Sources of streamflow and potential climate warming effects on streamflow regime in the Merced River, Sierra Nevada, California

Fengjing Liu, Martha H. Conklin, Roger C. Bales, Glenn Shaw
University of California, Merced, CA

Mark E. Conrad
Lawrence Berkeley National Laboratory, Berkeley, CA
Why do we study this?

Studies have shown that

- Mountain snow is declining in the West [e.g., Mote et al. 2005];
- Snowmelt becomes earlier [e.g., Cayan et al., 2001];
- Precipitation is shifting to more rain than snow [e.g., Knowles et al. 2006];
- The peak of streamflow is also shifting toward early spring & winter [e.g., Dettinger and Cayan, 1995; Barnett et al., 2005; Stewart et al., 2005];

What are effects of these changes on streamflow regime in snow-dominated catchments, particularly during the low flow season?
Research Objectives

• Understanding sources and controls of streamflow in the upper Merced River;
• Assessing impact of early onset of snowmelt and decline in snow water equivalent (SWE) on streamflow regime, particularly during the low flow season.
Method: 3-Component Mixing Model (Using discharge fractions)

- Two Conservative Tracers
- Mass Balance Equations for Water and Tracers

Simultaneous Equations

\[ f_1 + f_2 + f_3 = 1 \]
\[ C_1^1 f_1 + C_2^1 f_2 + C_3^1 f_3 = C_t^1 \]
\[ C_1^2 f_1 + C_2^2 f_2 + C_3^2 f_3 = C_t^2 \]

Solutions

\[ f_1 = \frac{(C_1^1 - C_3^1)(C_2^2 - C_3^2) - (C_1^1 - C_3^1)(C_2^2 - C_3^2)}{(C_1^1 - C_3^1)(C_2^2 - C_3^2) - (C_1^1 - C_3^1)(C_2^1 - C_3^1)} \]
\[ f_2 = \frac{C_1^1 - C_3^1}{C_2^1 - C_3^1} \frac{1 - f_1}{C_2^1 - C_3^1} \]
\[ f_3 = 1 - f_1 - f_2 \]

f - Discharge Fraction
C - Tracer Concentration
Subscripts - # Components
Superscripts - # Tracers
Hydrology & Climate in 2006 & 2007

Happy Isles

Q (m$^3$/s$^{-1}$)

Briceburg

Q (m$^3$/s$^{-1}$)

Gin Flat

Precipitation (mm)

J F M A M J J A S O N D
Specific Conductivity & Deuterium

- **Happy Isles**
  - 2006 (blue)
  - 2007 (pink)

- **Pohono Bridge**
  - 2006 (blue)
  - 2007 (pink)

- **Briceburg**
  - 2006 (blue)
  - 2007 (pink)
Mixing

Diagrams

BB – Briceburg
HI – Happy Isles
PB – Pohono Bridge
YF – Yosemite Falls
BVF – Bridalveil Falls
CAS – Cascade Falls
TN – Tenaya Creek
CC – Crane Creek
SF140 – South Fork at Highway 140
SWC – Sweetwater Creek
BC – Beer Creek
FS – Fern Spring
HISP – Happy Isles Spring
THSP – Trail Head Spring
HS – Harding Spring
DF – Drinking Fountain
AR – Arch Rock Well
HM – Hodgon Meadow Well
CF – Crane Flat Well
VW’s – Valley Wells
EPW’s – El Portal Wells
Why was subsurface flow in 2007 about the same as in 2006 and even higher at higher elevations?
Samples collected during the snowmelt period in 2006 violated the assumption, meaning that the contribution of overland flow was significant from the drainage area b/w Happy Isles and Pohono Bridge.

Get right results with right reasons

Mixing model was re-constructed for Pohono Bridge (and Briceburg as well) by replacing snowmelt endmember by Happy Isles streamflow. The modeled discharge by this new model was compared against the measurements by USGS. Doing so, we assume that overland flow from the area controlled b/w Happy Isles & Pohono Bridge was zero.

However, it does not work for the snowmelt period in 2006!
Concentration of Cl\(^-\) was up to 280 μeq L\(^{-1}\) at baseflow from 1968 to 1994 at Happy Isles [Clow, HP, 1996] & 360 μeq L\(^{-1}\) on October 22, 2006 at Tenaya Creek [this study].
Decay of Overland Flow & Shallow Subsurface Flow During the Recession

\[ y = 99e^{-0.0419(x-139)} \quad R^2 = 0.89 \]
\[ y = 33.7e^{-0.0581(x-121)} \quad R^2 = 0.97 \]

\[ y = 150e^{-0.0475(x-139)} \quad R^2 = 0.92 \]
\[ y = 26.6e^{-0.058(x-121)} \quad R^2 = 0.90 \]

\[ y = 228e^{-0.0437(x-139)} \quad R^2 = 0.93 \]
\[ y = 47.3e^{-0.0592(x-121)} \quad R^2 = 0.98 \]
Contributions of overland flow & shallow subsurface flow on October 1 if snowmelt starts earlier with the 2006 scenario.
Summaries

• Streamflow in the upper Merced River is primarily composed of overland flow, shallow subsurface flow and groundwater, even during the low flow season from August to October (baseflow ≠ groundwater).

• Snow water equivalent (SWE) in spring significantly affects the contribution of overland flow, but does not necessarily affect that of shallow subsurface flow, particularly at higher elevations.

• Precipitation pattern in spring appears to exert a major control on shallow subsurface flow.

• Earlier onset of snowmelt & decrease in spring snow could significantly reduce streamflow in the low flow season, particularly at higher elevations.
Acknowledgements

• Authors are grateful to the research permission that Yosemite National Park admitted and her staff’s assistance on logistic and sample collection.
• Liying Zhao at UCM completed chemical analysis.
• Denise Melendez at UCM completed isotopic analysis.
• This study is funded by California Energy Commission through PIER (CIEE AWARD No. MEX-06-07, WA No. MR-043).
References

Thank you!

Any questions?