABLE RECORDS OF MONTHLY DISCHARGE
AUTHENTICATED BY THIS COMMISSION

STATIONS

MAIN STREAM
FORT QUITMAN
UPPER PRESIDIO
LOWER PRESIDIO
LANGTRY
DEL RIO
EAGLE PASS
LAREDO
ROMA

TRIBUTARIES
IN MEXICO
RIO CONCHOS
LAS VACAS ARROYO
RIO SAN DIEGO
RIO SAN RODRIGO
RIO ESCONDIDO
RIO SALADO
RIO ALAMO

IN UNITED STATES
ALAMITO CREEK
TERLINGUA CREEK
PECOS RIVER
GOODENOUGH SPRINGS
DEVILS RIVER
SAN FELIPE CREEK
PINTO CREEK

1900 1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943

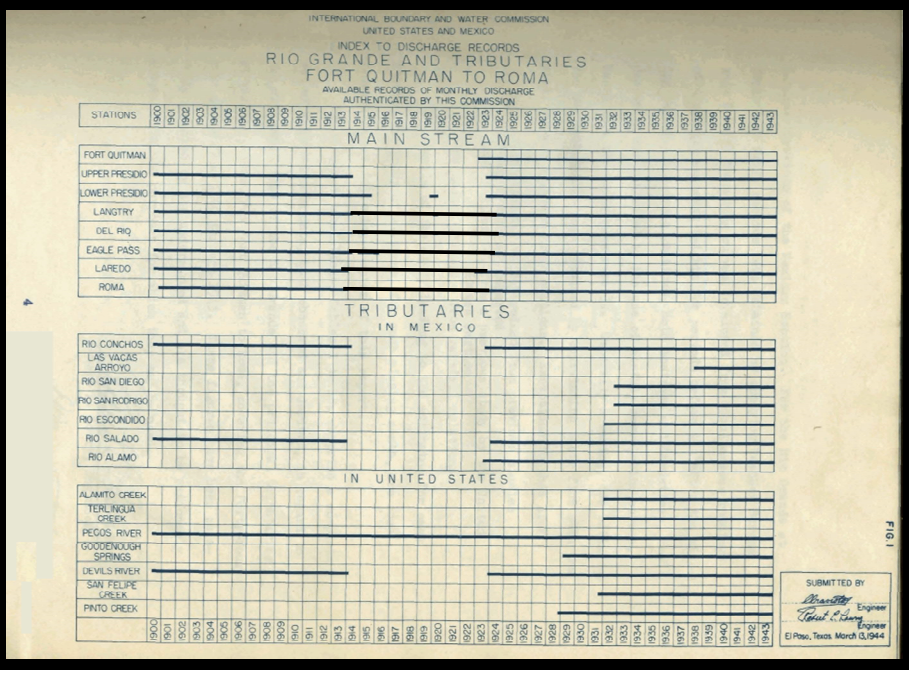
FIG 1

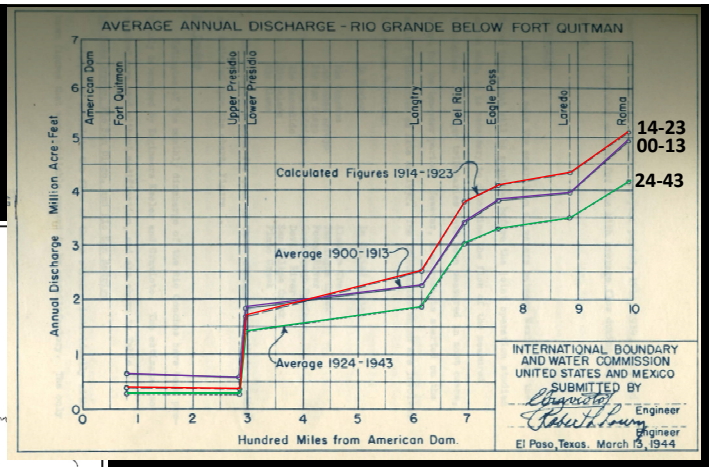
SUBMITTED BY
Engineer
Engineer
El Paso, Texas, March 13, 1944

# Data Analysis: Estimating Missing Data

- Eagle Pass – Del Rio
- Del Rio – Langtry
- Eagle Pass – Laredo
- Laredo - Roma

# Data Sources





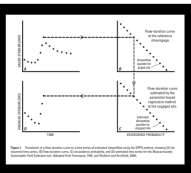
# Estimating Missing Data: Does it make sense?

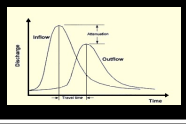
# Hydrologic Foundation

- Impaired Data ($Q_t^{Impaired}$, $Q_t^{Observed}$): CDEC, GAGESII, USGS. Flow + Type of Alteration
- Impaired Data ($Q_t^{Unimpaired}$):

**Mass Balance** → Mass Balance $\Delta S_t = I_t - O_t$ → $Q_t^{Upstream}$, $Return_t$, $Import_t$, $Gains_t$, $Q_t^{Downstream}$, $Diver_t$, $Export_t$, $Losses_t$ → **Naturalized Flow** $Q_t^{Naturalized} \rightarrow IF_t = O_t - I_t$

**Hydrologic Modeling** → Rainfall-Runoff Model → Climate: P, T, W, R, Land Use: Areas, Soil Charac., Crops Kc, Runoff: $Q_t^{Impaired}$, Calib., Valid. Change to Nat. Landscape = $Q_t^{Unimpaired}$ → **Unimpaired Flow** $Q_t^{Unimpaired}$

**Percentile Method** → QPPQ Method →  → **Unimpaired or Nat. Flow** $Q_t^{Unimpaired\ or\ Nat.}$

**Hydraulic Routing** → Muskingum → 

→ **Unimpaired or Nat. Flow** $Q_t^{Unimpaired\ or\ Nat.}$

**Regression Analysis** → **Unimpaired or Nat. Flow** $Q_t^{Unimpaired\ or\ Nat.}$

*Thank you*

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University of California
Agriculture and Natural Resources

UCDAVIS WATER MANAGEMENT LAB