CLIMATE CHANGE AND THE CHANGING WATER BALANCE FOR CALIFORNIA'S NORTH FORK FEATHER RIVER

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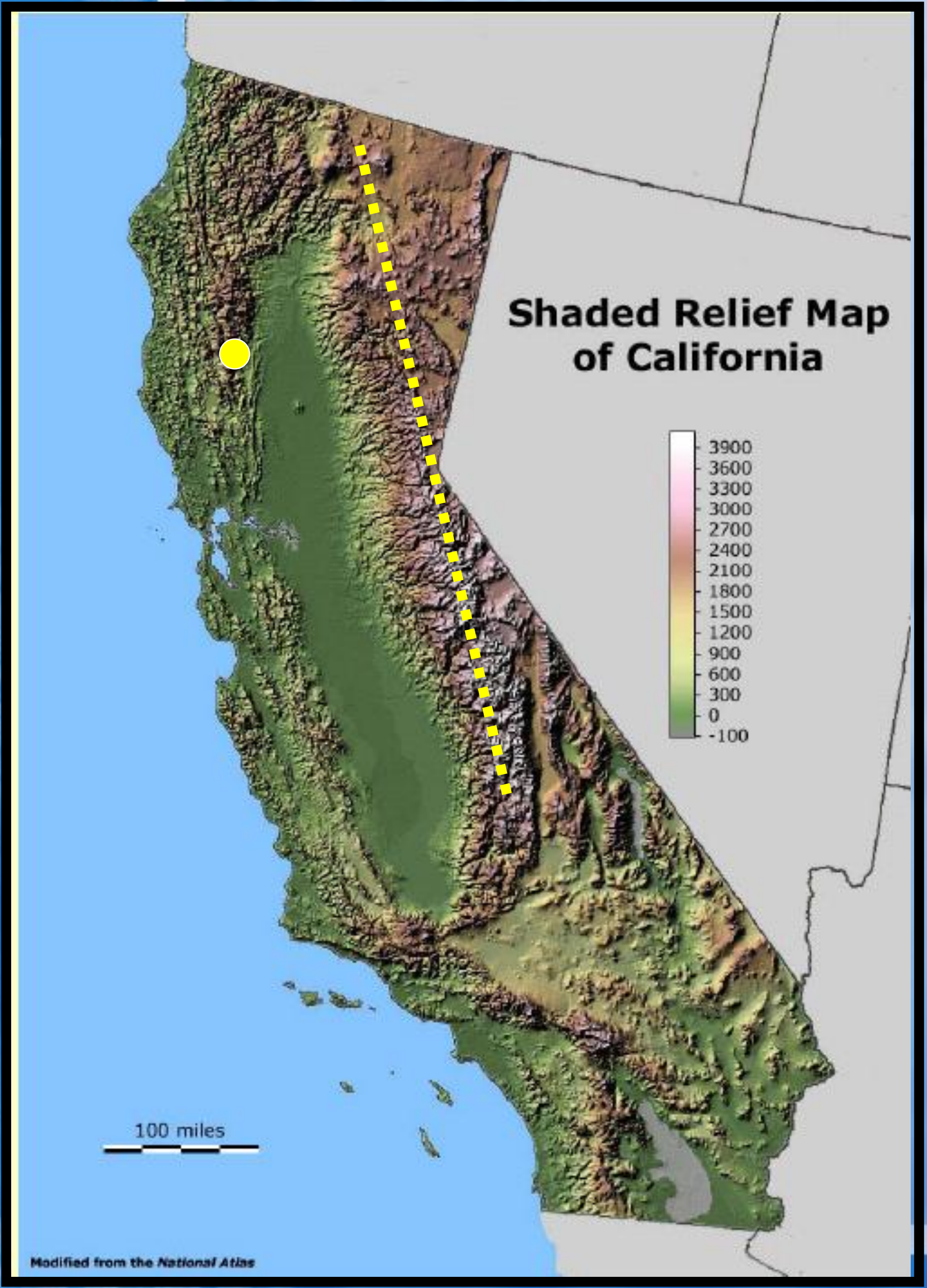
Pacific Gas and Electric Company

Rock Creek Cresta ERC Field Trip
November 4, 2013
Quincy, CA



- Elevation generally increases from north to south for PG&E's hydroelectric system.
- Regional geology, orographic/rain shadow effects, and elevation are essential when considering climate change for California's mountain areas.
- Feather River exists mostly on ancestral Sierra, mostly metamorphic and topographically complex with a few rain shadowed subbasins.
- Feather River cuts through the Sierra Crest into Basin & Range Geomorphic Provence

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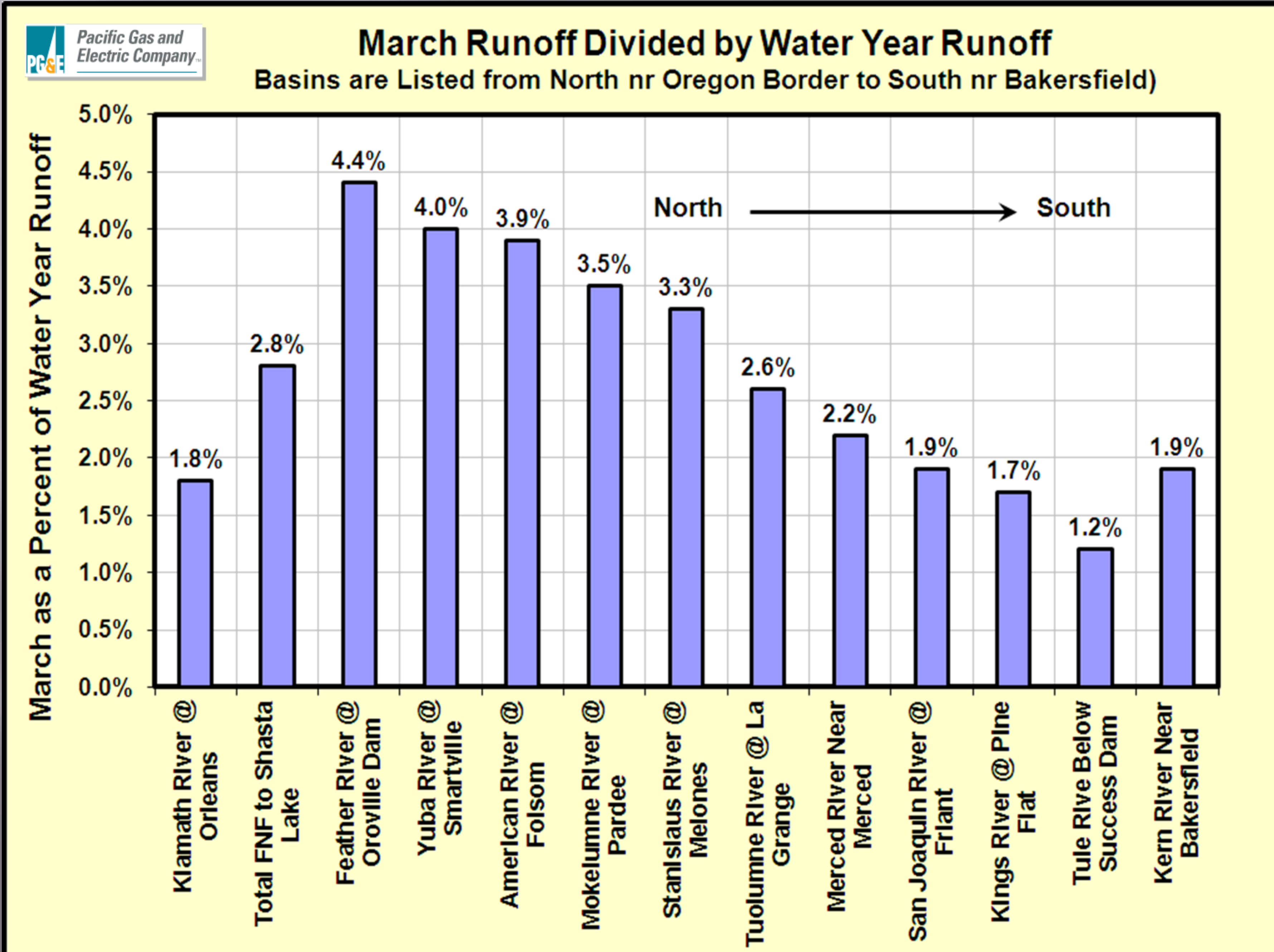
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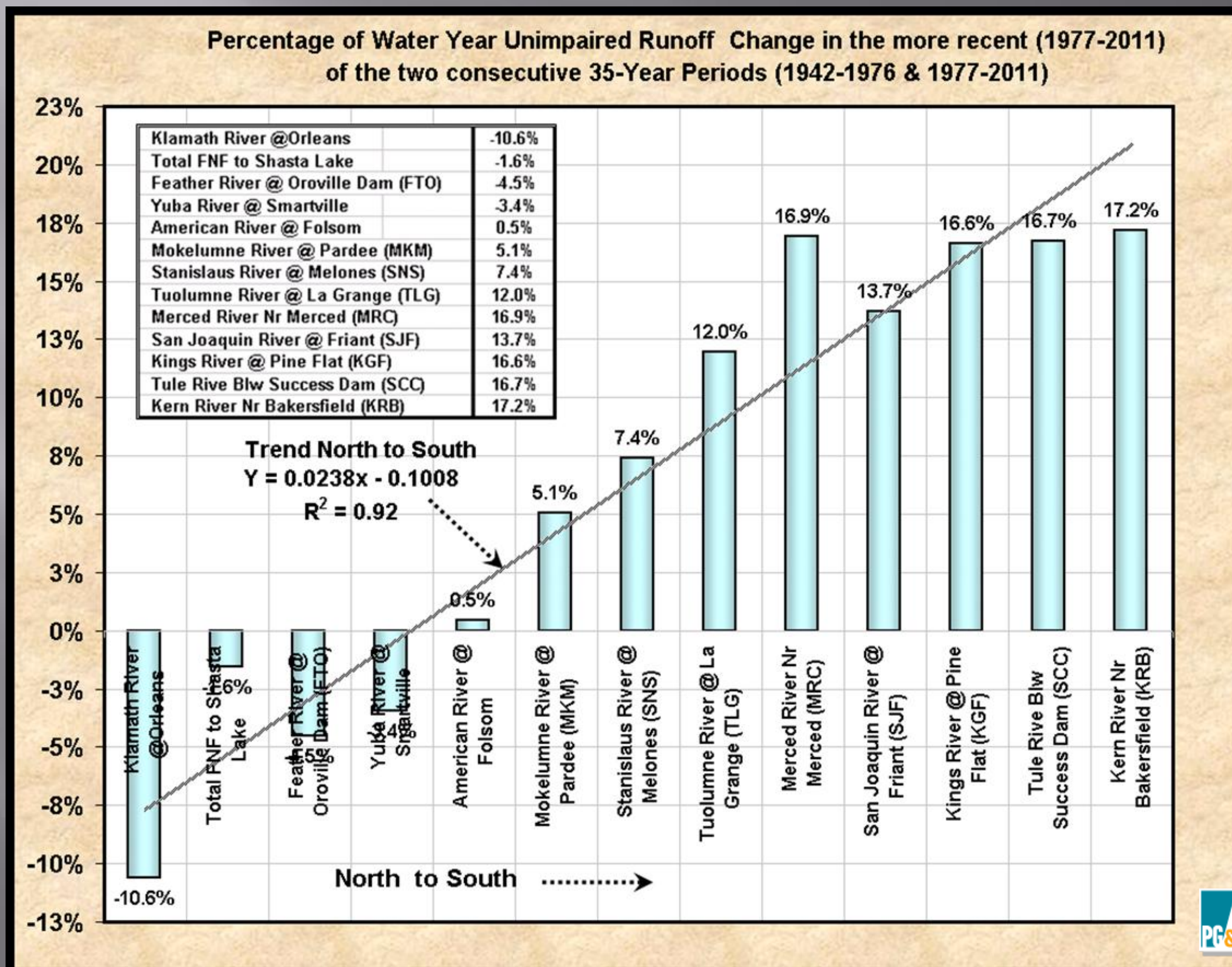
March Runoff Divided by Water Year Runoff
Basins are Listed from North nr Oregon Border to South nr Bakersfield)
March as a Percent of Water Year Runoff
5.0%
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
North
South
1.8%
2.8%
4.4%
4.0%
3.9%
3.5%
3.3%
2.6%
2.2%
1.9%
1.7%
1.2%
1.9%
Klamath RIver @ Orleans
Total FNF to Shasta Lake
Feather RIver @ Orovllle Dam
Yuba RIver @ Smartvllle
Amerlcan RIver @ Folsom
Mokelumne RIver @ Pardee
Stanlslaus RIver @ Melones
Tuolumne RIver @ La Grange
Merced RIver Near Merced
San Joaquln RIver @ Frlant
KIngs RIver @ PIne Flat
Tule RIve Below Success Dam
Kern RIver Near Bakersfield

South of the Yuba River, Water Year Runoff has increased during the most recent 35-Year Period (1977-2011)



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The North Fork Feather River

- Complex topography located on the older ancestral metamorphic Sierra block lacks a clearly defined mountain crest compared with that which characterizes the Yuba river southward.
- The Feather River crosses the divide into the relatively dry Basin and Range geomorphic province.
- Both orographically influenced and rain shadowed subbasins exist on the North Fork Feather River Watershed.
- Two rain shadowed subbasins exist on the North Fork Feather.
- PG&E's system wide climate change tracking procedure clearly identified both the 491 Sq Mi Lake Almanor and the 1,025 Sq Mi East Branch of North Fork Feather River (EBNFFR) as already being significantly impacted from the impacts of climate change.
- Our tracking procedure tracks the impact of climate change using a spring runoff index.

Lake Almanor and EBNFFR Climate Change Impacts

- The Lake Almanor and the EBNFFR Subbasins have the following identified impacts:
  - 1) snowpack decline – Lk Almanor, EBNFFR
  - 2) warmer winter temperatures – Lk Almanor, EBNFFR
  - 3) declining outflow of springs (aquifer outflow)– Lk Almanor
  - 4) declining aquifer storage – Lk Almanor
  - 5) declining water year runoff – Lk Almanor, EBNFFR
  - 6) declining snowmelt runoff – Lk Almanor, EBNFFR
  - 7) timing shift in spring runoff – Lk Almanor, EBNFFR
  - 8) declining summer flows, – Lk Almanor, EBNFFR
  - 9) reduced drought buffering capability – Lk Almanor
  - 10) increased evapotranspiration – Lk Almanor, EBNFFR

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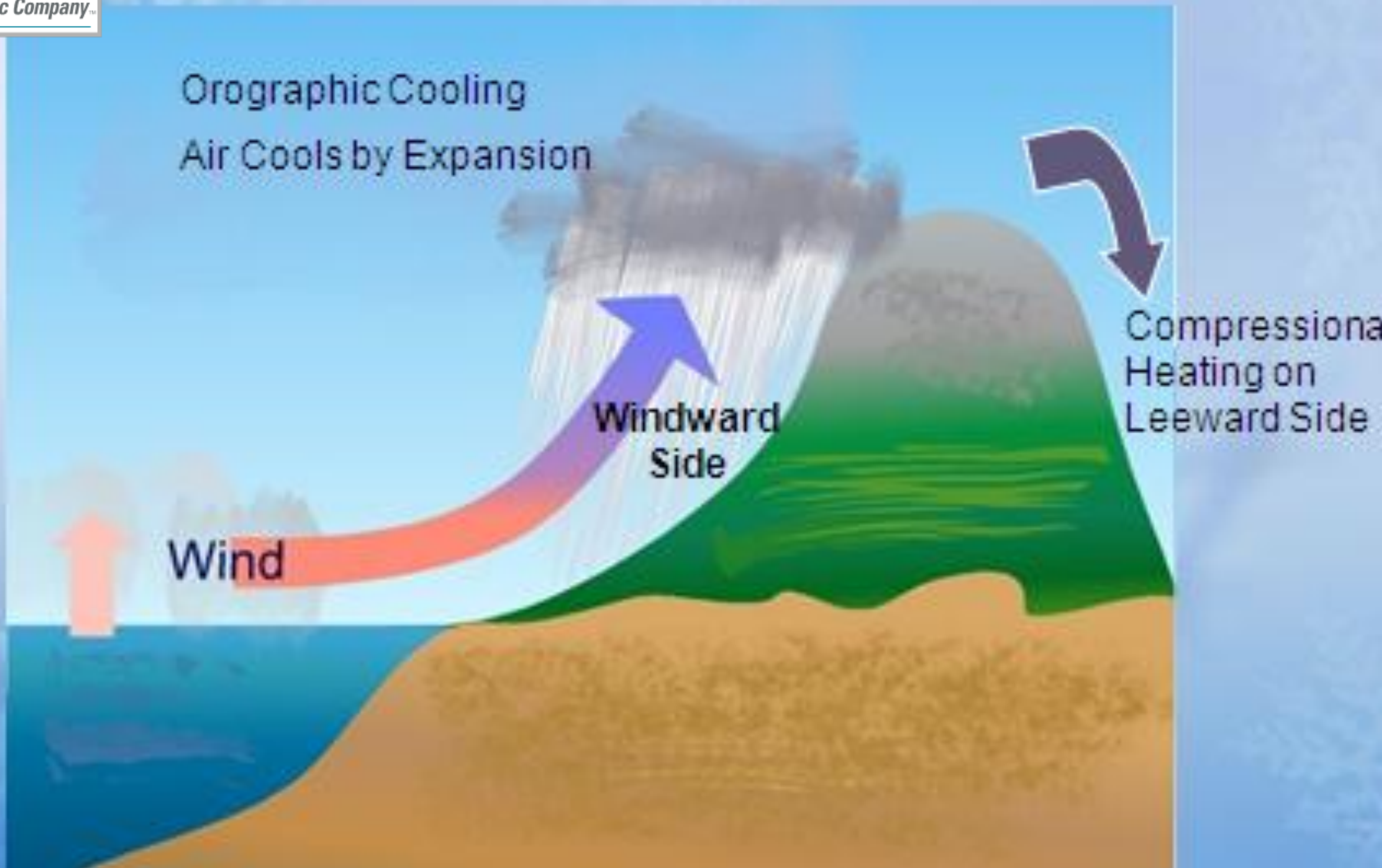
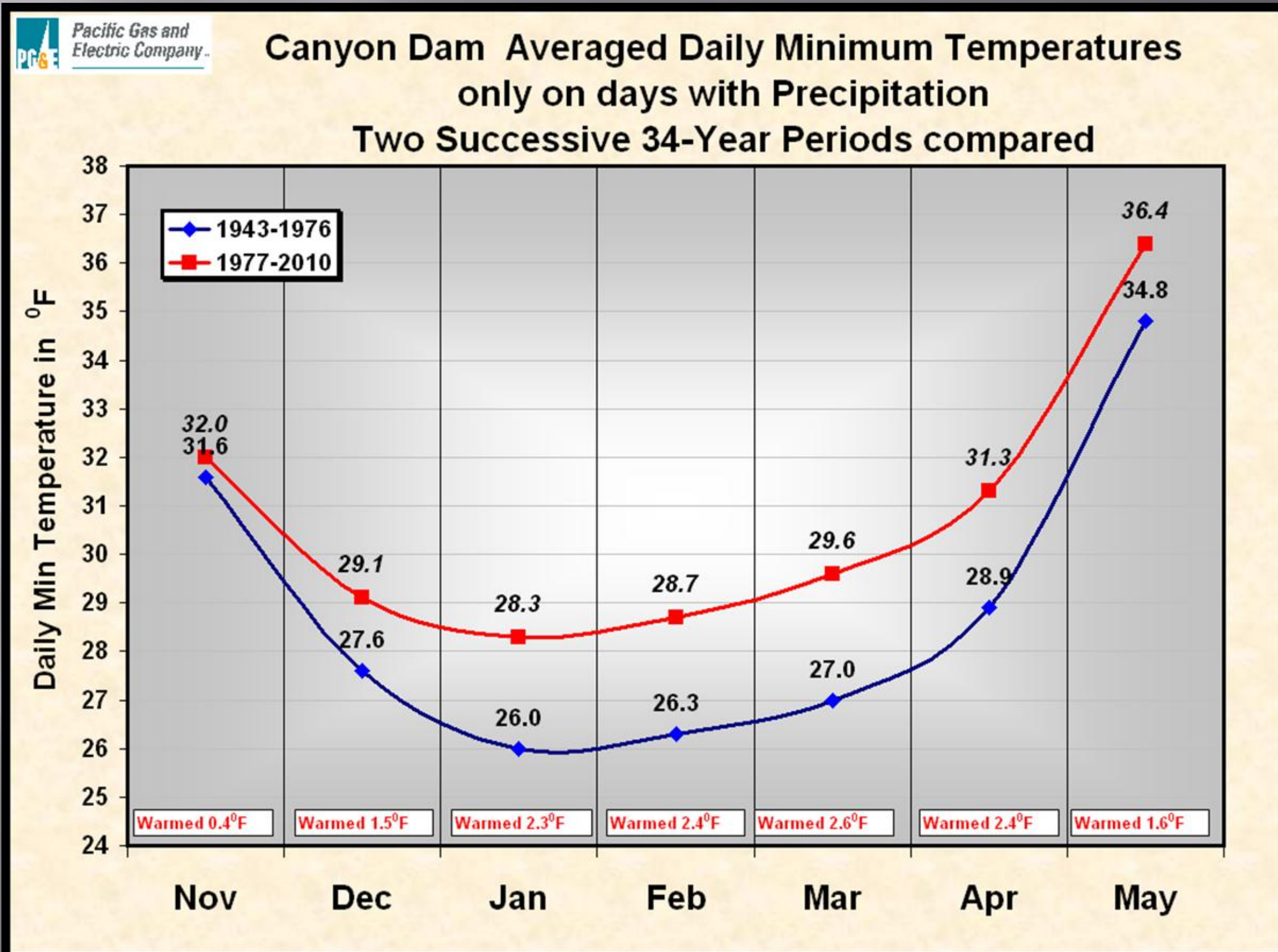


Orographic precipitation occurs on the windward side of mountains and is caused by the rising air motion of a large-scale flow of moist air across the mountain ridge



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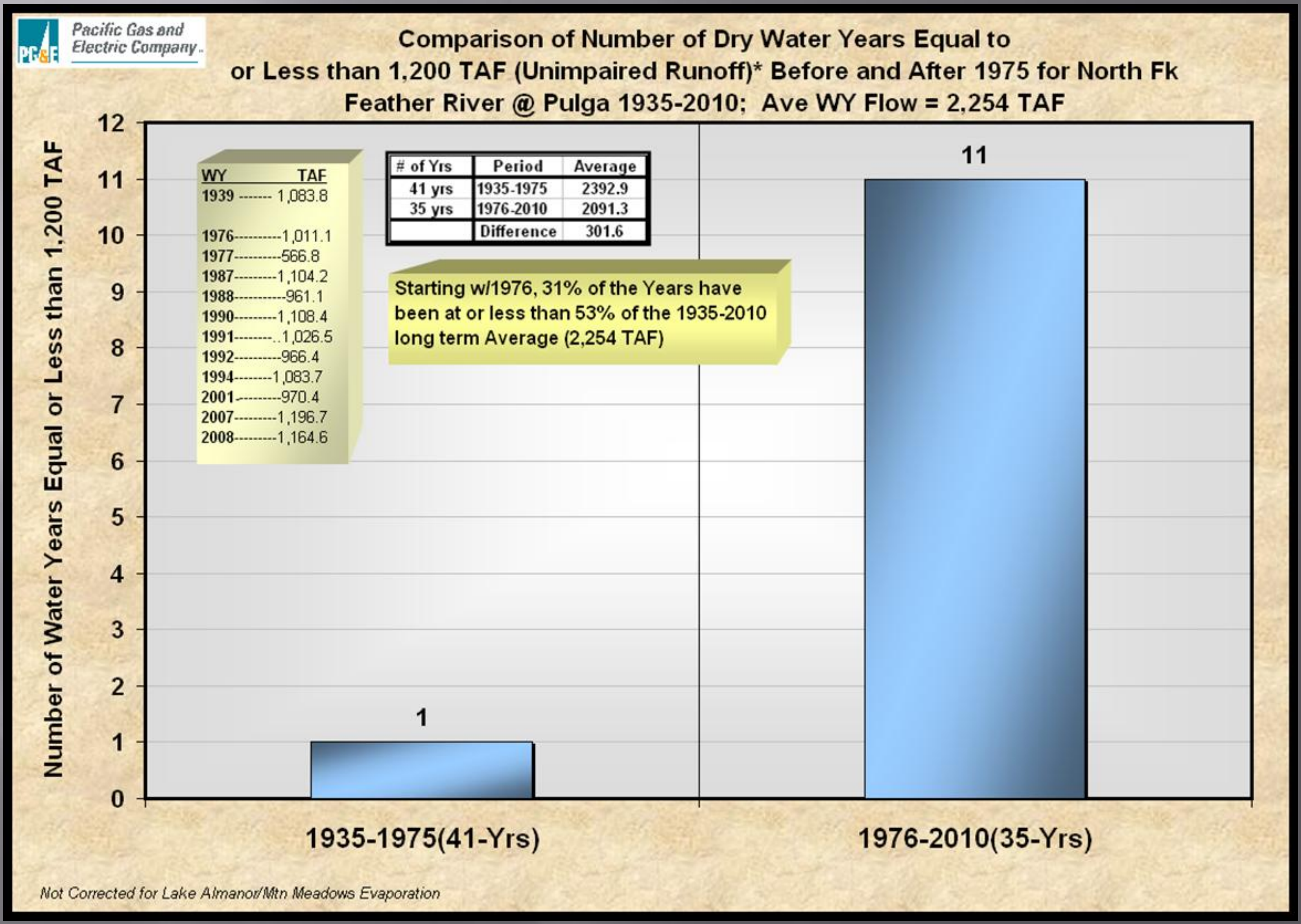
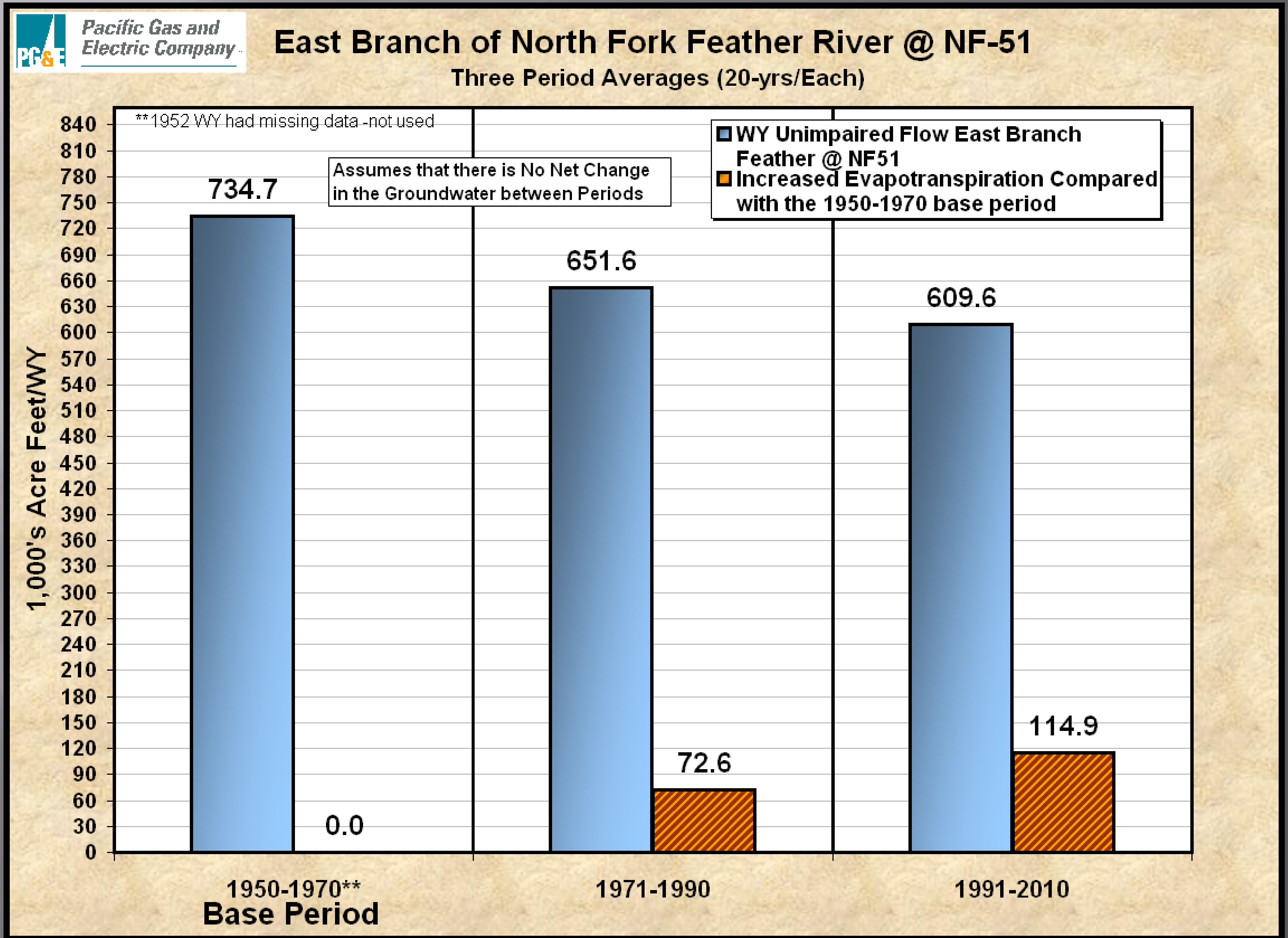
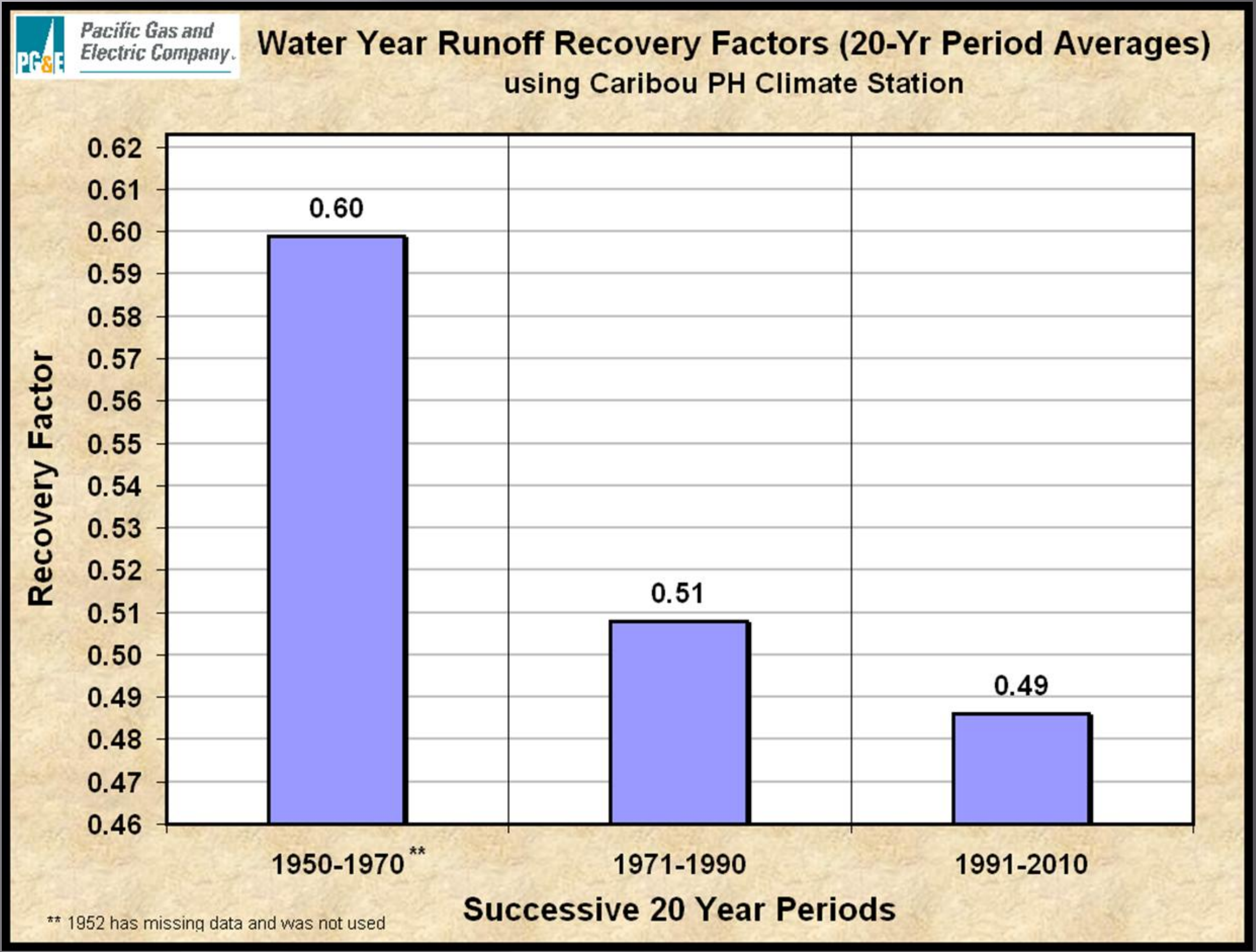
Canyon Dam Averaged Daily Minimum Temperatures
only on days with Precipitation
Two Successive 34-Year Periods compared
Daily Min Temperature in 0F
1943-1976
1977-2010
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
32.0
31.6
29.1
27.6
28.3
26.0
28.7
26.3
29.6
27.0
31.3
28.9
36.4
34.8
Warmed 0.4⁰F
Warmed 1.5⁰F
Warmed 2.3⁰F
Warmed 2.4⁰F
Warmed 2.6⁰F
Warmed 2.4⁰F
Warmed 1.6⁰F
Nov
Dec
Jan
Feb
Mar
Apr
May

Recent Years Reveal an Increase in Number of Dry Years for North Fork Feather River



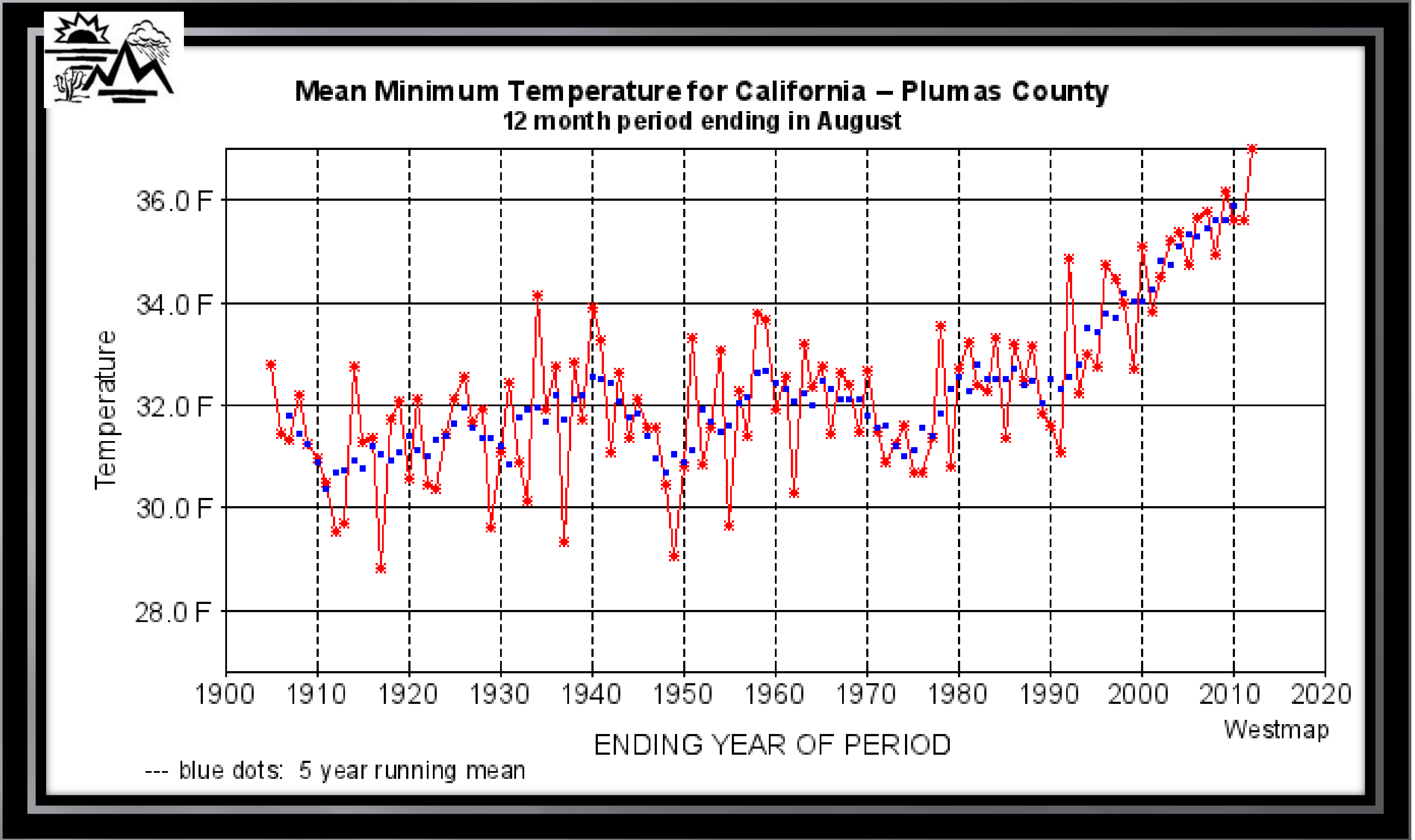
Utilizing Recovery Factors based on the Caribou PH Precipitation Record, an Increase in Evapotranspiration can be Approximated




Pacific Gas and Electric Company
Water Year Runoff Recovery Factors (20-Yr Period Averages)
using Caribou PH Climate Station
Recovery Factor
0.62
0.61
0.60
0.59
0.58
0.57
0.56
0.55
0.54
0.53
0.52
0.51
0.50
0.49
0.48
0.47
0.46
0.60
0.51
0.49
1950-1970 **
1971-1990
1991-2010
Successive 20 Year Periods
** 1952 has missing data and was not used

Looking for Indications of Recent Climate Change

- Relatively recent decline in July and/or August Minimum night time temperatures.
- Rain Shadowed areas tend to be more impacted than orographically influenced mountain areas.
- Decline in snowpack since mid-1970's.
- Decline in April through June/July and water year unimpaired inflow in recent years.
- Decline in aquifer outflow in recent years.
- Warmer water temperatures for some Lakes.
- Increase in fire frequency and intensity in recent years.
- Increase in precipitation and glacier size on CA stratovolcanoes.
- Changes in subalpine forest succession especially in ecotones.



1990	31.6
1991	31.1
1992	34.9
1993	32.3
1994	33.0
1995	32.7
1996	34.7
1997	34.5
1998	34.0
1999	32.7
2000	35.1
2001	33.8
2002	34.5
2003	35.2
2004	35.4
2005	34.7
2006	35.7
2007	35.8
2008	34.9
2009	36.2
2010	35.6
2011	35.6
2012	37.0

12-Month Period Ending in August
AVERAGE 32.303
MEDIAN 32.138
MINIMUM 28.817
MAXIMUM 37.050
SKEWNESS 0.562
COEFF OF VAR 0.049
SIGMA (RMS) 32.345
NUMBER OBS 108.000

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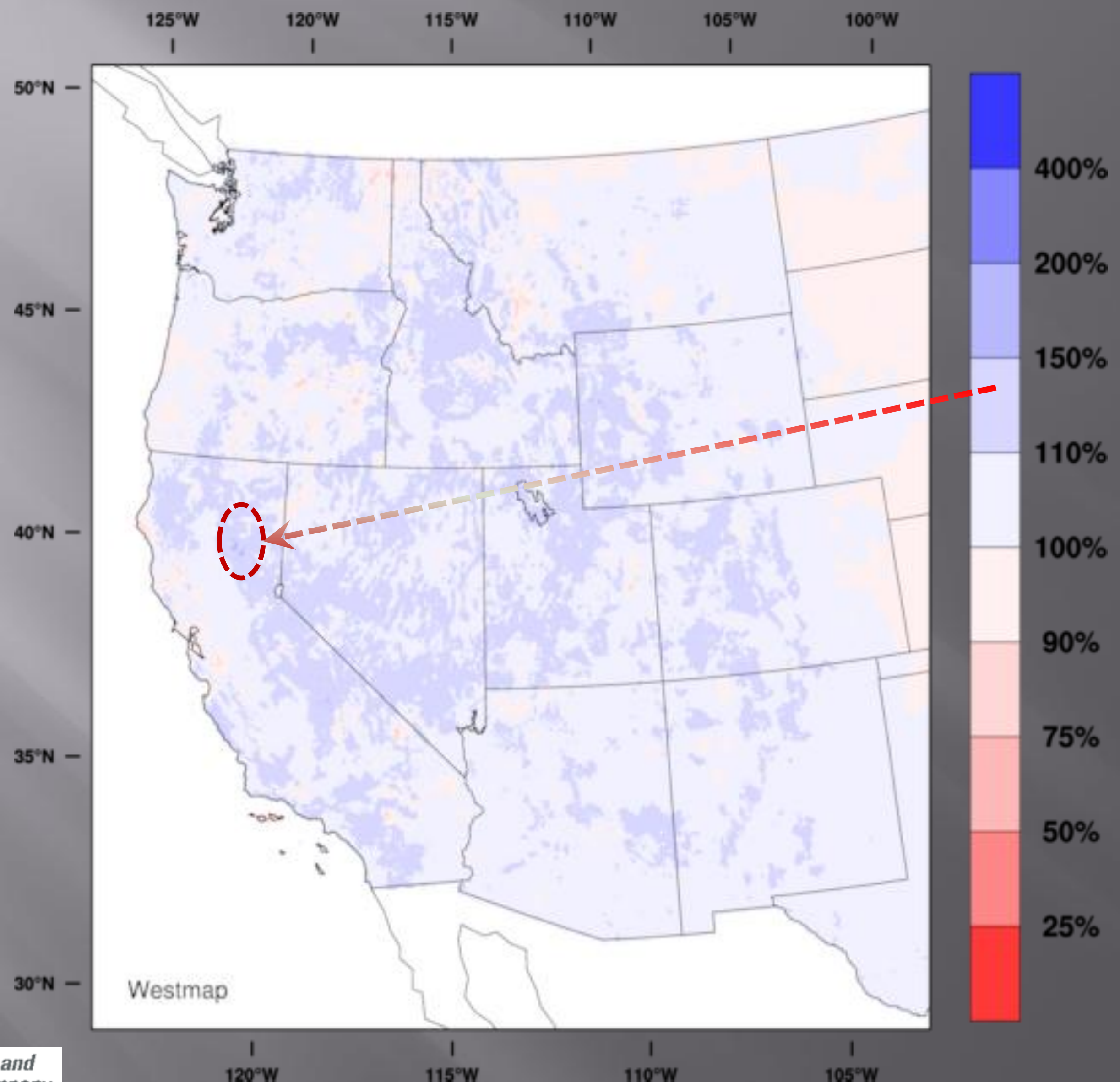
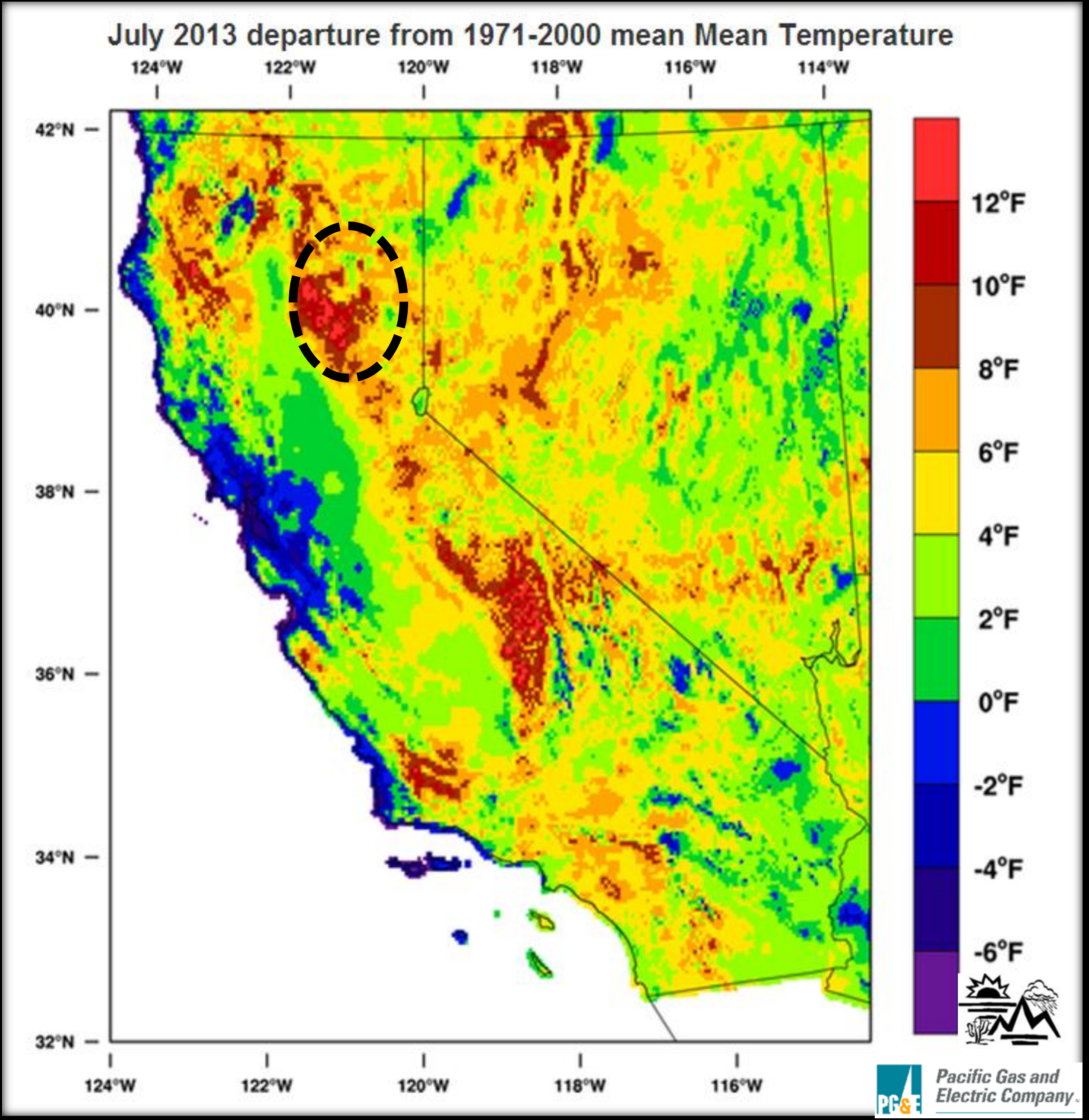
Min Temp Anomaly Map: Aug 2012 vs 1961-1990




July 2013 departure from 1971-2000 mean Mean Temperature
124°W
122°W
120°W
118°W
116°W
114°W
42°N
40°N
38°N
36°N
34°N
32°N
12°F
10°F
8°F
6°F
4°F
2°F
0°F
-2°F
-4°F
-6°F
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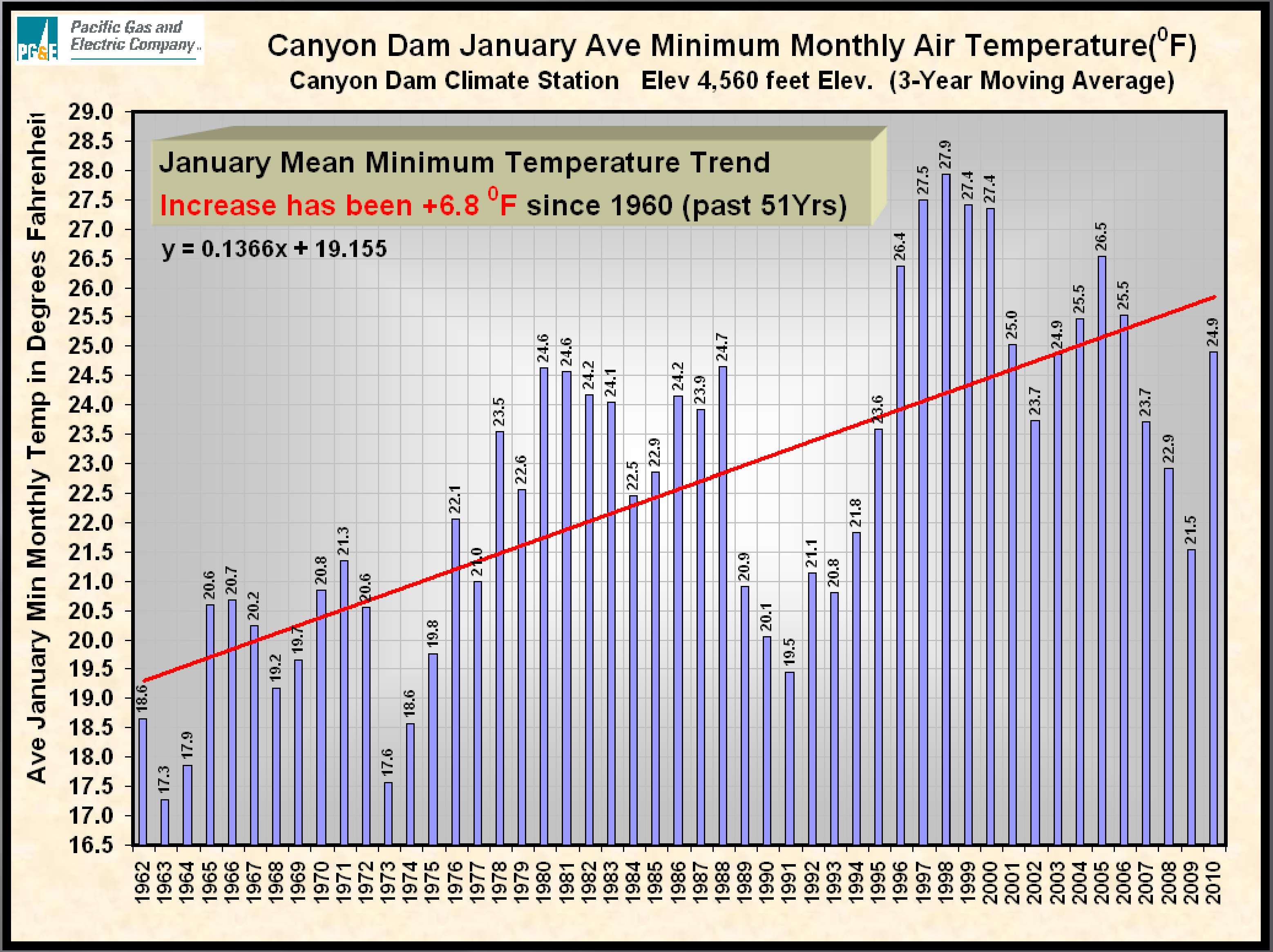
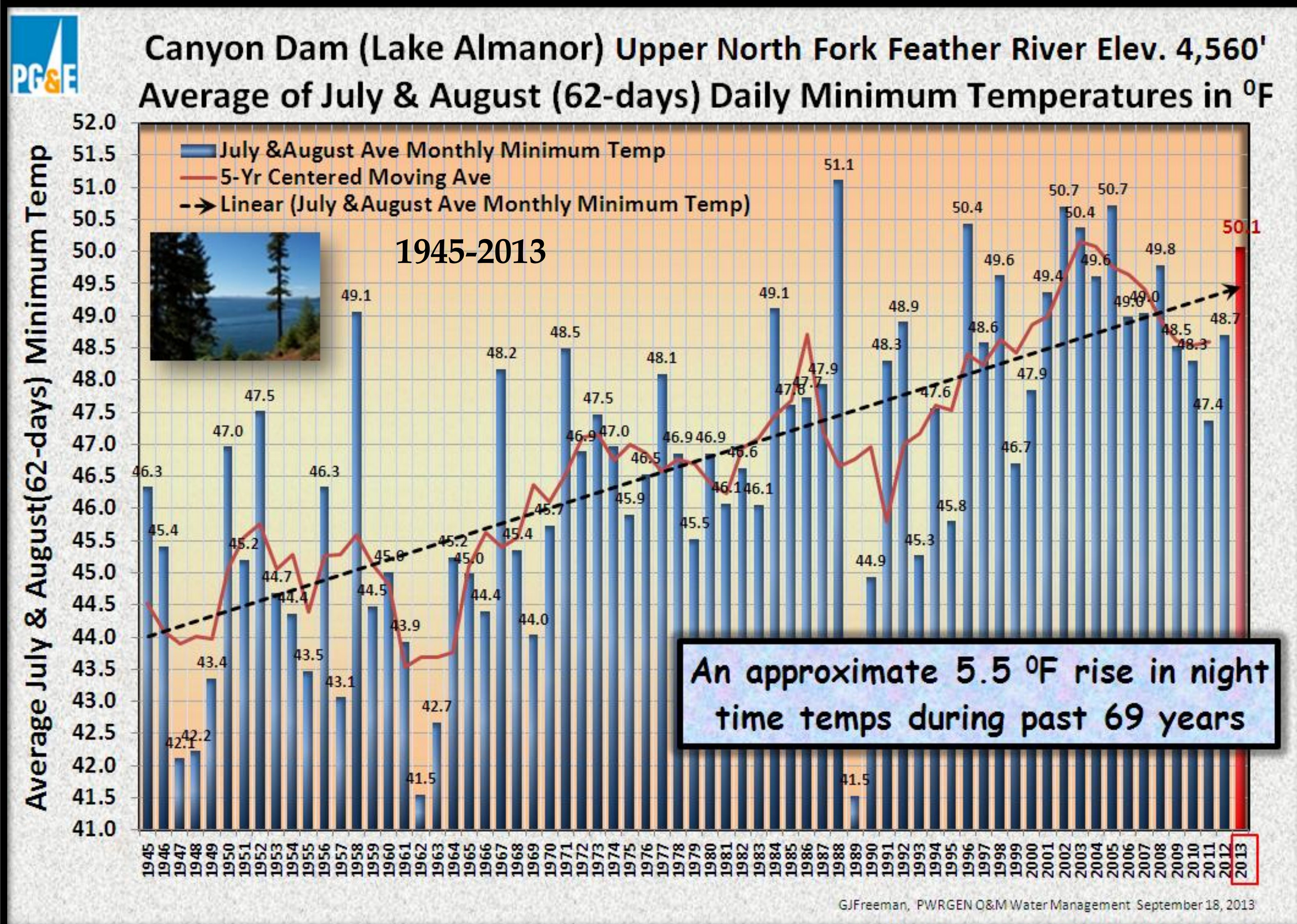
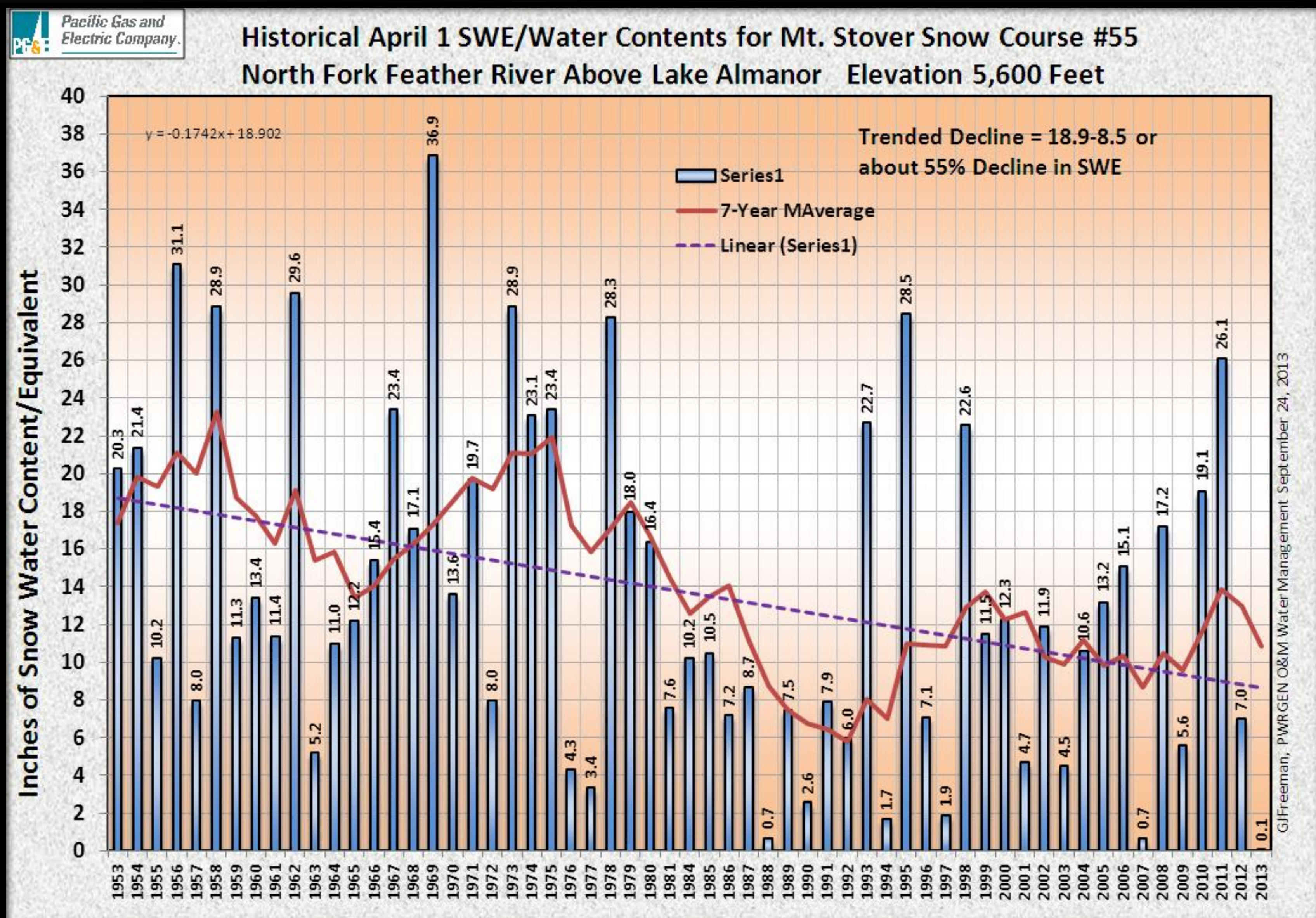
Increase in the Canyon Dam January Average Minimum Monthly Air Temperature in ^{0}F (3-Year Moving Average)





Canyon Dam (Lake Almanor) Upper North Fork Feather River Elev. 4,560'
Average of July & August (62-days) Daily Minimum Temperatures in 0F
July &August Ave Monthly Minimum Temp
5-Yr Centered Moving Ave
Linear (July &August Ave Monthly Minimum Temp)
1945-2013
Average July & August(62-days) Minimum Temp
An approximate 5.5 0F rise in night time temps during past 69 years
GJFreeman, PWRGEN O&M Water Management September 18, 2013



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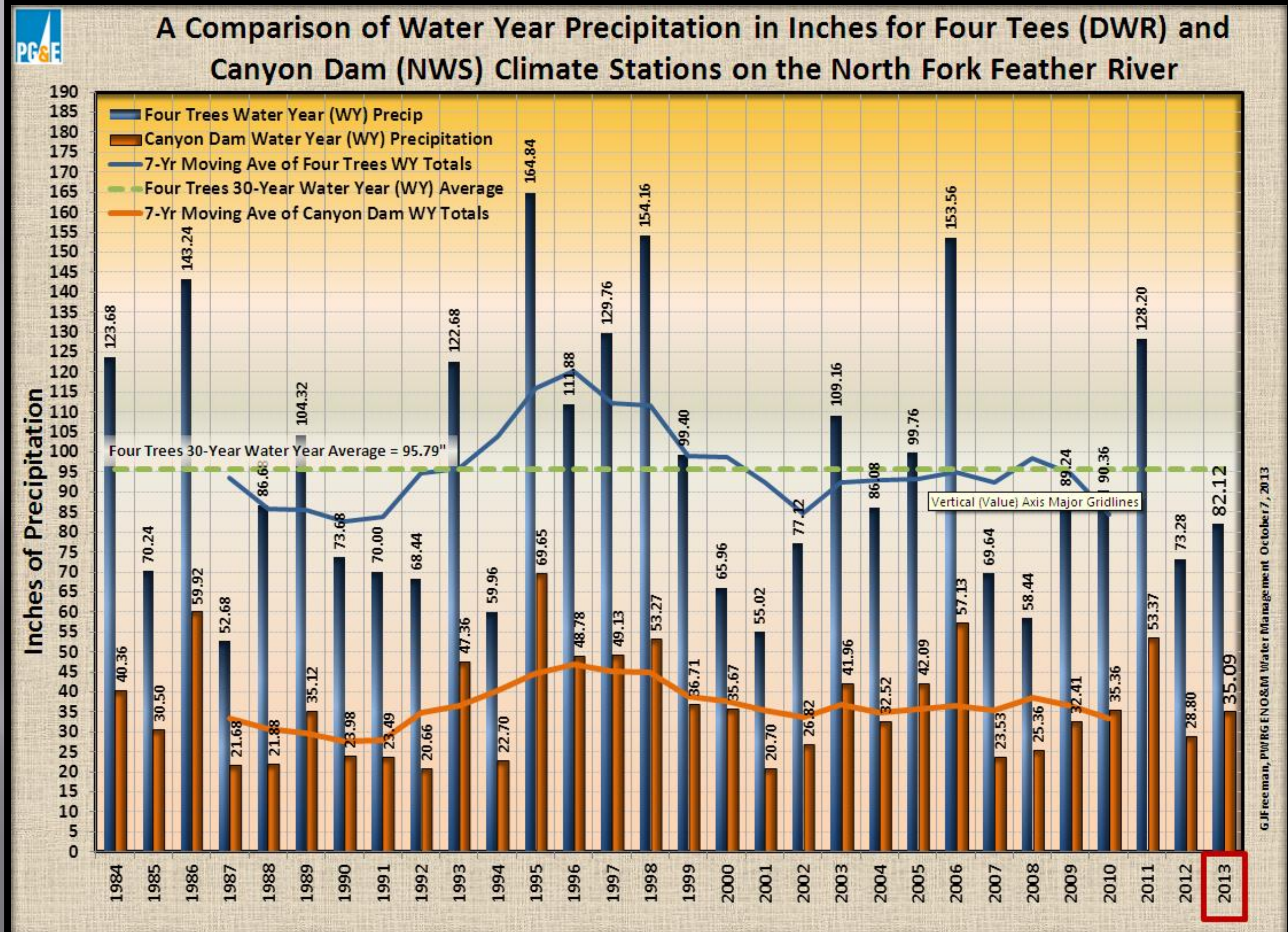
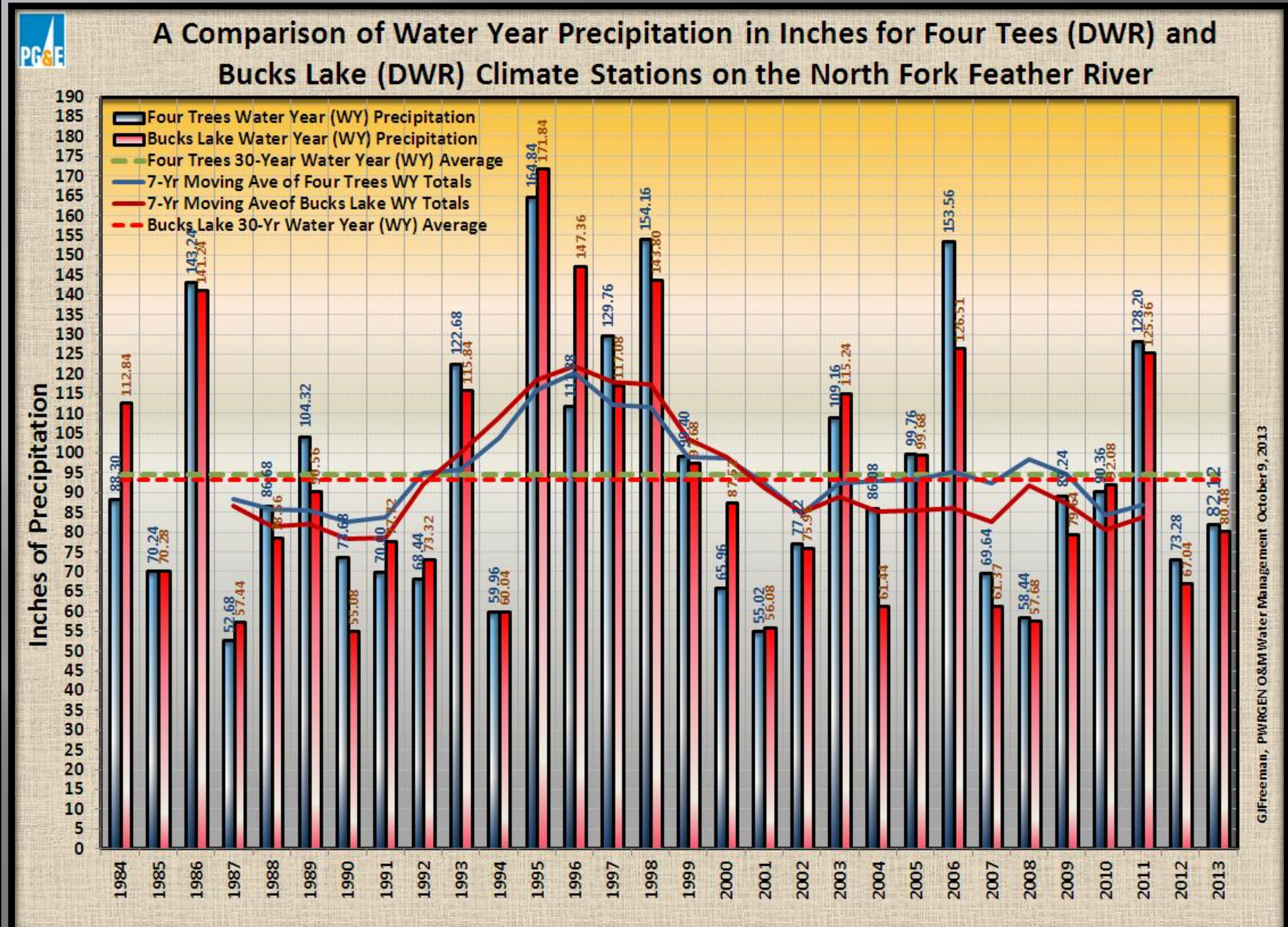
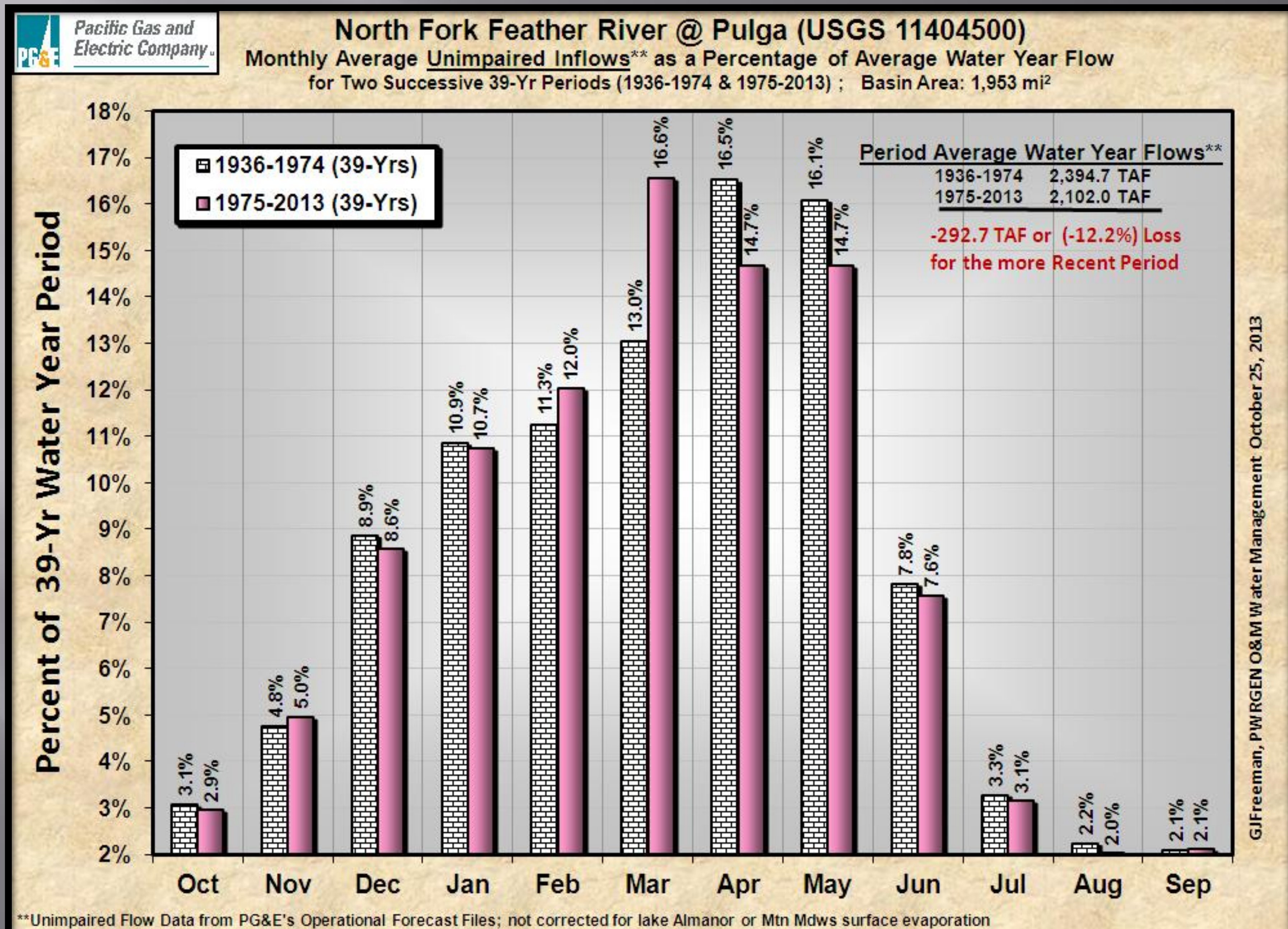
Historical April 1 SWE/Water Contents for Mt. Stover Snow Course #55
North Fork Feather River Above Lake Almanor Elevation 5,600 Feet
y = -0.1742x + 18.902
Trended Decline = 18.9-8.5 or about 55% Decline in SWE
Series1
7-Year MAverage
Linear (Series1)
Inches of Snow Water Content/Equivalent
GJFreeman, PWRGEN O&M Water Management September 24, 2013

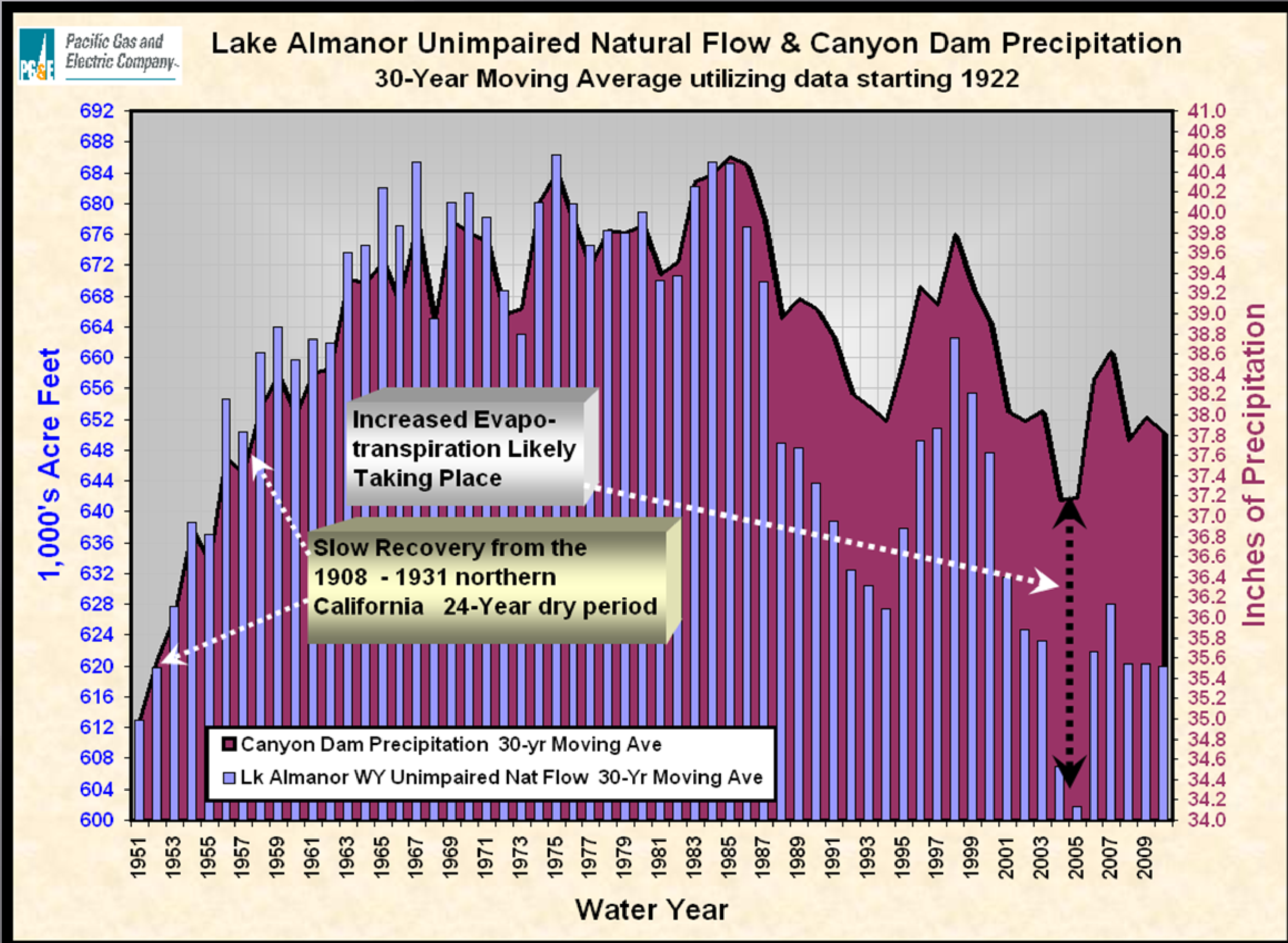


PG&E
A Comparison of Water Year Precipitation in Inches for Four Tees (DWR) and Canyon Dam (NWS) Climate Stations on the North Fork Feather River
Four Trees Water Year (WY) Precip
Canyon Dam Water Year (WY) Precipitation
7-Yr Moving Ave of Four Trees WY Totals
Four Trees 30-Year Water Year (WY) Average
7-Yr Moving Ave of Canyon Dam WY Totals
Four Trees 30-Year Water Year Average = 95.79"
Vertical (Value) Axis Major Gridlines
Inches of Precipitation
1984 123.68 40.36
1985 70.24 30.50
1986 143.24 59.92
1987 52.68 21.68
1988 86.68 21.88
1989 104.32 35.12
1990 73.68 23.98
1991 70.00 23.49
1992 68.44 20.66
1993 122.68 47.36
1994 59.96 22.70
1995 164.84 69.65
1996 111.88 48.78
1997 129.76 49.13
1998 154.16 53.27
1999 99.40 36.71
2000 65.96 35.67
2001 55.02 20.70
2002 77.12 26.82
2003 109.16 41.96
2004 86.08 32.52
2005 99.76 42.09
2006 153.56 57.13
2007 69.64 23.53
2008 58.44 25.36
2009 89.24 32.41
2010 90.36 35.36
2011 128.20 53.37
2012 73.28 28.80
2013 82.12 35.09
GJFreeman, PWRG ENO&M Water Management October 7, 2013



PG&E
A Comparison of Water Year Precipitation in Inches for Four Tees (DWR) and Bucks Lake (DWR) Climate Stations on the North Fork Feather River
Four Trees Water Year (WY) Precipitation
Bucks Lake Water Year (WY) Precipitation
Four Trees 30-Year Water Year (WY) Average
7-Yr Moving Ave of Four Trees WY Totals
7-Yr Moving Aveof Bucks Lake WY Totals
Bucks Lake 30-Yr Water Year (WY) Average
Inches of Precipitation
GJFreeman, PWRGEN O&M Water Management October 9, 2013


Pacific Gas and Electric Company
North Fork Feather River @ Pulga (USGS 11404500)
Monthly Average Unimpaired Inflows** as a Percentage of Average Water Year Flow
for Two Successive 39-Yr Periods (1936-1974 & 1975-2013) ; Basin Area: 1,953 mi²
Percent of 39-Yr Water Year Period
1936-1974 (39-Yrs)
1975-2013 (39-Yrs)
Period Average Water Year Flows**
1936-1974 2,394.7 TAF
1975-2013 2,102.0 TAF
-292.7 TAF or (-12.2%) Loss for the more Recent Period
Oct 3.1% 2.9%
Nov 4.8% 5.0%
Dec 8.9% 8.6%
Jan 10.9% 10.7%
Feb 11.3% 12.0%
Mar 13.0% 16.6%
Apr 16.5% 14.7%
May 16.1% 14.7%
Jun 7.8% 7.6%
Jul 3.3% 3.1%
Aug 2.2% 2.0%
Sep 2.1% 2.1%
GJFreeman, PWRGEN O&M Water Management October 25, 2013
**Unimpaired Flow Data from PG&E's Operational Forecast Files; not corrected for lake Almanor or Mtn Mdws surface evaporation



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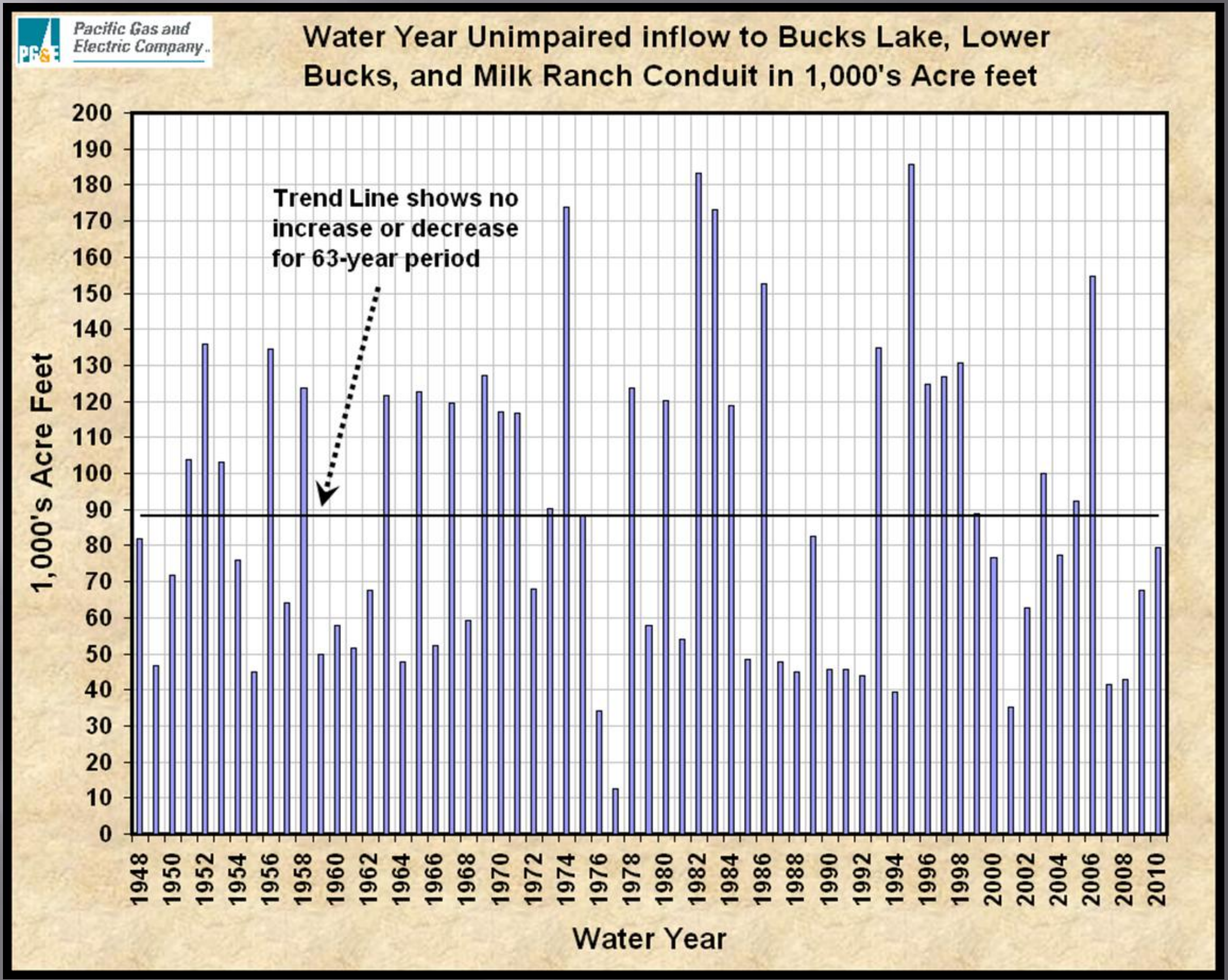
Lake Almanor Unimpaired Natural Flow & Canyon Dam Precipitation
30-Year Moving Average utilizing data starting 1922
1,000's Acre Feet
Inches of Precipitation
Water Year
Increased Evapo-transpiration Likely Taking Place
Slow Recovery from the 1908 - 1931 northern California 24-Year dry period
Canyon Dam Precipitation 30-yr Moving Ave
Lk Almanor WY Unimpaired Nat Flow 30-Yr Moving Ave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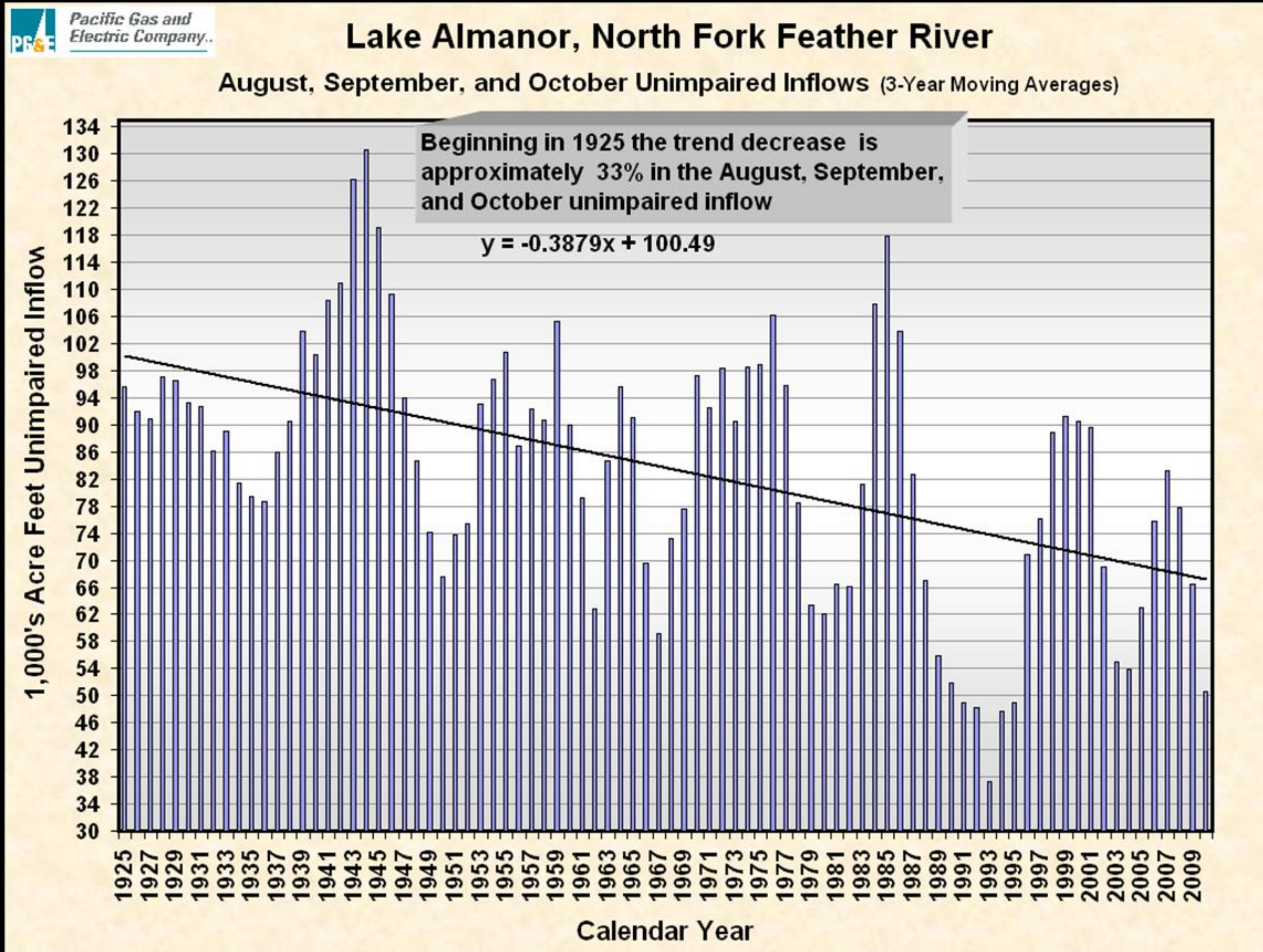
Water Year Unimpaired inflow to Bucks Lake, Lower Bucks, and Milk Ranch Conduit in 1,000's Acre feet
Trend Line shows no increase or decrease for 63-year period
1,000's Acre Feet
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Water Year



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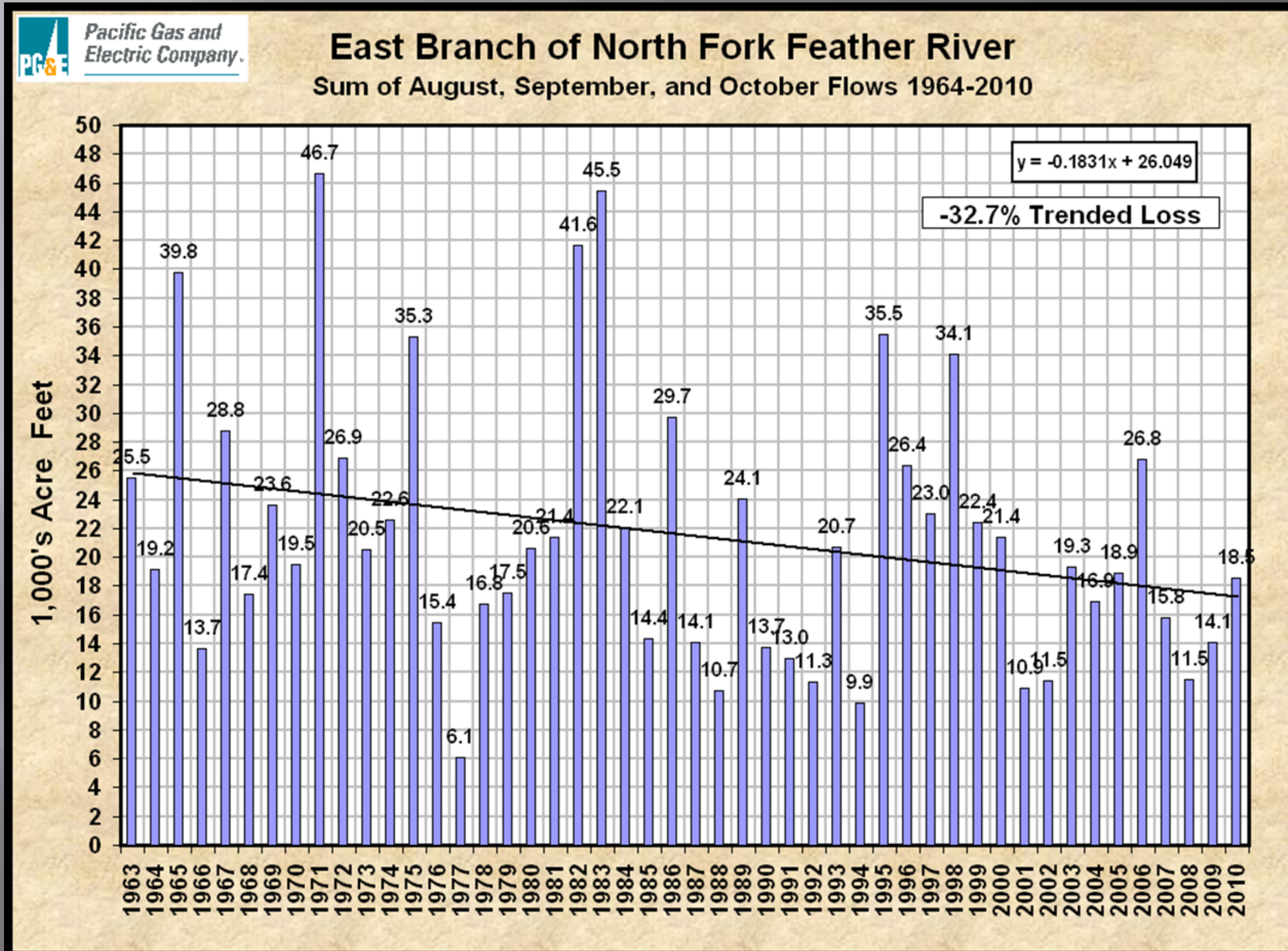
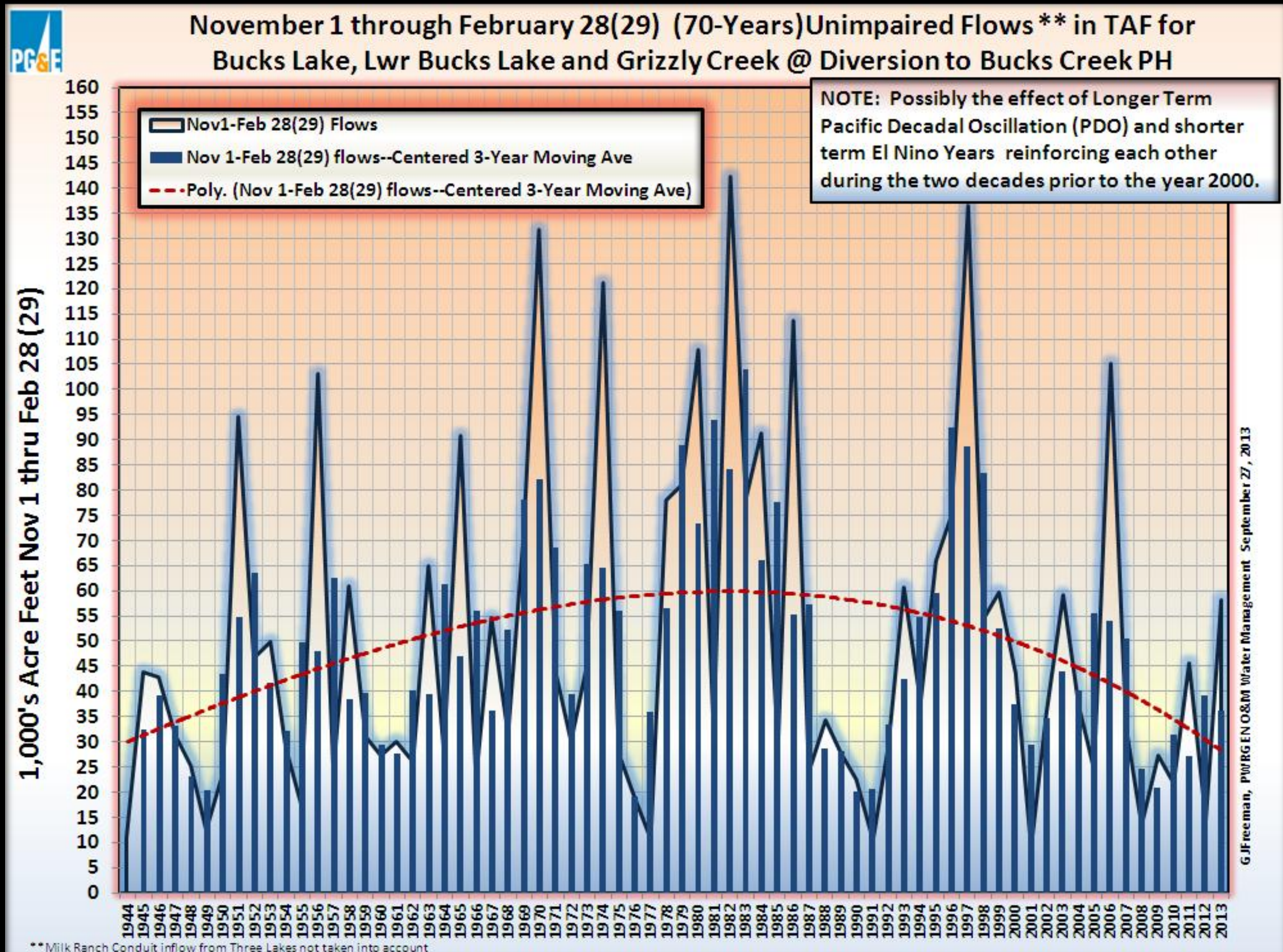
Lake Almanor, North Fork Feather River
August, September, and October Unimpaired Inflows (3-Year Moving Averages)
Beginning in 1925 the trend decrease is approximately 33% in the August, September, and October unimpaired inflow
y = -0.3879x + 100.49
1,000's Acre Feet Unimpaired Inflow
134
130
126
122
118
114
110
106
102
98
94
90
86
82
78
74
70
66
62
58
54
50
46
42
38
34
30
1925
1927
1929
1931
1933
1935
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Calendar Year

Continued Decline in Late Summer and Fall Flows for East Branch of the North Fork Feather River





November 1 through February 28(29) (70-Years)Unimpaired Flows ** in TAF for
Bucks Lake, Lwr Bucks Lake and Grizzly Creek @ Diversion to Bucks Creek PH
Nov1-Feb 28(29) Flows
Nov 1-Feb 28(29) flows--Centered 3-Year Moving Ave
Poly. (Nov 1-Feb 28(29) flows--Centered 3-Year Moving Ave)
NOTE: Possibly the effect of Longer Term Pacific Decadal Oscillation (PDO) and shorter term El Nino Years reinforcing each other during the two decades prior to the year 2000.
1,000's Acre Feet Nov 1 thru Feb 28 (29)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
135
140
145
150
155
160
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
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1964
1965
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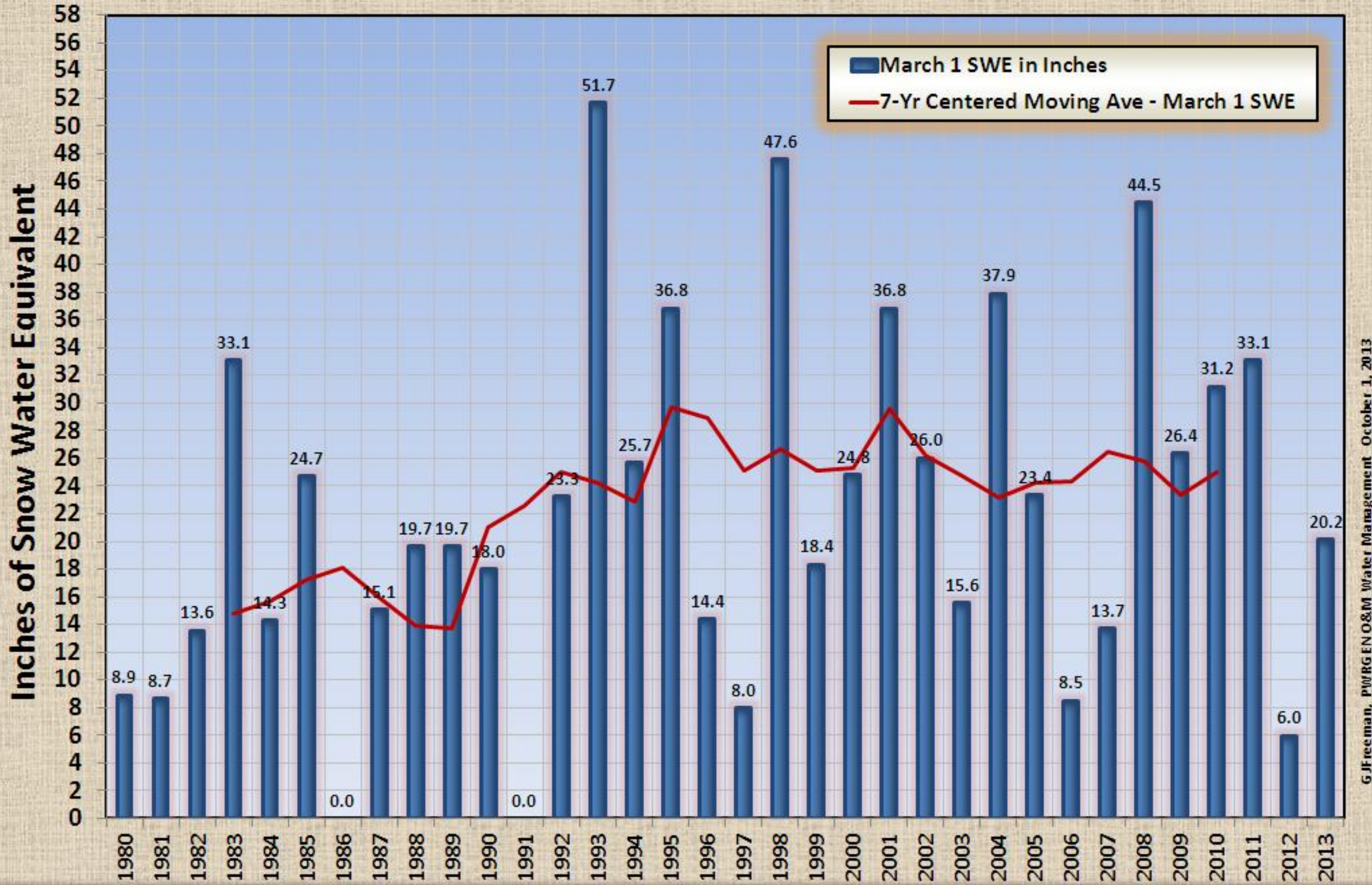
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
GJFreeman, PWRGEN O&M Water Management September 27, 2013
**Milk Ranch Conduit inflow from Three Lakes not taken into account

1980-2013 (34 Years) March 1 Snow Water Content/Equivalent for Four Trees Snow Sensor (FOR) located at Elevation 5,150 feet above Cresta Powerhouse in Canyon along HWY 70



Lake Almanor Subbasin's Increasing Loss to Evapotranspiration in Recent Years

- The increasing loss to evapotranspiration in recent years likely results from increased soil moisture demands.
- Aquifer outflow of the springs has declined in recent years likely indicating reduced opportunity for deeper aquifer recharge.
- Increased heating of land surfaces and increased vegetation density may have both occurred. Leaf surfaces may be utilizing more water for 'cooling'.
- Less runoff now occurs with historically equivalent amounts of precipitation or in other words the surface runoff to precipitation ratio has changed.
- The Lake Almanor watershed may be drifting in characteristics to that which somewhat typify the drier Basin and Range environment to more inland "rain shadowed" mountain basins.

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Some Effects of Warmer Air Temperatures

- If soil moisture is available, warmer temperatures are likely to support increased forest growth and therefore conifer density increases
- **Larger and more intense fires**
- If sufficient soil moisture is available, increased evapotranspiration helps support forest growth and leaf cooling
- Less low elevation snowpack, earlier snowmelt, loss of watershed albedo, and maybe change in the Bowen Ratio
- Reduced aquifer recharge opportunity from decline in low elevation snowpack
- Changes in temperatures may lead to less opportunity for cloudseeding on the Lake Almanor Watershed
- Glacier increase on slopes of Mt Shasta and increased river flow on west side Mt. Lassen (Battle Creek) suggests that incoming frontal air masses may contain more moisture supporting annual precipitation increases where air can be sufficiently cooled with the orographic process.

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Use of Historical Data to Reveal Trends (continued)

- Topographic complexity has the potential for some relatively low elevation subbasins in northern California, which are rain shadowed to produce climate warming 3-4 times that being observed on the west facing windward slopes of the Sierra typical of the central and southern Sierra or even on the same basin for orographically influenced subbasins.
- Some subbasins on the North Fork Feather River such as the Bucks Lake-Grizzly subbasin and the Feather River Canyon below Belden, which have strong orographic cooling associated with typical winter storms, show less decline in spring runoff, and little or no decline in water year runoff.

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Conclusions

- Both the Lake Almanor and EBNFFR are rain shadowed subbasins, which in addition to declining April through June Runoff have declining water year runoff.
- Average minimum January temperatures for these two rain shadowed subbasins show a large increase compared with orographic influenced subbasins elsewhere on the North Fork Feather River and the Sierra subbasins in the central and southern Sierra.
- Increased evapotranspiration appears to be the most likely reason for less water year runoff and the decline in surface runoff recovery from water year precipitation.
- The loss of aquifer (groundwater) storage in recent years for Lake Almanor reduces the watershed's ability to buffer against short term (2-3 years) back-to-back dry years.