2009 Western Regional Dam Safety Forum

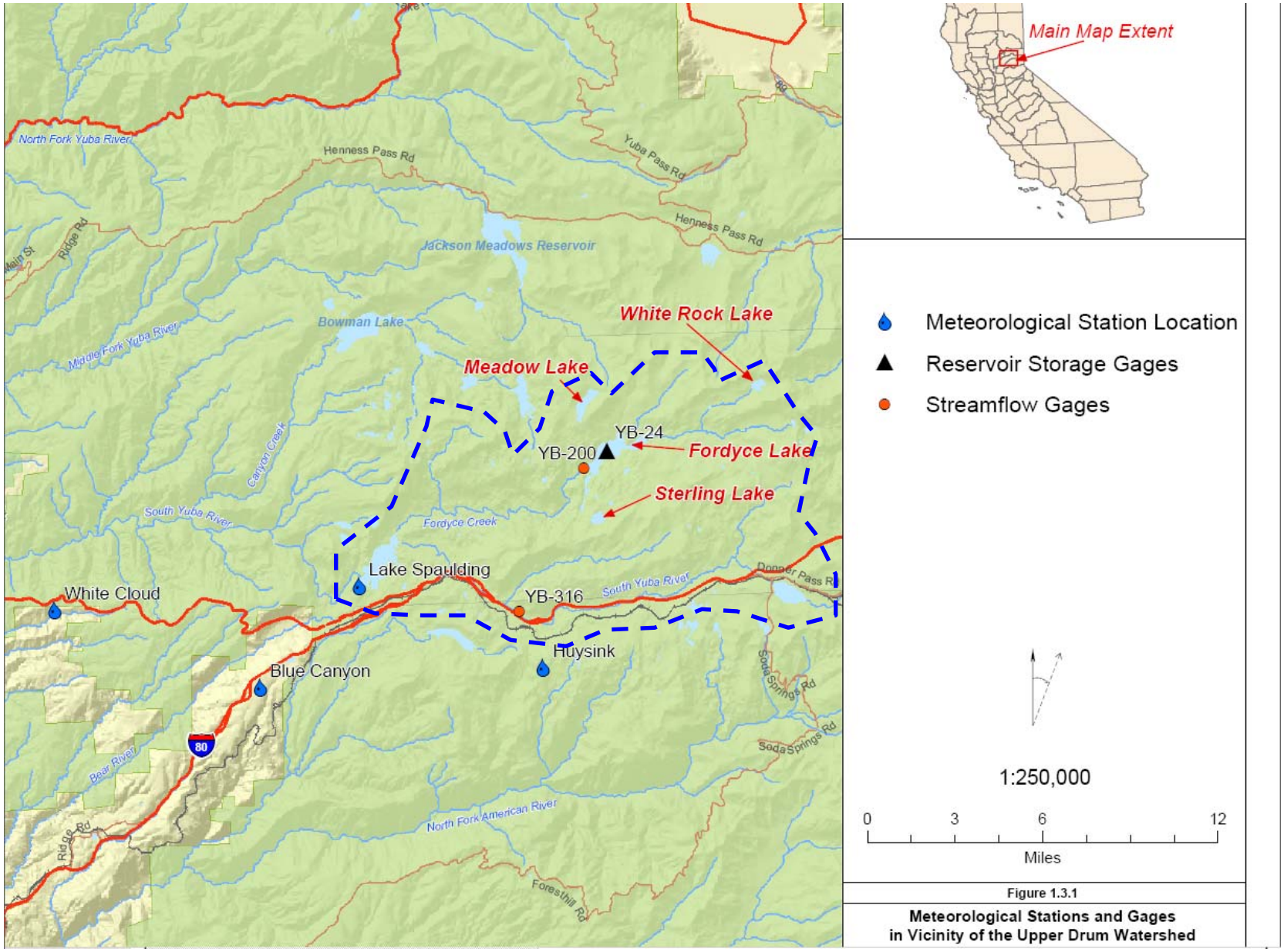
PMF snowmelt methods – energy-budget *versus* degree-day

A test case of the effects of alternative snowmelt methods on PMF prediction for key dams in a PG&E watershed

Presented by Rob White, PG&E

Extent of PG&E's PMF program

- 11 major watersheds
- 53 dams with PMFs
- 21 PMF analyses using HEC-1 and HMR 36/49
- Most PMF analyses done circa 1977-1992
- 9 analyses updated since 1998 using HMR 59



PG&E dams on upper reach of So Fork of Yuba River and Fordyce Creek

PMF analysis of PG&E dams on upper reach of So Fork of Yuba River

Previously performed using HMR 36 in 1985:

Key steps:

1. Calibrate HEC-1 basin loss rate and unit hydrograph parameters to historical storms of record using degree-day snowmelt method.

2. Run PMF calculation with calibrated parameters, estimated PMP and snowpack from HMR36, again using degree-day snowmelt method.

January 1997 storm – the “pineapple express”

The tropical origin of the storm resulted in storm precipitation changing from snow to rain, and the snowpack in the watershed became “ripened” due to rain-on-snow interaction at increasingly higher elevations.

At the peak of the event (January 1, 1997 around 10:00 AM based on observed data at Blue Canyon), precipitation fell as rain in even the highest elevations of the watershed.

The four-day precipitation total of 12/30/06 – 1/2/97 was not the highest total on record, but the combination of relatively high temperatures, substantial snowpack and heavy precipitation led to an extraordinary amount of snowmelt in the basin which was responsible for the runoff and volumes that were observed.

FERC review comment regarding 1997 storm:

“In many areas of California the January 1, 1997 storm produced a flood/flow of record.”

“... precipitation values coincident with this storm could ...change the existing unit hydrographs and assumed basin characteristics developed for the affected watersheds.”

“As such, a change in the unit hydrograph characteristics could impact the project’s ability to pass a flood of this magnitude.”

“Therefore, you should **review the existing unit hydrographs and basin characteristics** that were utilized in the storm routing associated with the previously accepted PMF analysis and provide a recommendation on whether a revised analysis is necessary.”

Assessing impact of 1997 storm

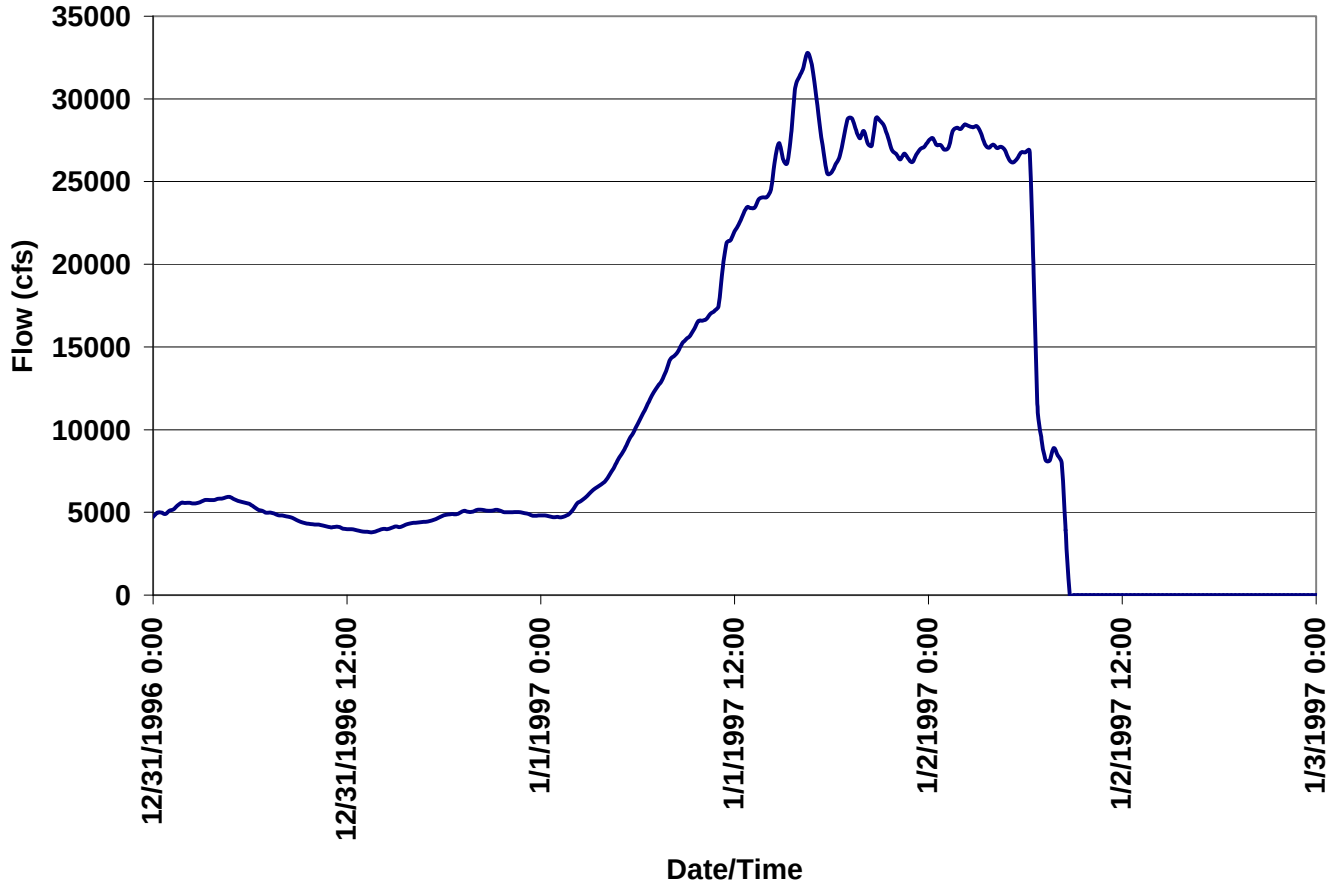
Two methods of assessing new storm impact:

1. recalibrate previously optimized parameters with new storm added to mix of old storms (more difficult)

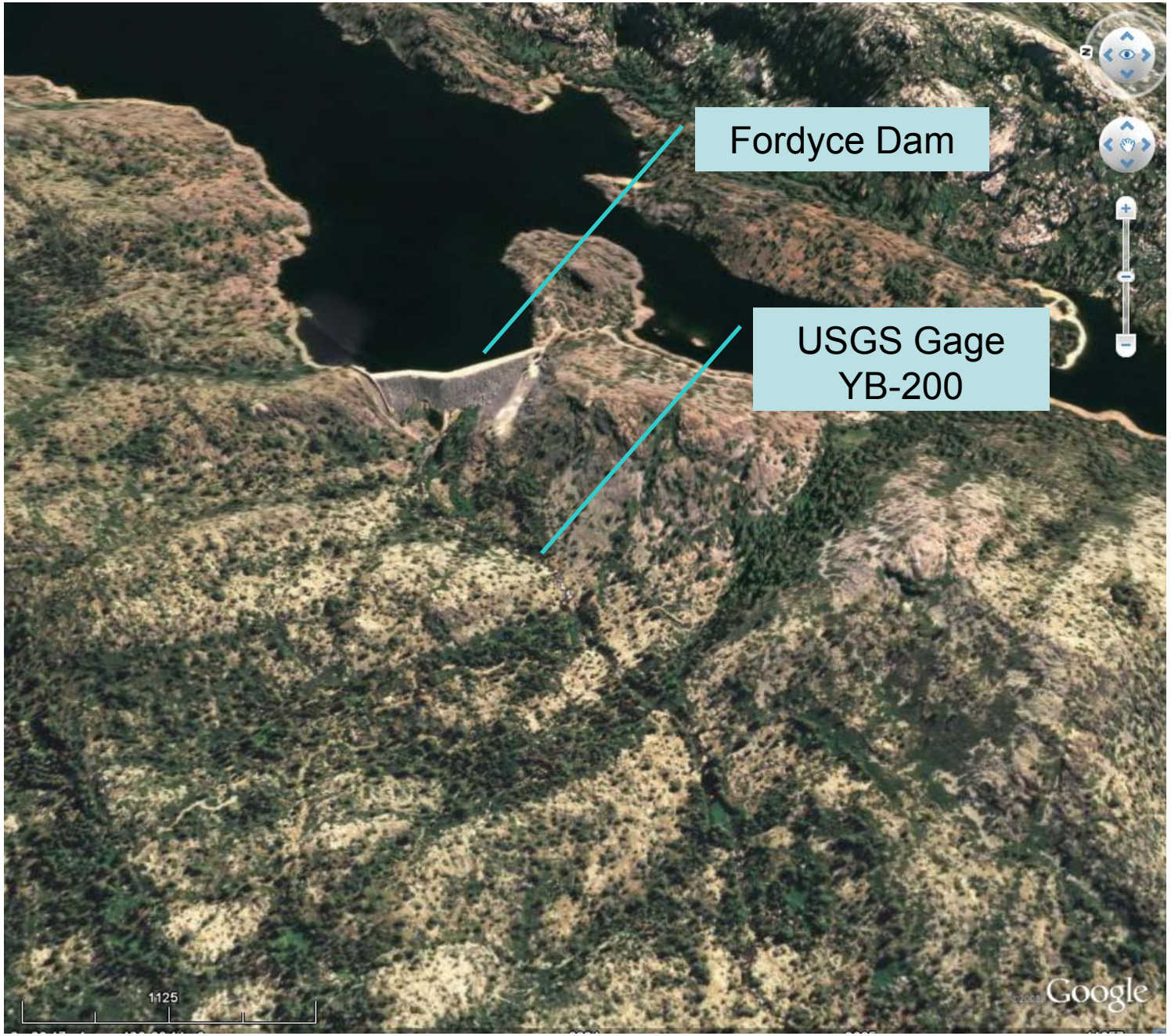
2. run previous model with new storm inputs and compare recorded storm outputs with model outputs (less difficult)

Both require reliable data from existing stream gage during storm.

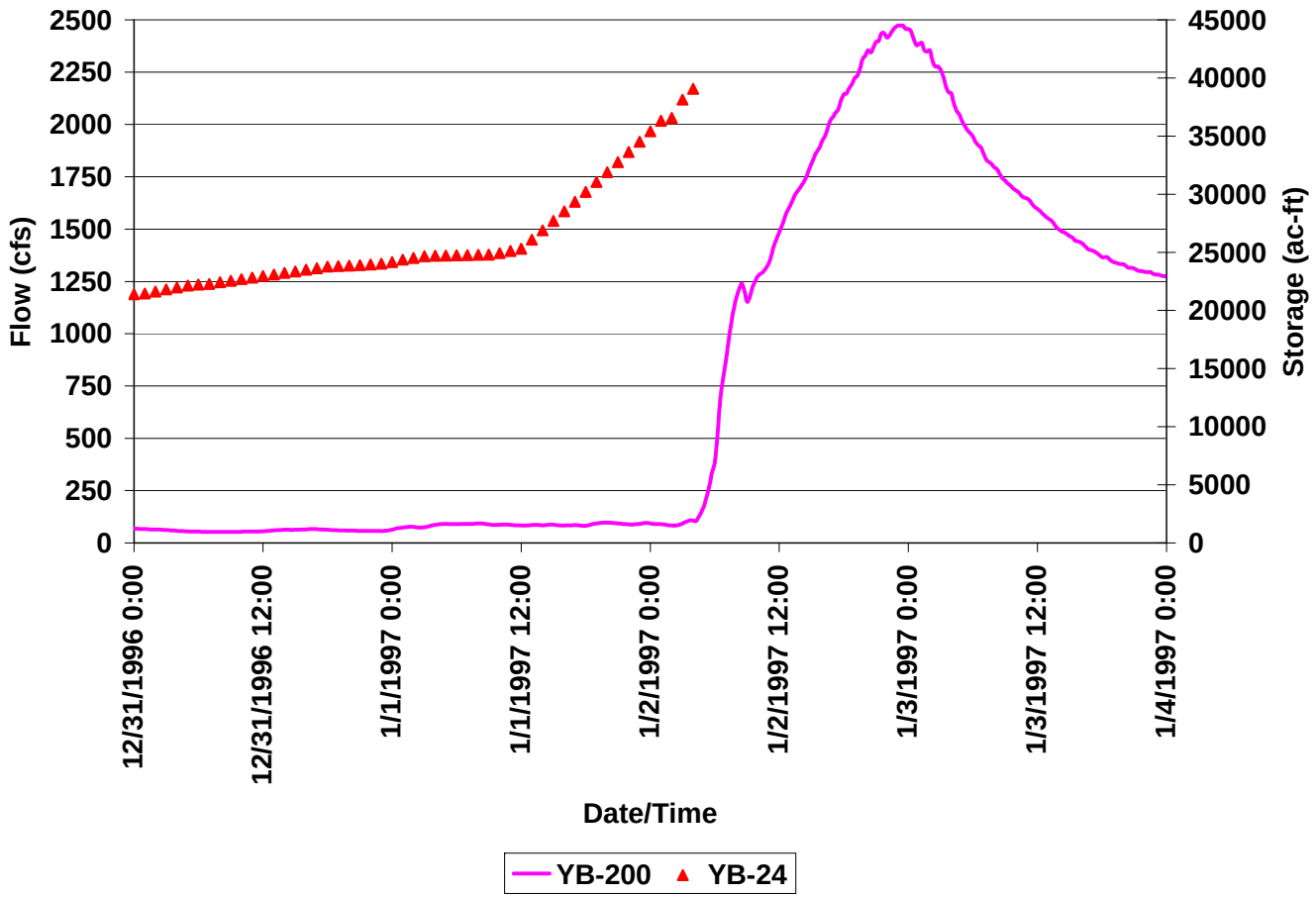
Cisco gage previously used for calibrations



Recorded 15-minute flows at the South Yuba River at Cisco gage (YB-316) during the January 1997 storm event. Note persistence of high flows and apparent gage failure at 0600-0800 hrs on 1/2/97.

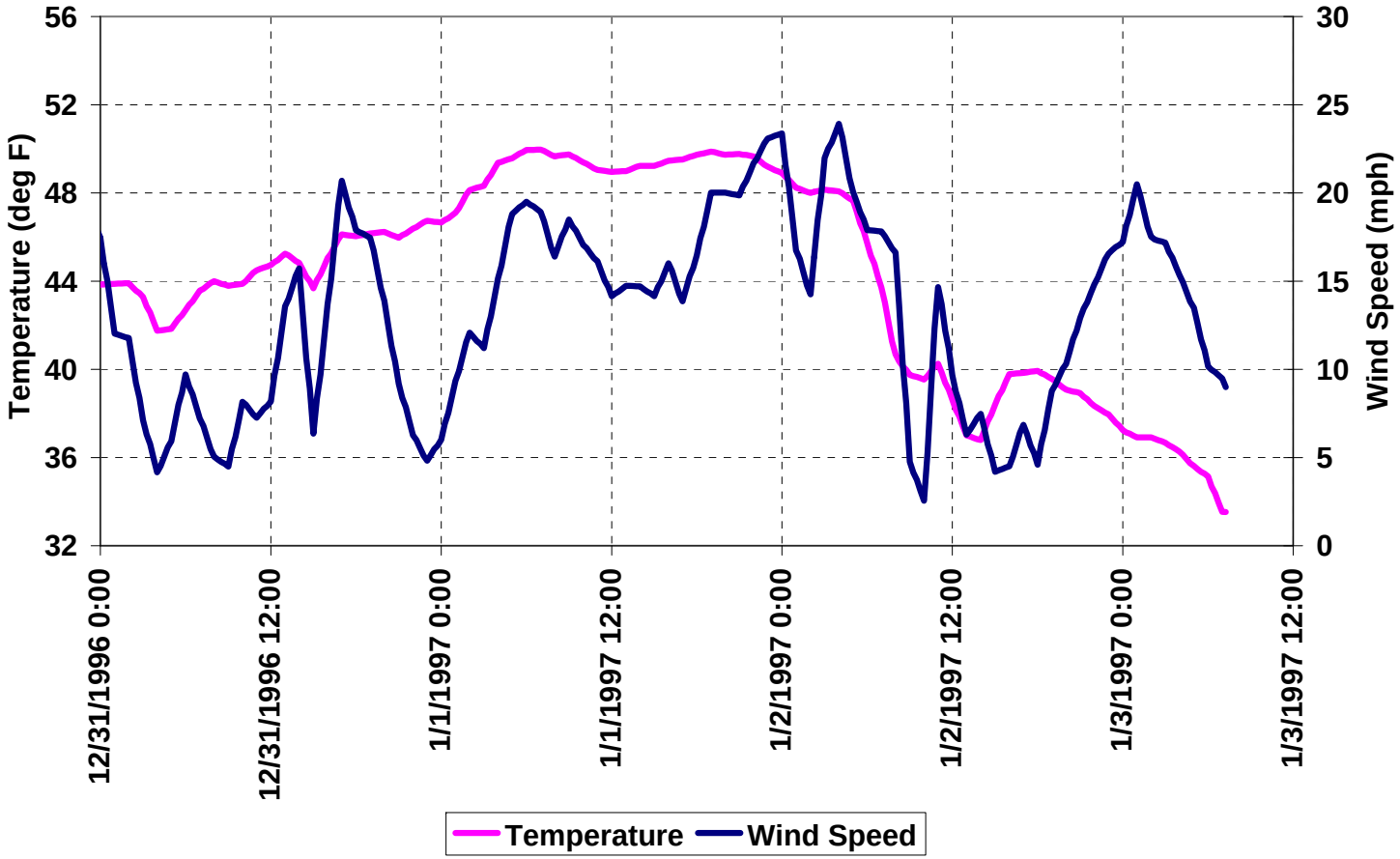

Fordyce Dam
USGS Gage
YB-200
1125
Google

Stream gage and reservoir depth during 1997 storm



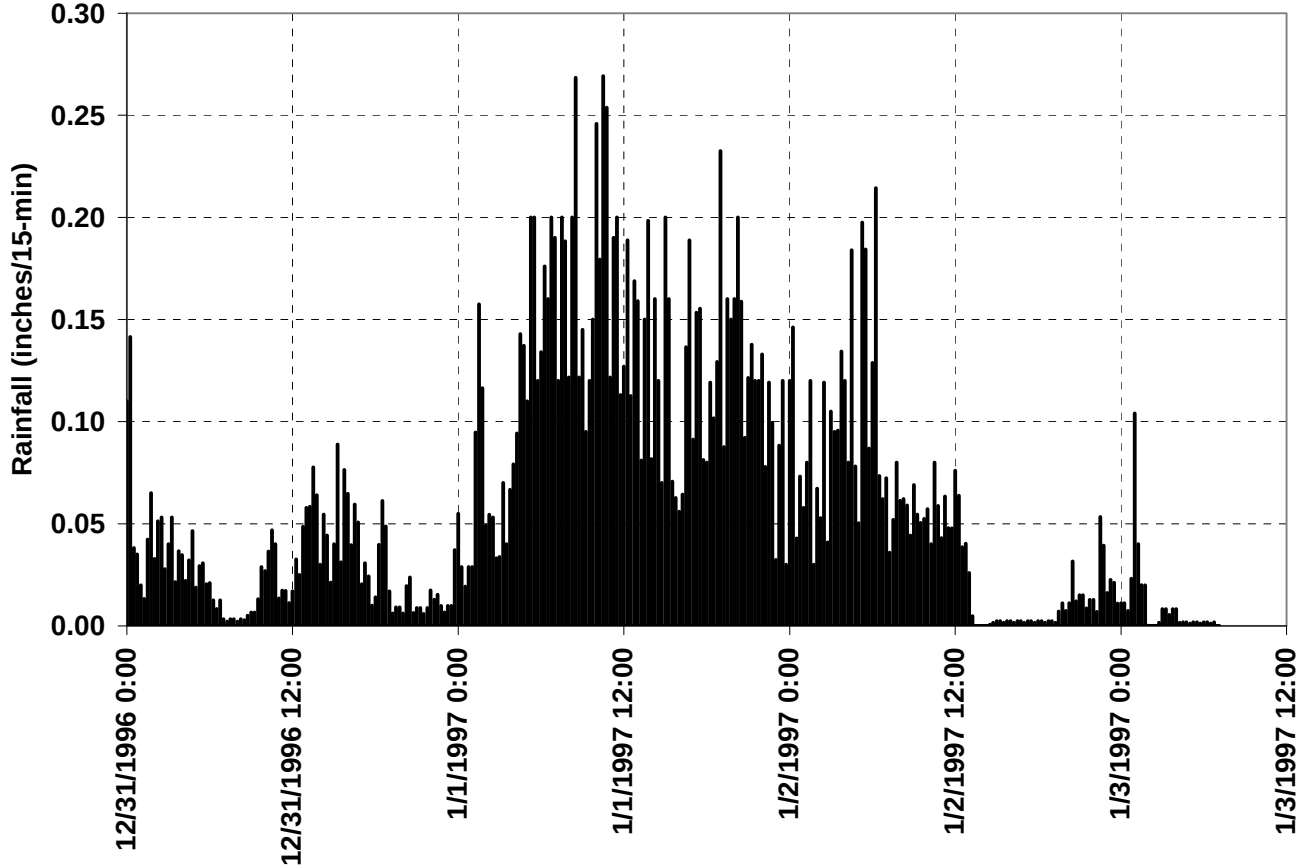
Recorded 15-minute flows at Fordyce Creek below Fordyce Dam gage (YB-200) paired with hourly recorded storage at Lake Fordyce (YB-24) during the January 1997 storm.

Temperature input during 1997 storm



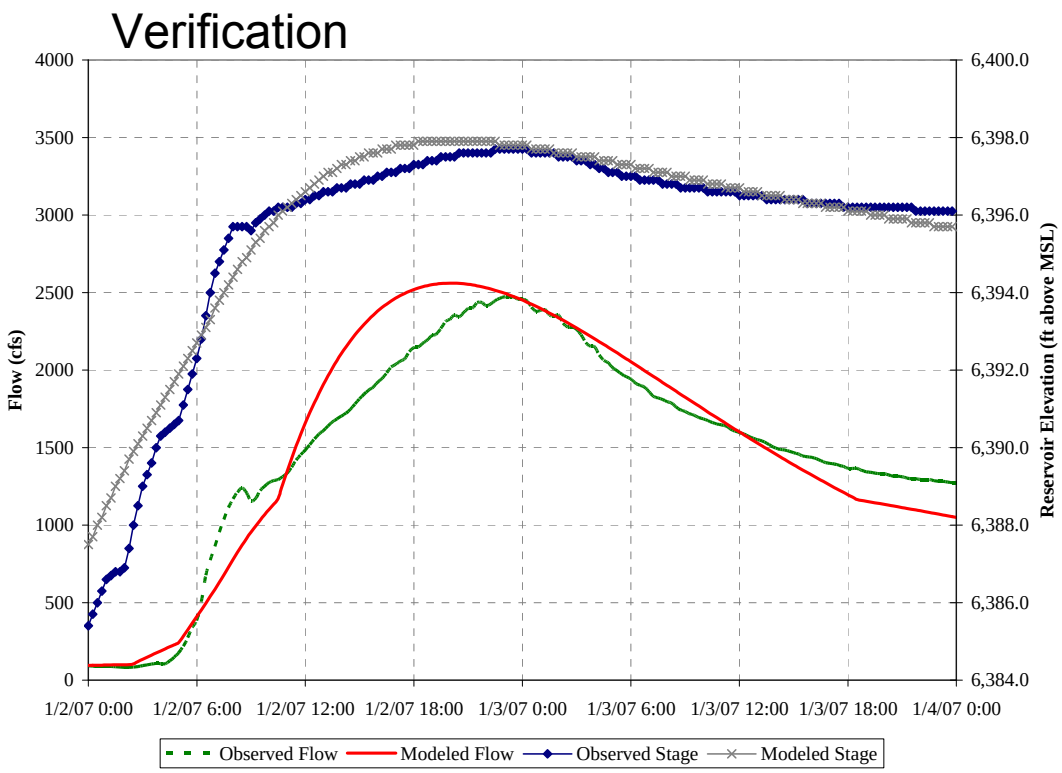
Observed wind speed and temperature measurements at Lake Spaulding during the 1997 storm

Rainfall input during 1997 storm



Observed 15-minute rainfall rates at the Blue Canyon meteorological station during the 1997 storm

Comparison of calculated versus observed 1997 flow



Comparison of modeled reservoir stage and outflow (using previous basin parameters optimized with degree day method) with recorded stage at Lake Fordyce and recorded flows below Fordyce Dam during the January 1997 storm

Conclusion: previous parameters still valid for prediction

PMF analysis of PG&E dams on upper reach of So Fork of Yuba River

Revised PMF assessment using HMR 59 in 2005:

Key steps:

1. Rerun PMF calculation with previously calibrated parameters, estimated PMP from HMR59, again using degree-day snowmelt method.

FERC review comment regarding snowmelt method:

“The report used the degree-day snowmelt method to determine snowmelt parameters. The use of the energy-budget method is recommended in our Engineering Guidelines for spring snowmelt floods. Your consultant should justify the use of the degree-day snowmelt method or recalculate the snowmelt using the energy budget method.”

PMF analysis of PG&E dams on upper reach of So Fork of Yuba River

Rerunning with energy budget method:

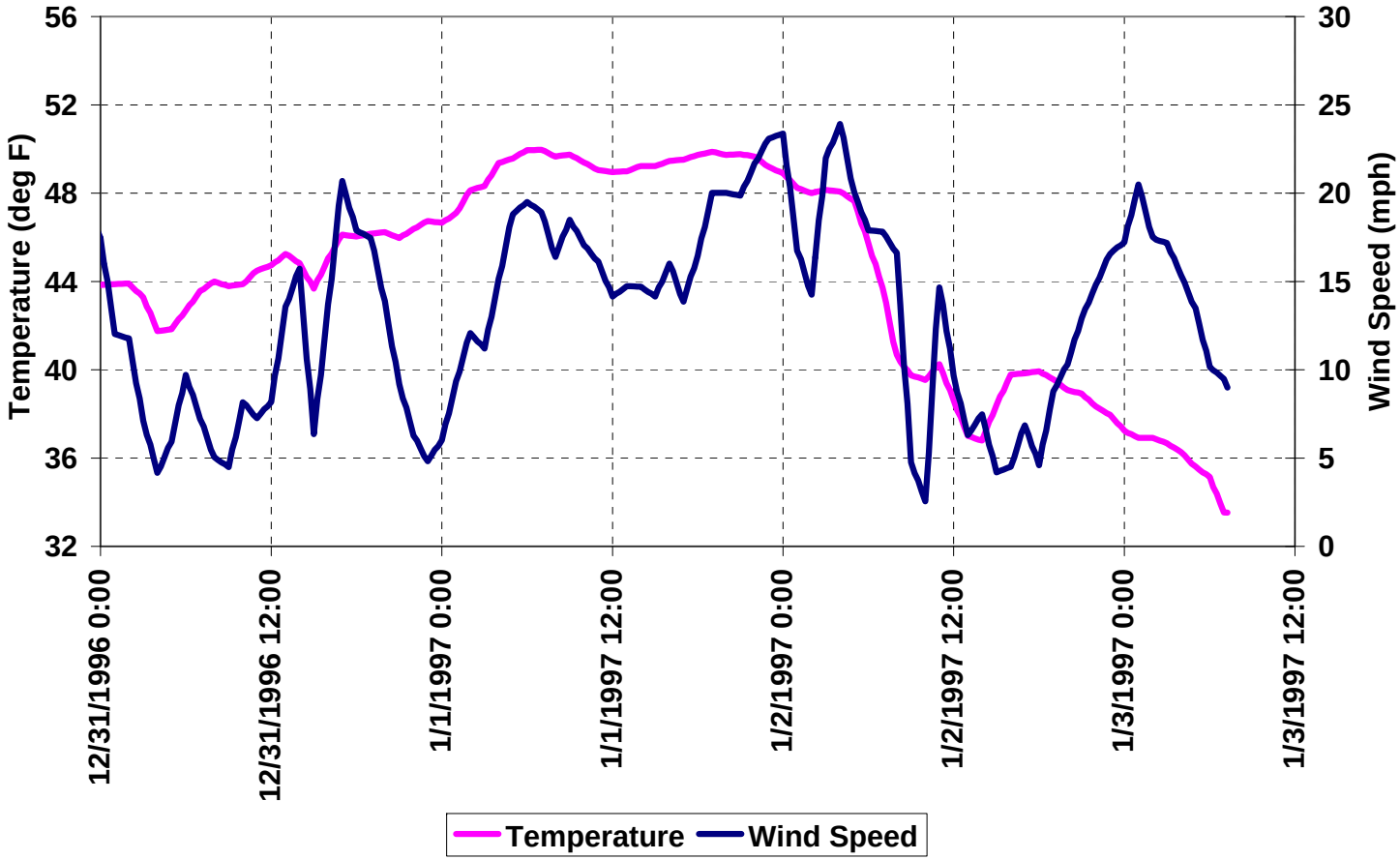
***Warning**: Running PMF calculation using energy budget method with basin parameters previously calibrated using degree-day method will result in overestimation of runoff!*

Key steps:

1. Recalibrate model loss rate and unit hydrograph parameters with historical storm data using energy budget snowmelt method.

2. Rerun PMF calculation with recalibrated parameters, estimated PMP from HMR59, again using energy budget snowmelt method.

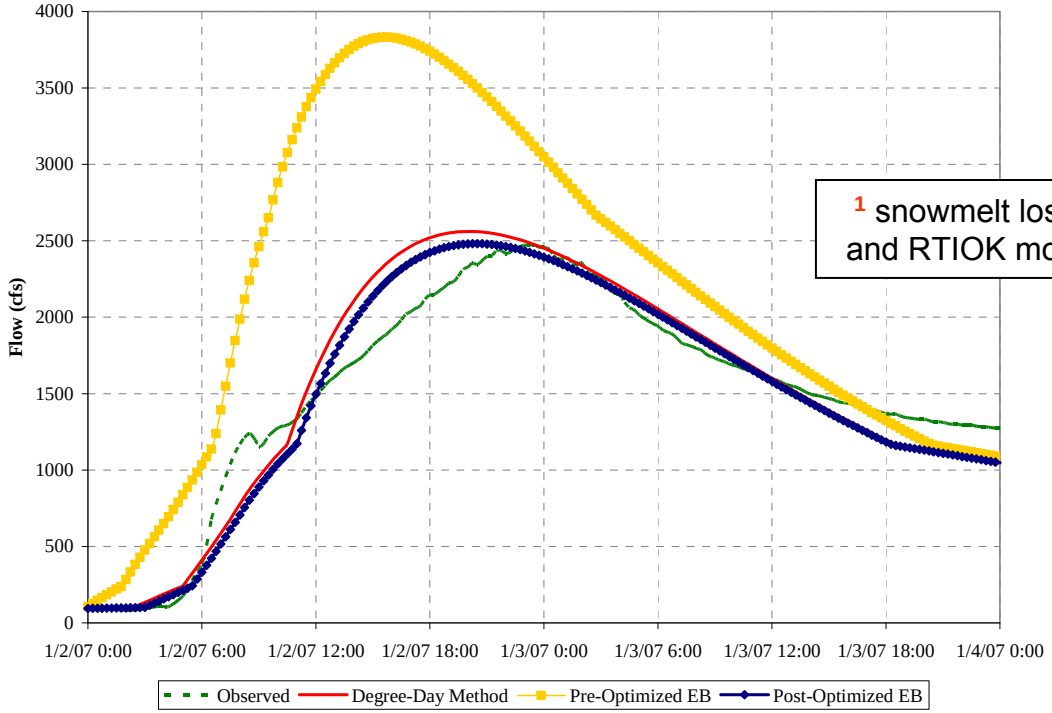
Key energy budget parameter is wind speed



Observed wind speed and temperature measurements at Lake Spaulding during the 1997 storm

Recalibrate model using energy budget method for 1997 storm

Re-Calibration results



[1] snowmelt loss parameters STRKS and RTIOK modified to obtain best fit

Comparison of calculated flow using degree-day, pre-optimized and post-optimized [1] energy-budget snowmelt methods at Fordyce Creek below Fordyce Dam during the 1997 storm.

With re-optimized parameters, can proceed to PMF analysis

Wind speeds during Central Sierra storms

“The typical chronology of storm systems in the Central Sierra Nevada Mountains features a long period of moist southerly flow with **the heaviest precipitation amounts**, either as rain or snow, depending on the height of the freezing level.”

“The cold front then moves through, accompanied by the greatest pressure gradient and consequently **the highest wind speeds**, conversion of rain to snow, again depending upon the height of the freezing level, and a general cessation of precipitation as conversion from steady rain or snow to more showery conditions.”

“While each storm is different, the wind speeds are usually highest during a brief period of time prior to cold frontal passage. Therefore, the most extreme wind speeds usually occur over brief periods of time and typically when the precipitation type is changing from liquid to frozen.” -- PG&E Meteorology Svcs

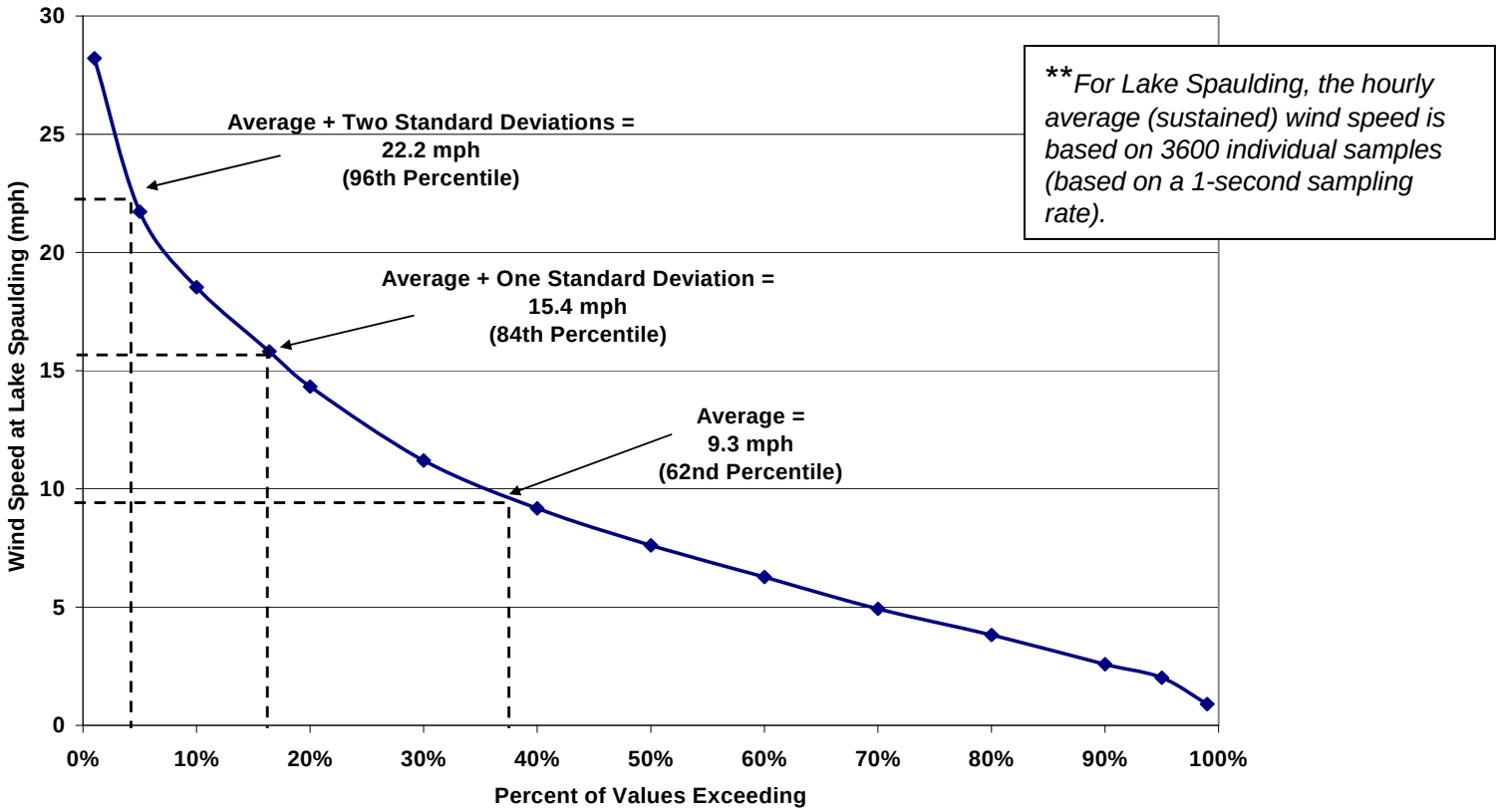
Wind speed data from HMR 59 via HMR 36

Snowmelt is specifically outside the scope of HMR 59. Instead, snowmelt procedure (including wind speed determination) is referred to HMR 36 (1961). Wind speeds as derived from the HMR 36 figures range from 38 to 62 mph and are arranged such that peak winds coincide with peak precipitation.

These wind speeds are derived as proportions of theoretical maximum wind speeds for a given elevation in the Sierra Nevada, and neglect to account for the negative correlation of warm temperature and high precipitation versus high sustained wind speeds as observed in actual storm data.

Historical storm wind speed data for basin

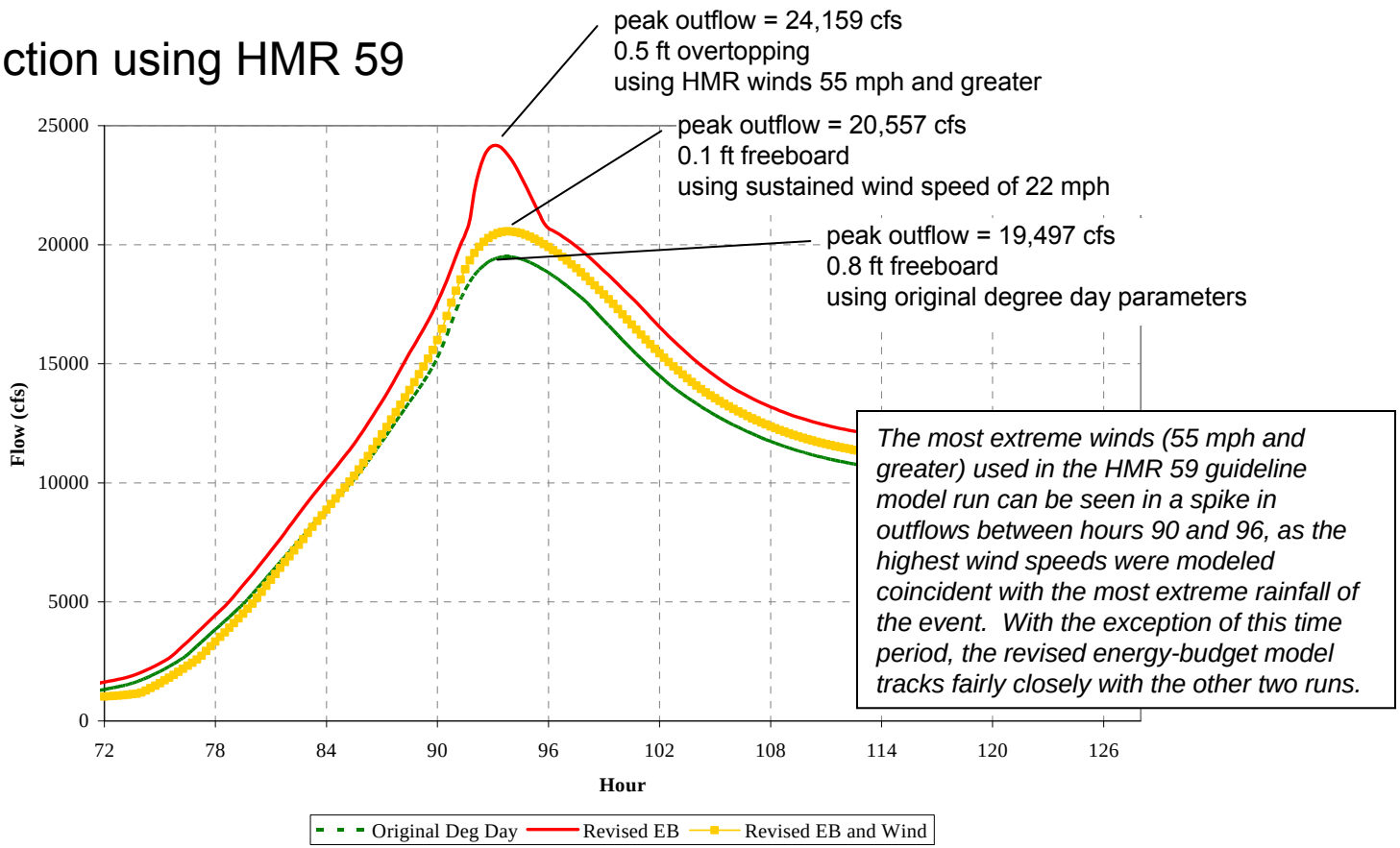
Statistical analysis of wind speed data during heavy precipitation



Sustained wind speed** exceedance curve for a variety of winter storms recorded at the Lake Spaulding station, taken from the period of December 1996 through January 2008. Includes 12 significant rain events (over 1400 data points) including the January 1997 storm.

Effect of wind speed on predicted flow

PMF prediction using HMR 59

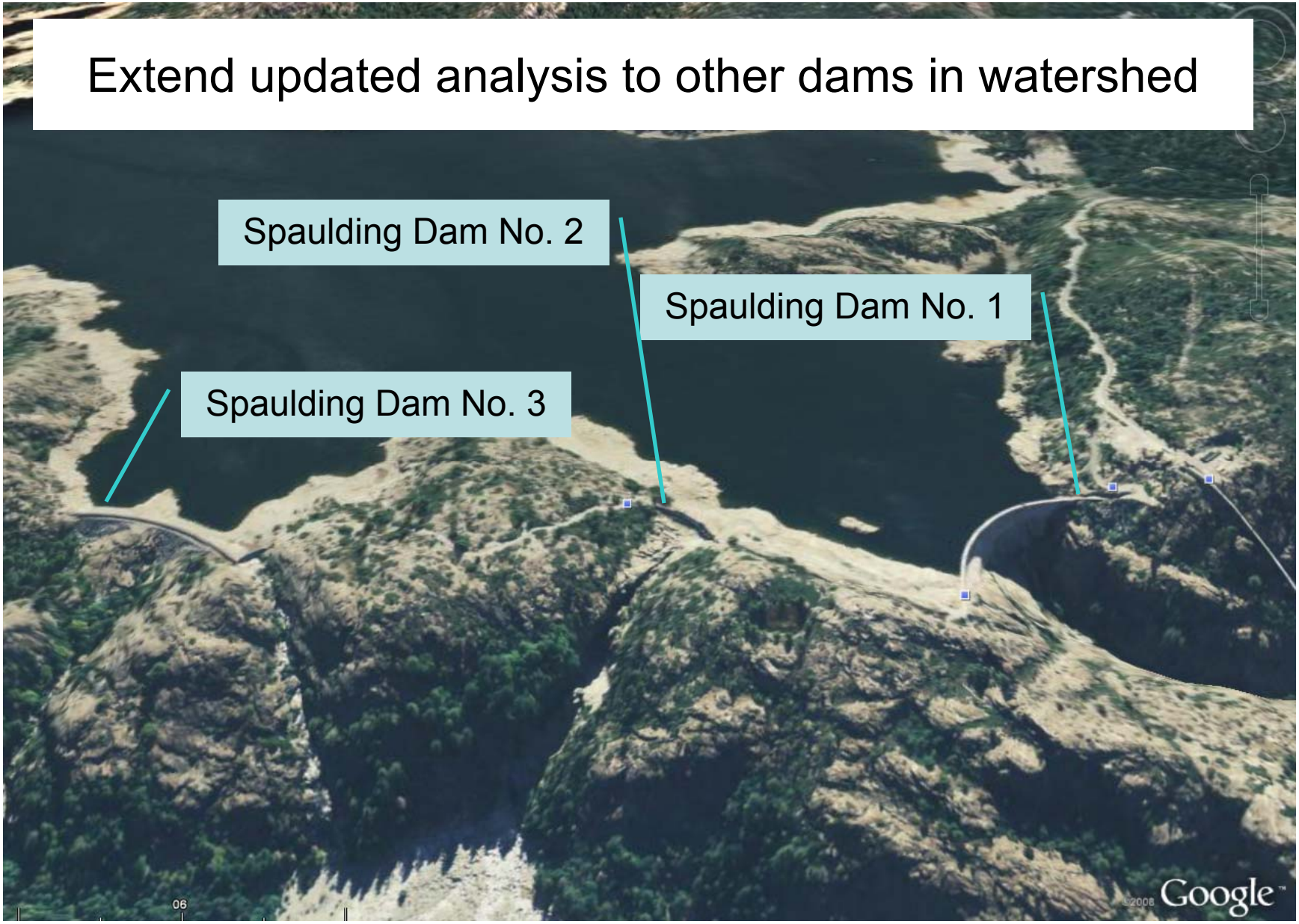


The most extreme winds (55 mph and greater) used in the HMR 59 guideline model run can be seen in a spike in outflows between hours 90 and 96, as the highest wind speeds were modeled coincident with the most extreme rainfall of the event. With the exception of this time period, the revised energy-budget model tracks fairly closely with the other two runs.

Comparison of December PMF modeled outflows in Fordyce Creek below Fordyce Dam.

Note: 1985 report (HMR 36) calculated peak outflow = 15,810 cfs and 3.0 ft freeboard

Extend updated analysis to other dams in watershed



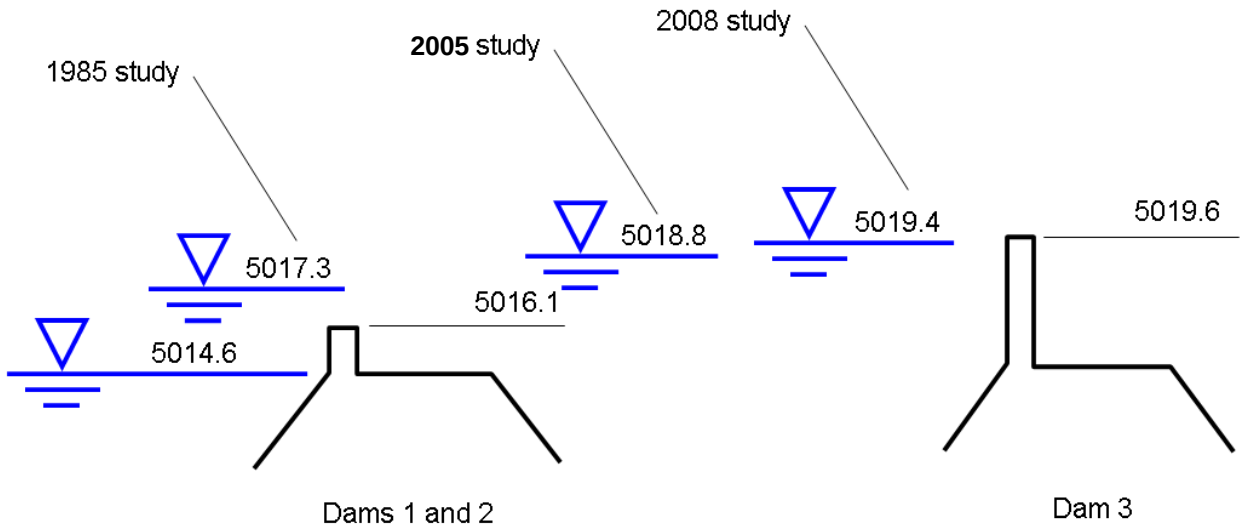
Extend updated analysis to other dams in watershed

procedure used to re-calculate for Spaulding Dam December PMF

- use same optimized snowmelt parameters determined for Fordyce
- use energy budget method to determine snowmelt
- use same sustained wind speed of 22 mph as determined for Fordyce
- precipitation and snowpack from HMR 59
- route inflow through spillways, assuming:
  - all dam no. 2 radial gates raised
  - all dam no. 2 flashboards permanently in place
  - dam no. 3 flashboards tripped at elevation 5016.6 ft (0.5 ft over dams 1,2)

PMF using energy budget method and basin wind speeds

results from recent runs for Spaulding Dam December PMF



Duration of overtopping of dams 1 and 2 ≈ 18 hours

Note: 1985 study assumed all flashboards out

Conclusion: overtopping of dams 1 and 2 continues to be predicted; overtopping of dam 3 prevented by timely operational response

PG&E PMF analyses going forward

case history conclusions

- 1997 and perhaps 1986 storms best data sources for calibration
- actual wind speed data during storms more rational than HMR 59 winds
  - HMR 59 defers to 36, origins appear obscure
  - perhaps not sustained winds?
  - may not being used appropriately?
  - big storms don’t have high precip, temps, and winds at same time
- no marked difference in results between snowmelt methods