The Hydrology of Climate Change on Battle Creek and the North Fork Feather River
LVNP Headquarter’s, Mineral, CA
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Bumpass Hell Parking Lot - May 6, 2009
Date: May 06, 2009
Location: Bumpass Hell
Photographer: Todd Hisaichi
Description: Mist shrouds the Bumpass Hell parking lot with 6 feet of snow along the edges.
Historical Sources of Runoff for PG&E's Hydroelectric System

- Rainfall: 25%
- Snowpack: 37%
- Groundwater: 38%
The PG&E Hydroelectric System

- 68 Powerhouses; 110 Generating Units; Total Generation Capacity of 3,896 MW
- Approximately 2.3 Million acre-feet of Reservoir Capacity
- 99 Reservoirs, 174 Dams
- 184 Miles of Canals; 44 Miles of Flumes; 135 Miles of Tunnels; 19 Miles of Pipe
- 140,000 Acres of Land
- 26 FERC Licenses; 3 Unlicensed Projects
- Hydroelectric System Extends 500 Miles from Mt Shasta to Bakersfield
- Provides about Five Percent of California’s Electric Energy
The Seasonal Ground Water Contribution To PG&E’s Hydro Resource Mix

Northern California’s Volcanic Rock Aquifers

The Northern California volcanic-rock aquifers consist of volcanic-rocks that yield water primarily from fractures and locally from intergranular spaces in porous tuffs.
Layers of Fractured Volcanics
Section showing the broken end of the Sierra Nevada buried beneath young volcanic rocks just north of Lake Almanor. Sediments beneath the volcanics were deposited when the area was flooded by sea water after separation of the Klamaths and Sierra Nevada.

Gentle Lava Flow Slope for Subsurface water - see attached Area Elevation Curve for Lk Almanor Sub Basin

Likely Area for most of Aquifer Upwelling

The Sierra Block once again shows itself 60 miles to the west in the granite peaks of the Klamath Mountains.

Impervious block to subsurface gravity flow.
Climate Change

- Warming in recent Years
- Higher Snow Lines
- Possibly Periodic Cycles
- ENSO
- More Floods in recent Years
- Less Low Elevation Snow since 1950
For the 5,100 Feet Elevation in the northern Sierra - A possible change in the snowpack appears to have possibly occurred about the mid-late 1970's

Warner Creek Snow Course #59 @ 5,100' on No Fk Feather River
The 1932-2002 April 1 Snow Water Equivalent/Content Record

Between 1976-2002 (27 yrs) 4/1 snowpack lost about 99 inches of water compared with 1932-1975 (44 yrs) period. This is equivalent to losing 22 percent of the April 1 Snowpack from this elevation (5,100')
January w/35.9% decrease is the Month w/largest decrease

24% Trend Loss since 1950

<table>
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<th>Median</th>
<th>Average</th>
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<tbody>
<tr>
<td>1949-1978</td>
<td>141.8</td>
<td>142.9</td>
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<tr>
<td>1979-2008</td>
<td>104.3</td>
<td>104.0</td>
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Change: 0.26, 0.28
January with 27.1% decrease is the Month with the largest decrease.

24% Trend Loss since 1950
Increasing Magnitude in 15-Year Variance Oscillation for Annual Runoff for successive wet/dry Periods affects Runoff forecasting, planning, and commitments.

East Br of NoFk Feather River @ NF-51 Water Yr Unimpaired Runoff

Centered 5-Yr Moving Ave Smoother Applied to:

"WY Total minus the Historic 52-yr Period Mean Divided by Period Std Dev."

Water Year

G Freeman, Water Management, SP&El 4-24-2002
East Branch of No Fork Feather River - March FNF
1950-2009 moving average of 30-year March Mean Runoff starting 1964

Trend Increase of 38.5% in the 30-Yr Mean Moving Average of the March Snowmelt Runoff

\[ y = 0.8709x + 103.25 \]

\[ R^2 = 0.8379 \]

March Runoff increasing at an overall rate 871 AF/Year
East Branch of No Fk Feather River, CA FNF
1935-2009 moving average of 30-yr** April-June mean Roff starting 1964

Overall trend indicates a 3,005 Ac Ft annual decrease in spring (April through June) snowmelt runoff.

Trend Decrease of 40% in the 30-Yr Mean Moving Average of the Apr-June Snowmelt Runoff

** Record started in 1950. 30-yr mean prior to 1964 based on available data.

\[ y = -3.0054x + 350.45 \]

\[ R^2 = 0.9363 \]
Note: the 13-15 yr decadal periodicity signal revealing itself as wet/dry pulsing

Next Likely Wet Period
2010-2014

Watershed Area is 1,025 Sq Mi to Confluence w/North Fk Feather River nr Rich Bar; Ave annual Precip =~36.8”; 73.5% of Watershed is below elevation 6,000’. Annual Runoff Recovery Rate =~37-40%
Battle Creek BLW Coleman Fish Hatchery

Approximate 14-Wet/Dry Year Return Period

Water Year

2012 = next likely wetness Peak

GFreeman, PG&E, Water Management    July 14, 2009
Battle Creek BLW Coleman Fish Hatchery 1941-2008 Water Year total flow includes the charted Aquifer Outflow Component.

1941-2008 Average WY/Aquifer Outflow = 50%
1941-2008 Median WY/Aquifer Outflow = 49%

GFreeman, PG&E Water Management  June 10, 2009
There has been a 15% increase in Aquifer Outflow of the Springs for the more recent Period.
Volta PH Water Year Precipitation - Battle Creek 1941-2009

-3% Tended Decrease in Precipitation
Mineral (MNR)-NWS-Observer; Tehama Co, Elev 4,875'  
1928-2009 Moving Average of 30-Yr WY Mean Precip starting 1957

Trend Increase of 9.8% in the 30-Yr Mean Moving Average of the Water Year Precipitation for the 1928-2009 Period

\[ y = 0.0954x + 51.674 \]
\[ R^2 = 0.748 \]
Battle Creek Water Year Aquifer Outflow of Springs
3-YR Moving Average


1,000's of Acre-Feet: 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270

Graph by Freeman, PG&E Water Management, June 10, 2009
Median Elevation of Basin =~ 4,300'
Battle Creek Watershed
(357 Sq Mi @ USGS 11376550 BLW Coleman Fish Hatchery)
Adiabatic Cooling with Increased Precipitation in Recent Years

ISOHYETAL MAP
S.E. Rantz, USGS 1969
Using the 1969 isohyetal map compiled by SE Rantz, USGS, compilation for basin mean precipitation = 48.33”

From USGS Surface Water Records for USGS #11376550 Battle Creek BLW Coleman Fish Hatchery, the 1962 through 2004 Ave Water Year Runoff is 368,500 Acre Feet

368,500 Ac Ft Annual Roff/(357 Sq Mi*53.333*48.33”Annual Precip Basin Ave) = 40% runoff Recovery Rate; 553,000 Ac Ft going to evapotranspiration! ....and likely groundwater leakage from basin!! (I suspect that approx. 250 cfs year-round subsurface flow entering Sacramento R. and/or recharging Sac groundwater basin)

Average Historical Water Year Aquifer Outflow of the springs accounts for 50% of flow BLW Coleman. This helps buffer the effects of successive dry years. During a very dry year such as 1977, aquifer outflow assumed an 80% of total Water Year runoff proportion. This is likely very important to maintaining cool/cold water temperatures.

This year Water Year runoff is forecasted to be approx. 198 TAF or only 54% of historical 1962-2004 average. Aquifer outflow from springs is forecast at 70% of the Total Water Year runoff, contributing approximately 138 TAF.
Battle Creek BLW Coleman Fish Hatchery (USGS #11376550)

1941-2009 (69-Yrs) Likelihood for Equaling or Exceeding Water Year Flow

Average Historical Runoff (1962-2004) = 368.5 TAF

Likelihood for Exceeding or Equaling Water Year Flow

This Year at only 54% of the Historical Average is the 3rd lowest Flow in past 69 Yrs
• PG&E’s Helen Lake Cosmic Gamma Sensor -8,250’ Elevation

• Primarily utilized for Monitoring Climate Change & Runoff Forecasting for both Battle Creek and North Fork Feather River

• Highest Automated snow sensor in CA north of the American River

• This site receives over 90” of Precipitation/Year

• Deepest snowcourse in the State.

• Available on CA DWR’s California Data Exchange Center (CDEC)

http://cdec.water.ca.gov/cgi-progs/queryF?s=llp
Snow Water Equivalent** for Selected Sensor Sites
in North Fork Feather River Basin - 2008

**From CDEC Revised Sensor Snow Water Equivalent

GFreeman, Water Management, PG&E July 1, 2008