ESTIMATING RESERVOIR EVAPORATION AT CVP/SWP RESERVOIRS FOR USE IN CALSIM II (Draft)

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Introduction

This paper describes the processes used to calculate the timeseries of evaporation at SWP and CVP reservoirs for use in the CALSIM II Joint Model. It was necessary to calculate a timeseries of evaporation data for most of the reservoirs in the model since actual data is not available for the full study period of 1921-1994. Total monthly evaporation was calculated as a function of average monthly temperature. For some reservoirs, this total monthly evaporation represented pan evaporation and had to be adjusted to represent lake evaporation. Temperature data was taken from EarthInfo's "NCDC Summary of the Day" database. The U.S. Bureau of Reclamation Central Valley Operations Office provided evaporation data for Trinity, Whiskeytown, Shasta, Folsom, San Luis, New Melones and Millerton. The Department of Water Resources Bulletin 73-79 pan evaporation data was used for Perris, Pyramid, Castaic, Hensley, Eastman, and New Hogan. Oroville pan evaporation data was provided by DWR's Oroville Field Division office. Eastbay Municipal Utility District (EBMUD) provided net evaporation data for Pardee and Camanche reservoirs for the time period 1921-1994. Dan Steiner provided net evaporation data for New Don Pedro for the time period 1921-1994.

Temperature Correlation

To calculate a timeseries of evaporation that covers the full study period, a timeseries of temperature that covers the study period must be obtained first. None of the reservoirs used in the CALSIM model had temperature data available for the full study period so temperatures were calculated at the reservoirs based on locations that did. Davis, Stockton, and Bakersfield were used to correlate temperatures with the reservoirs because these locations had temperature data for the study period 1921-1994.

A linear regression was done for each month using observed temperatures at the reservoirs as the dependent variable and observed temperatures at Davis, Stockton, or Bakersfield as the independent variable. These regressions resulted in twelve linear equations for each reservoir that could be used to calculate average monthly temperatures as a function of average monthly temperatures at one of the three locations. Observed average monthly temperatures were correlated between Davis and six reservoirs; Trinity, Whiskeytown, Shasta, Oroville, Folsom, and San Luis. New Melones and Millerton were correlated with Stockton. A timeseries of calculated temperatures at each of these reservoirs for the period 1921-1994 was then created.

Some of the reservoirs used in the CALSIM Joint Model did not have enough temperature data available to perform a temperature correlation with Davis, Stockton, or Bakersfield. This was the case for Pyramid, Castaic, Perris, and Silverwood. For these reservoirs, evaporation was calculated directly as a function of temperature at Bakersfield. Also, New Hogan, Lake McClure, Eastman, and Hensley were believed to be close enough to Stockton to use its temperatures directly for calculating total evaporation.

Evaporation Correlation

For each reservoir, twelve linear regressions were done using observed average monthly temperature as the independent variable and observed total monthly evaporation as the dependent variable. In the case of Folsom, Millerton, New Melones, San Luis, Shasta, Trinity, and Whiskeytown, the total monthly evaporation used for the regressions was provided by the U.S. Bureau of Reclamation Central Valley Operations Office and represented evaporation from the lakes as calculated by mass balance. The Department of Water Resources' Bulletin 73-79 evaporation data, which was used for Perris, Pyramid, Castaic, Hensley, Eastman, and New Hogan, was pan evaporation data so the regression equations obtained by using these values would have to be adjusted by a pan coefficient. Oroville pan evaporation data was provided by DWR's Oroville Field Division office and was also adjusted by a pan coefficient. Eastbay Municipal Utility District (EBMUD) provided net lake evaporation data for Pardee and Camanche reservoirs for the time period 1921-1994. Dan Steiner provided net lake evaporation data for New Don Pedro for the time period 1921-1994.

Where possible, evaporation data at the reservoir was compared with temperature data at the reservoir. However, as mentioned previously, some reservoirs did not have enough temperature data available for a direct correlation. The evaporation data at Silverwood, Perris, Pyramid, and Castaic was correlated directly with the temperature data at Bakersfield. The evaporation data at New Hogan, Lake McClure, Hensley, and Eastman was correlated directly with the temperature data at Stockton. This resulted in twelve linear regression equations for each reservoir that could be used to calculate total monthly evaporation in inches as a function of average monthly temperature in degrees Fahrenheit. The timeseries of calculated temperatures at each reservoir were used to calculate a timeseries of total evaporation at each reservoir for the period 1921-1994.

The linear regression equations for each reservoir are listed below. In all the equations y, the total monthly evaporation in inches, is calculated as a function of x, average monthly temperature in degrees Fahrenheit. The ranges of observed temperatures used in the linear regressions are also listed. Some reservoirs are located close enough to each other to use the same set of equations. Unless otherwise noted, the average monthly temperature is that at the reservoir. In some cases, the linear regressions yielded equations with negative slopes, implying that evaporation decreased with increased temperature. This was attributed to lack of sufficient data. In these cases, the total monthly evaporation was set equal to the average of that month's observed total monthly evaporation. The total monthly evaporation calculated for Perris, Pyramid, Castaic, Hensley, Eastman, New Hogan, and Oroville using the equations listed below was then multiplied by a pan coefficient of 0.79. The pan coefficient 0.79 is listed in the Department of Water Resources Bulletin 73-79 as the coefficient used to correlate Lake Elsinore evaporation with pan evaporation.

Trinity

January	$y = 0.0495x - 1.48$	$36 \le x \le 44$
February	$y = 0.0804x - 2.51$	$39 \le x \le 49$
March	$y = 0.191x - 6.65$	$40 \le x \le 51$

April	y = 0.210x - 6.35	39 ≤ x ≤ 58
May	y = 0.184x - 3.87	52 ≤ x ≤ 66
June	y = 0.166x - 2.55	61 ≤ x ≤ 72
July	y = 0.133x + 0.379	66 ≤ x ≤ 77
August	y = 0.329x - 14.3	66 ≤ x ≤ 76
September	y = 0.175x - 5.19	60 ≤ x ≤ 70
October	y = 0.108x - 2.88	49 ≤ x ≤ 61
November	y = 0.0459x - 1.16	38 ≤ x ≤ 51
December	y = 0.0452x - 1.35	29 ≤ x ≤ 43

Whiskeytown

January	y = 0.039x - 1.06	40 ≤ x ≤ 49
February	y = 0.106x - 3.90	41 ≤ x ≤ 54
March	y = 0.104x - 2.96	47 ≤ x ≤ 56
April	y = 0.175x - 5.82	46 ≤ x ≤ 63
May	y = 0.273x - 11.1	57 ≤ x ≤ 72
June	y = 0.319x - 15.0	67 ≤ x ≤ 77
July	y = 0.220x - 7.61	75 ≤ x ≤ 84
August	y = 0.340x - 17.7	71 ≤ x ≤ 85
September	y = 0.201x - 8.44	66 ≤ x ≤ 80
October	y = 0.147x - 5.83	56 ≤ x ≤ 71
November	y = 0.0852x - 3.24	43 ≤ x ≤ 58
December	y = 0.0474x - 1.46	38 ≤ x ≤ 50

Shasta

January	y = 0.0432x - 0.467	41 ≤ x ≤ 50
February	y = 0.107x - 3.27	41 ≤ x ≤ 55
March	y = 0.138x - 4.13	47 ≤ x ≤ 57
April	y = 0.224x - 8.08	50 ≤ x ≤ 66
May	y = 0.268x - 10.5	55 ≤ x ≤ 75
June	y = 0.223x - 7.59	67 ≤ x ≤ 80
July	y = 0.250x - 9.01	75 ≤ x ≤ 86
August	y = 0.273x - 11.7	73 ≤ x ≤ 86
September	y = 0.292x - 14.1	69 ≤ x ≤ 81
October	y = 0.241x - 10.8	59 ≤ x ≤ 72
November	y = 0.161x - 6.32	46 ≤ x ≤ 59
December	y = 0.114x - 3.72	39 ≤ x ≤ 53

Oroville and Thermalito

January	y = 0.00160x + 1.04	43 ≤ x ≤ 52
February	y = 0.0109x + 1.20	46 ≤ x ≤ 54
March	y = 0.146x - 4.78	48 ≤ x ≤ 59
April	y = 0.167x - 4.81	54 ≤ x ≤ 65
May	y = 0.0856x + 1.62	54 ≤ x ≤ 71

June	y = 0.363x - 17.2	68 ≤ x ≤ 76
July	y = 0.137x + 0.381	73 ≤ x ≤ 82
August	y = 0.506x - 28.0	73 ≤ x ≤ 79
September	y = 0.257x - 10.2	63 ≤ x ≤ 73
October	y = 0.146x - 3.74	59 ≤ x ≤ 68
November	y = 0.0813x - 2.25	46 ≤ x ≤ 58
December	y = 0.0482x - 0.992	41 ≤ x ≤ 51

Folsom

January	y = 0.0512x - 1.45	41 ≤ x ≤ 53
February	y = 0.0376x - 0.314	46 ≤ x ≤ 57
March	y = 0.0922x - 1.91	50 ≤ x ≤ 63
April	y = 0.193x - 6.28	49 ≤ x ≤ 65
May	y = 0.267x - 9.77	58 ≤ x ≤ 74
June	y = 0.198x - 4.95	68 ≤ x ≤ 78
July	y = 0.107x + 2.45	72 ≤ x ≤ 83
August	y = 0.186x - 4.71	72 ≤ x ≤ 82
September	y = 0.208x - 8.04	67 ≤ x ≤ 78
October	y = 0.189x - 7.69	60 ≤ x ≤ 71
November	y = 0.100x - 3.61	48 ≤ x ≤ 60
December	y = 0.0475x - 1.25	40 ≤ x ≤ 53

San Luis and Del Valle

January	y = 0.0372x - 0.317	42 ≤ x ≤ 51
February	y = 0.0511x - 0.131	48 ≤ x ≤ 55
March	y = 0.201x - 6.16	52 ≤ x ≤ 59
April	y = 0.416x - 16.7	54 ≤ x ≤ 66
May	y = 0.479x - 18.9	60 ≤ x ≤ 74
June	y = 0.407x - 13.8	67 ≤ x ≤ 79
July	y = 0.407x - 13.6	72 ≤ x ≤ 82
August	y = 0.332x - 9.43	73 ≤ x ≤ 81
September	y = 0.387x - 16.7	69 ≤ x ≤ 78
October	y = 0.205x - 6.11	63 ≤ x ≤ 71
November	y = 0.120x - 3.34	49 ≤ x ≤ 60
December	y = 0.038x - 0.219	41 ≤ x ≤ 51

Pardee and Camanche
Timeseries supplied by EBMUD

New Hogan (using Stockton average monthly temperature)

January	y = 0.042x - 0.477	40 ≤ x ≤ 50
February	y = 0.0268x + 0.773	46 ≤ x ≤ 57
March	y = 0.00990x + 3.37	50 ≤ x ≤ 58
April	y = 0.257x - 9.19	50 ≤ x ≤ 63

May	y = 0.436x - 19.7	60 ≤ x ≤ 68
June	y = 0.255x - 7.29	67 ≤ x ≤ 76
July	y = 0.0711x + 7.79	72 ≤ x ≤ 78
August	y = 0.351x - 14.2	71 ≤ x ≤ 77
September	y = 0.122x + 0.241	64 ≤ x ≤ 74
October	y = 0.139x - 3.02	60 ≤ x ≤ 67
November	y = 0.123x - 4.24	50 ≤ x ≤ 56
December	y = 0.0395x - 0.457	40 ≤ x ≤ 50

New Melones

January	y = 0.0466x - 0.722	41 ≤ x ≤ 51
February	y = 0.0493x - 0.185	43 ≤ x ≤ 53
March	y = 0.128x - 3.18	48 ≤ x ≤ 58
April	y = 0.220x - 7.01	53 ≤ x ≤ 62
May	y = 0.282x - 9.50	57 ≤ x ≤ 72
June	y = 0.201x - 3.53	65 ≤ x ≤ 75
July	y = 0.0692x + 7.50	72 ≤ x ≤ 84
August	y = 12.0	
September	y = 0.165x - 3.17	66 ≤ x ≤ 76
October	y = 0.184x - 5.98	58 ≤ x ≤ 68
November	y = 0.0497x - 0.169	47 ≤ x ≤ 60
December	y = 0.0256x + 0.137	39 ≤ x ≤ 51

New Don Pedro (net evaporation from Dan Steiner)

October	y = 4.72
November	y = 1.27
December	y = -0.10
January	y = -0.65
February	y = -0.17
March	y = 0.84
April	y = 2.20
May	y = 5.88
June	y = 7.82
July	y = 10.31
August	y = 10.41
September	y = 7.65

Lake McClure (using Stockton average monthly temperature)

January	y = 0.000200x + 1.30	40 ≤ x ≤ 50
February	y = 2.18	
March	y = 0.174x - 5.18	49 ≤ x ≤ 58
April	y = 0.386x - 16.3	50 ≤ x ≤ 63
May	y = 0.608x - 29.5	60 ≤ x ≤ 68
June	y = 0.469x - 20.7	64 ≤ x ≤ 76
July	y = 0.279x - 6.08	72 ≤ x ≤ 78

August	y = 0.380x - 14.9	70 ≤ x ≤ 77
September	y = 0.190x - 3.61	64 ≤ x ≤ 74
October	y = 0.285x - 11.7	59 ≤ x ≤ 67
November	y = 0.063x - 0.985	50 ≤ x ≤ 58
December	y = 0.0360x - 0.335	40 ≤ x ≤ 51

Eastman (using Stockton average monthly temperature)

January	y = 1.12	
February	y = 1.03x - 51.1	51 ≤ x ≤ 52
March	y = 3.87	
April	y = 0.680x - 34.5	57 ≤ x ≤ 63
May	y = 0.236x - 6.60	60 ≤ x ≤ 68
June	y = 0.180x - 1.15	71 ≤ x ≤ 73
July	y = 14.3	
August	y = 0.537x - 27.8	71 ≤ x ≤ 75
September	y = 8.19	
October	y = 5.92	
November	y = 0.0521x - 0.361	50 ≤ x ≤ 55
December	y = 0.0342x - 0.334	42 ≤ x ≤ 50

Hensley (using Stockton average monthly temperature)

January	y = 0.00180x + 1.19	43 ≤ x ≤ 50
February	y = 1.93x - 96.9	51 ≤ x ≤ 52
March	y = 4.72	
April	y = 0.879x - 44.9	57 ≤ x ≤ 63
May	y = 0.321x - 9.83	60 ≤ x ≤ 68
June	y = 0.294x - 6.81	71 ≤ x ≤ 73
July	y = 16.8	
August	y = 0.596x - 30.2	71 ≤ x ≤ 75
September	y = 9.99	
October	y = 7.62	
November	y = 0.125x - 3.54	50 ≤ x ≤ 55
December	y = 0.125x - 4.04	42 ≤ x ≤ 46

Millerton

January	y = 0.0853x - 2.46	42 ≤ x ≤ 54
February	y = 0.0792x - 1.97	48 ≤ x ≤ 56
March	y = 3.56	
April	y = 0.218x - 8.07	57 ≤ x ≤ 67
May	y = 0.298x - 12.0	62 ≤ x ≤ 76
June	y = 0.294x - 11.5	72 ≤ x ≤ 83
July	y = 0.114x + 3.43	77 ≤ x ≤ 87
August	y = 0.206x - 5.50	73 ≤ x ≤ 84
September	y = 0.233x - 9.47	71 ≤ x ≤ 81
October	y = 0.077x + 0.216	61 ≤ x ≤ 71

November	y = 0.102x - 3.06	48 ≤ x ≤ 59
December	y = 0.0544x - 1.20	41 ≤ x ≤ 51

Pyramid (using Bakersfield average monthly temperature)

January	y = 3.89	
February	y = 0.0525x + 1.08	50 ≤ x ≤ 59
March	y = 0.198x - 6.09	54 ≤ x ≤ 63
April	y = 0.271x - 10.1	53 ≤ x ≤ 68
May	y = 0.356x - 16.5	67 ≤ x ≤ 74
June	y = 0.465x - 26.7	75 ≤ x ≤ 84
July	y = 12.1	
August	y = 11.9	
September	y = 0.133x - 1.38	75 ≤ x ≤ 83
October	y = 0.184x - 5.92	64 ≤ x ≤ 75
November	y = 4.59	
December	y = 0.259x - 8.75	44 ≤ x ≤ 57

Castaic (using Bakersfield average monthly temperature)

January	y = 4.01	
February	y = 0.0986x - 1.00	50 ≤ x ≤ 57
March	y = 0.286x - 10.8	54 ≤ x ≤ 63
April	y = 0.221x - 7.48	59 ≤ x ≤ 68
May	y = 8.07	
June	y = 0.359x - 20.1	77 ≤ x ≤ 84
July	y = 0.264x - 12.4	84 ≤ x ≤ 88
August	y = 0.114x + 0.424	79 ≤ x ≤ 86
September	y = 8.10	
October	y = 6.53	
November	y = 4.94	
December	y = 3.90	

Perris and Silverwood (using Bakersfield average monthly temperature)

January	y = 3.84	
February	y = 0.0200x + 2.88	49 ≤ x ≤ 59
March	y = 5.36	
April	y = 0.347x - 15.3	53 ≤ x ≤ 68
May	y = 0.178x - 4.20	67 ≤ x ≤ 77
June	y = 0.415 - 22.4	73 ≤ x ≤ 84
July	y = 0.0584x + 7.91	81 ≤ x ≤ 87
August	y = 0.117x + 2.60	79 ≤ x ≤ 88
September	y = 0.146x - 2.04	72 ≤ x ≤ 83
October	y = 0.180x - 5.56	66 ≤ x ≤ 75
November	y = 4.31	
December	y = 3.15	

Total Evaporation versus Net Evaporation

For some reservoirs in the CALSIM Joint Model, precipitation is taken into account in the inflow hydrology. For others, however, precipitation is accounted for by subtracting it from evaporation, thus giving a net evaporation amount. Net evaporation was used for Oroville, Thermalito, San Luis, Del Valle, Pardee, Camanche, New Don Pedro, Lake McClure, Silverwood, Perris, Pyramid, and Castaic. The average monthly precipitation amounts shown below were subtracted from the calculated evaporation to get a timeseries of net evaporation for the study period 1921-1994. In some cases, precipitation at one location was used for other nearby locations. New Don Pedro monthly precipitation was taken from the CDEC website and used for Lake McClure. Monthly precipitation values for Oroville, San Luis, Pardee, Perris, and Saugus Power Plant (for Pyramid and Castaic) were taken from EarthInfo's "NCDC Summary of the Day."

Oroville and Thermalito

January	6.07
February	4.25
March	3.40
April	2.12
May	0.76
June	0.37
July	0.06
August	0.10
September	0.32
October	1.73
November	3.78
December	4.81

San Luis and Del Valle

January	2.14
February	1.91
March	1.60
April	0.68
May	0.42
June	0.06
July	0.03
August	0.09
September	0.22
October	0.50
November	1.42
December	1.45

Pardee and Camanche
Net evaporation data supplied by EBMUD

New Don Pedro
Net evaporation data supplied by Dan Steiner

Lake McClure

January	3.01
February	2.04
March	1.82
April	1.00
May	0.96
June	0.05
July	0.00
August	0.04
September	0.04
October	0.56
November	1.23
December	2.07

Perris and Silverwood

January	1.63
February	1.94
March	1.29
April	1.04
May	0.16
June	0.06
July	0.33
August	0.06
September	0.35
October	0.14
November	1.97
December	1.45

Pyramid and Castaic (Saugus Power Plant)

January	3.73
February	3.56
March	3.08
April	1.47
May	0.51
June	0.11
July	0.03
August	0.12
September	0.30
October	0.49
November	2.01
December	2.42

References

Department of Water Resources, 1979. Bulletin 73-79: Evaporation from Water Surfaces in California.

Appendix A
Observed and Calculated Evaporation Charts

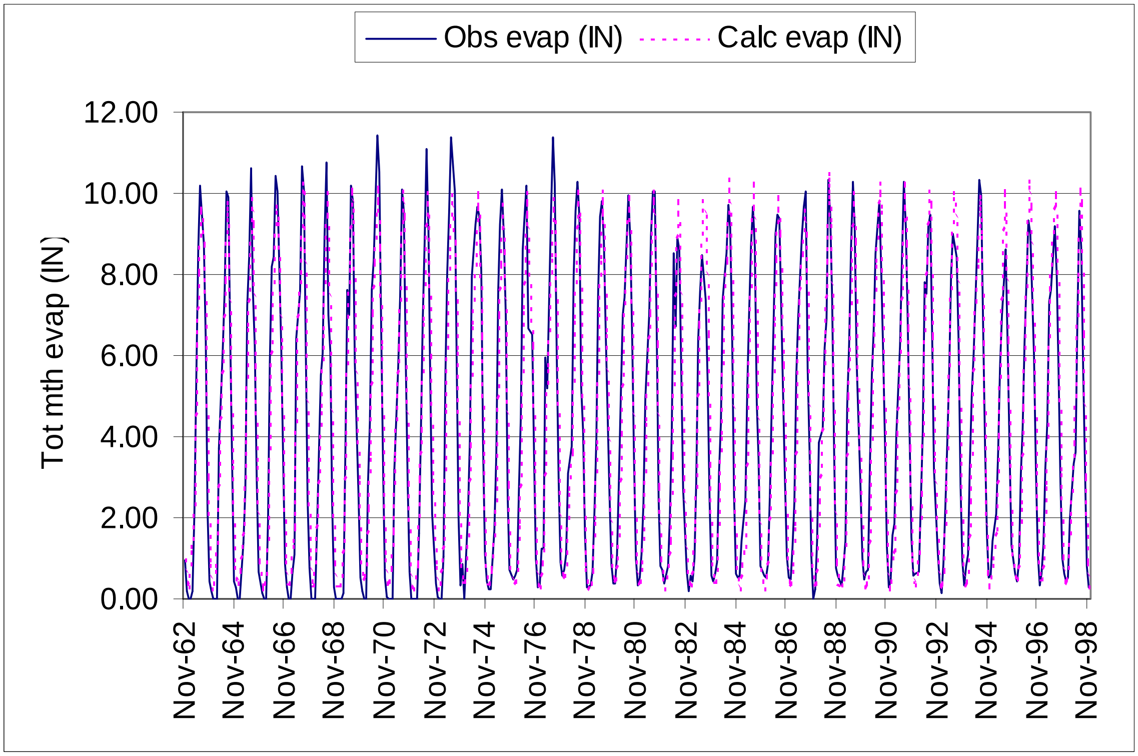

Figure 1: Trinity Observed and Calculated Evaporation

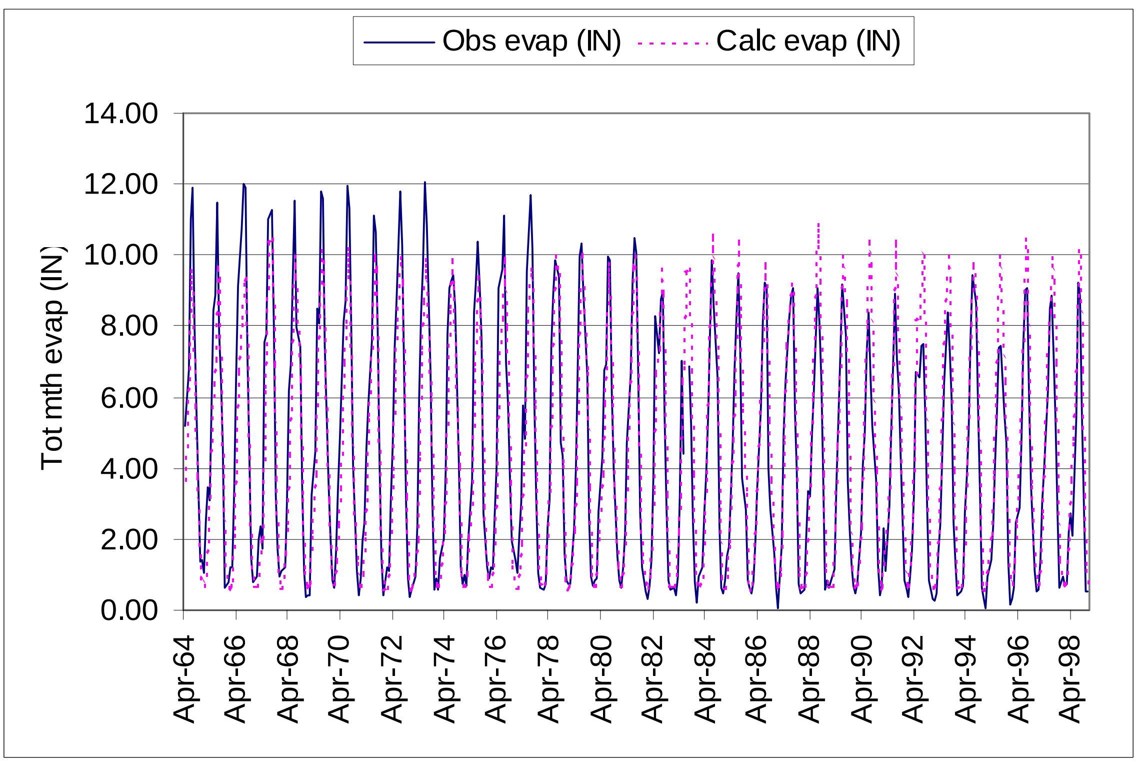

Figure 2: Whiskeytown Observed and Calculated Evaporation

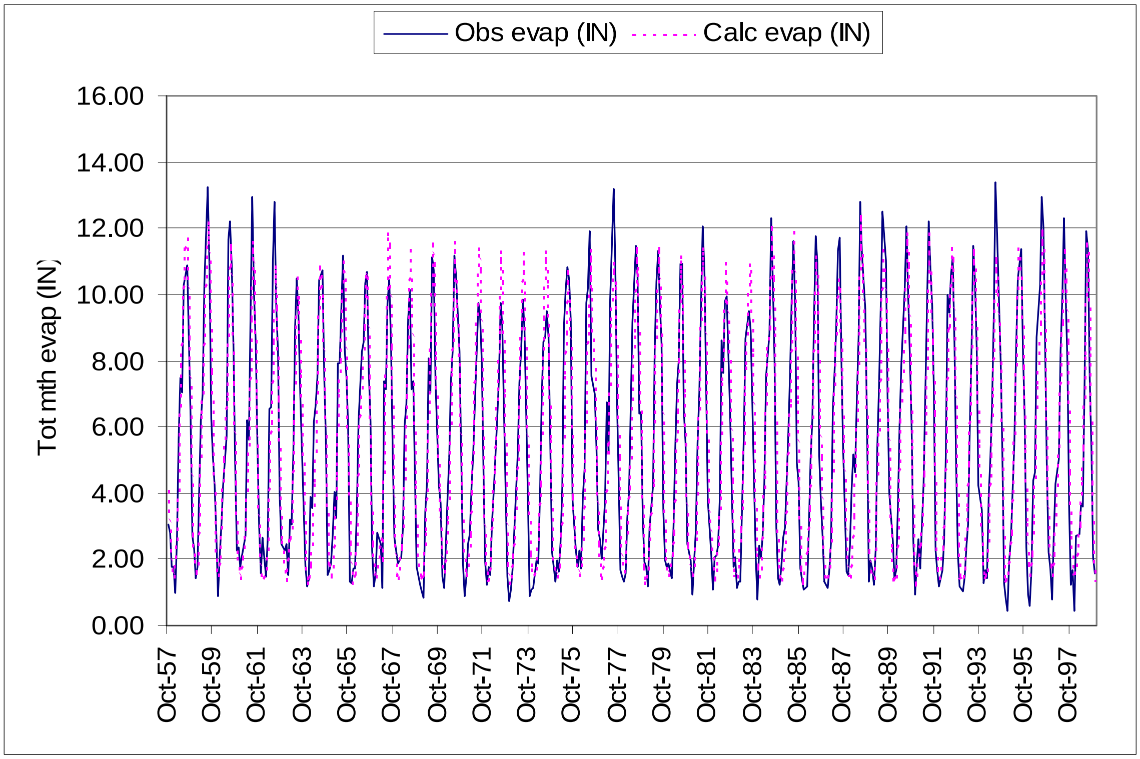

Figure 3: Shasta Observed and Calculated Evaporation

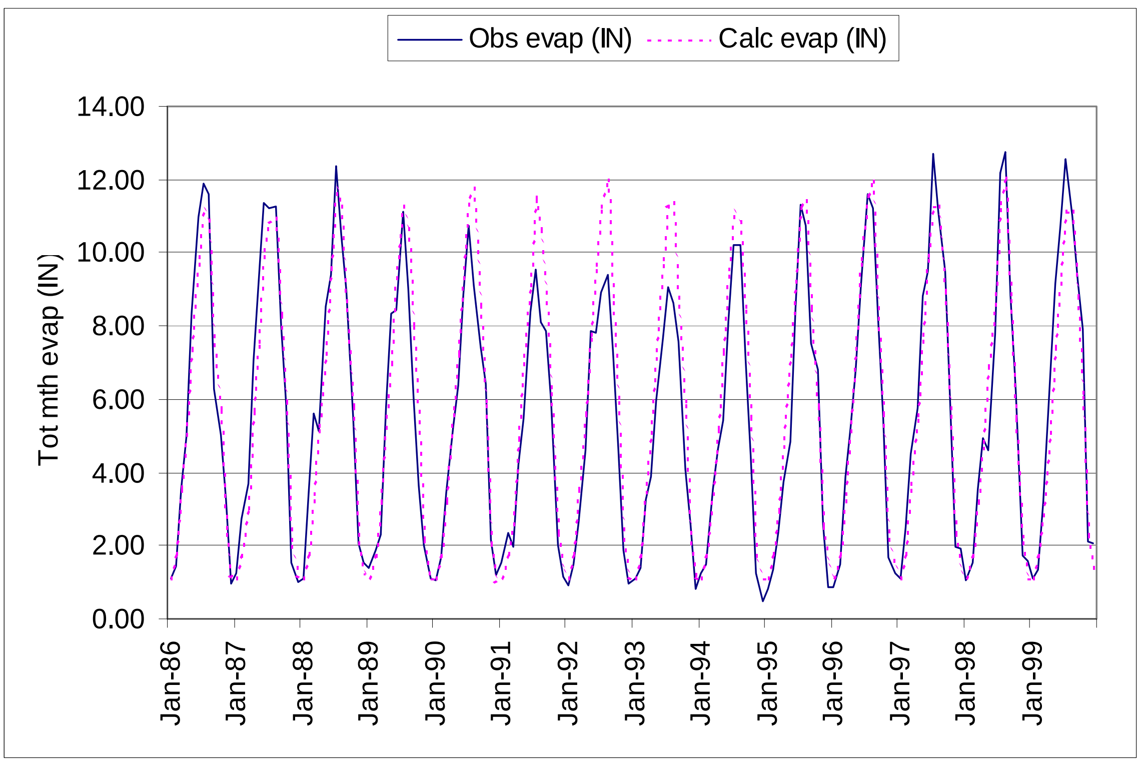

Figure 4: Oroville/Thermalito Observed and Calculated Evaporation

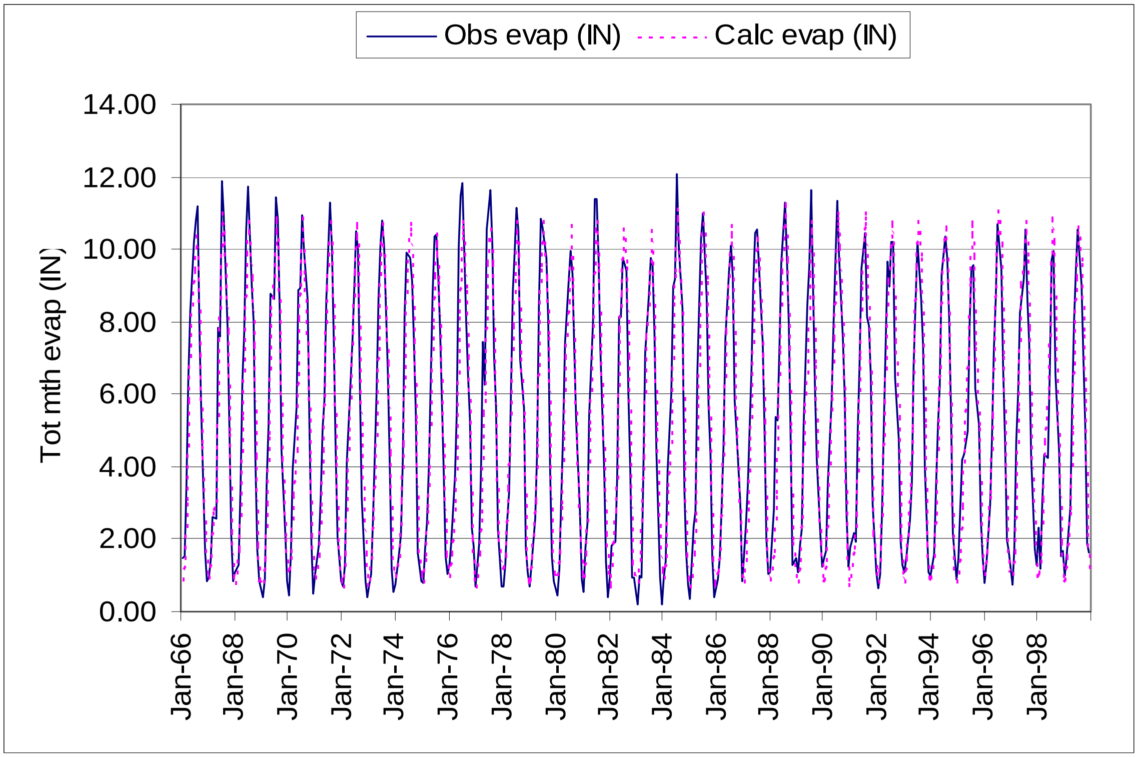

Figure 5: Folsom Observed and Calculated Evaporation

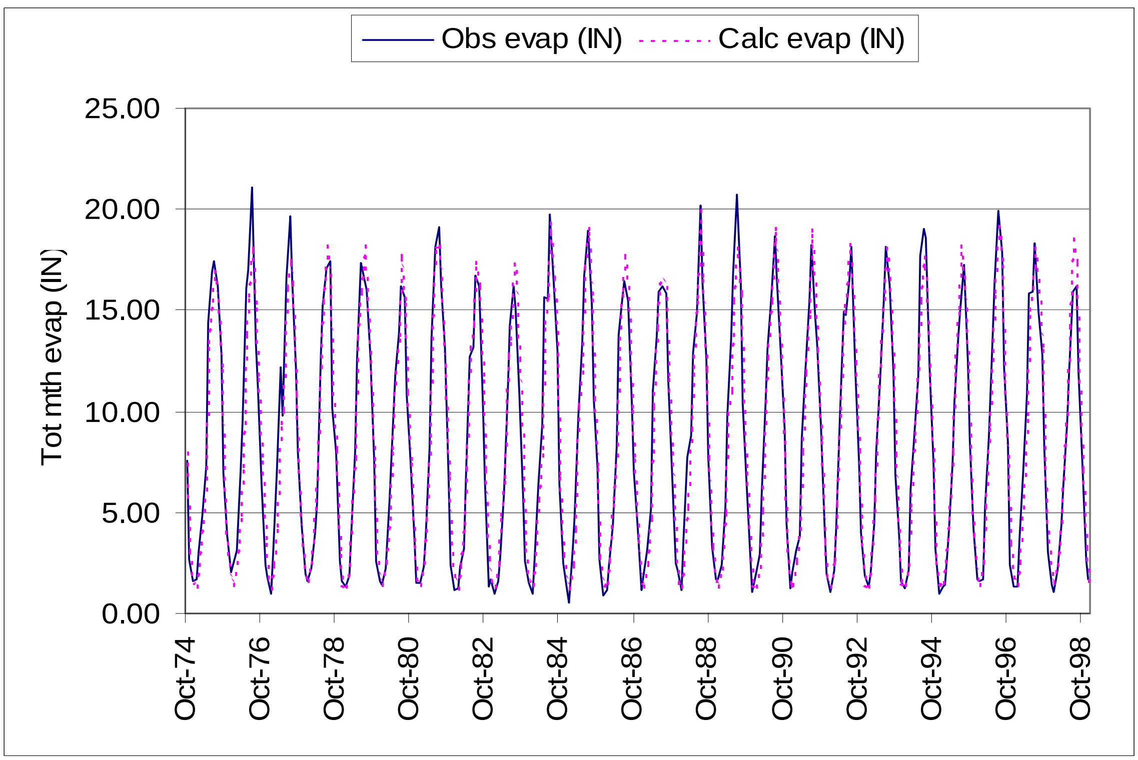

Figure 6: San Luis/Del Valle Observed and Calculated Evaporation

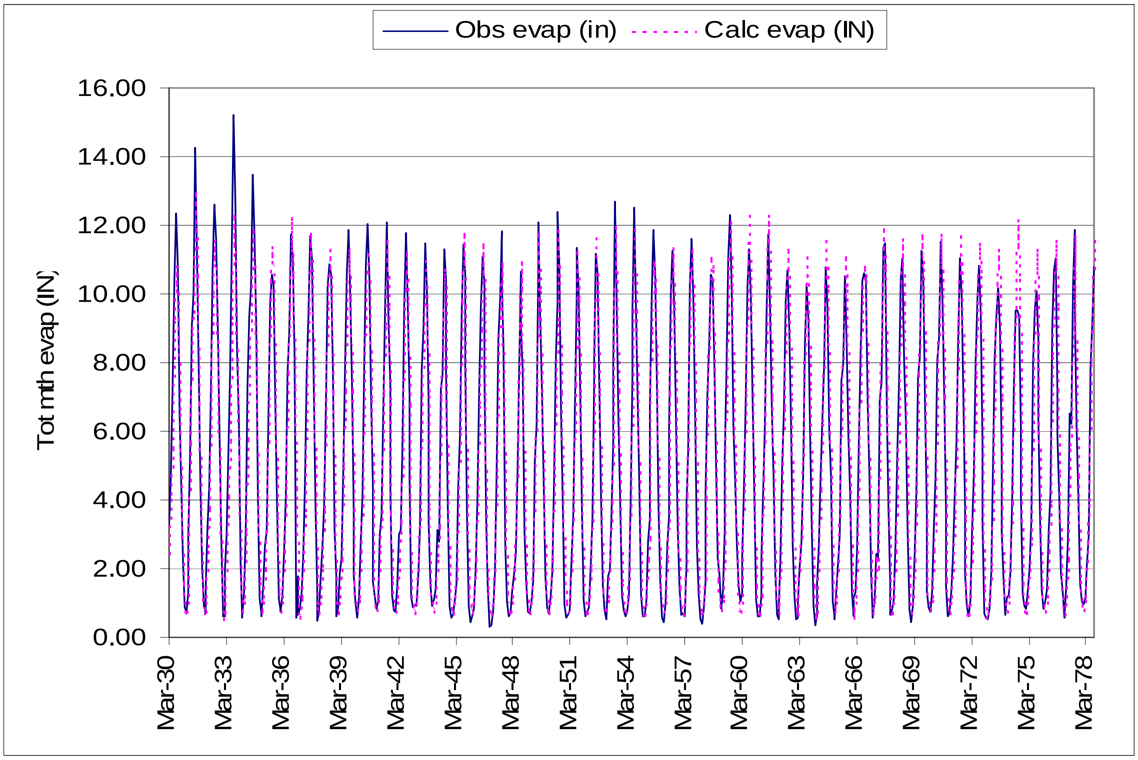

Figure 7: Pardee/Camanche Observed and Calculated Evaporation

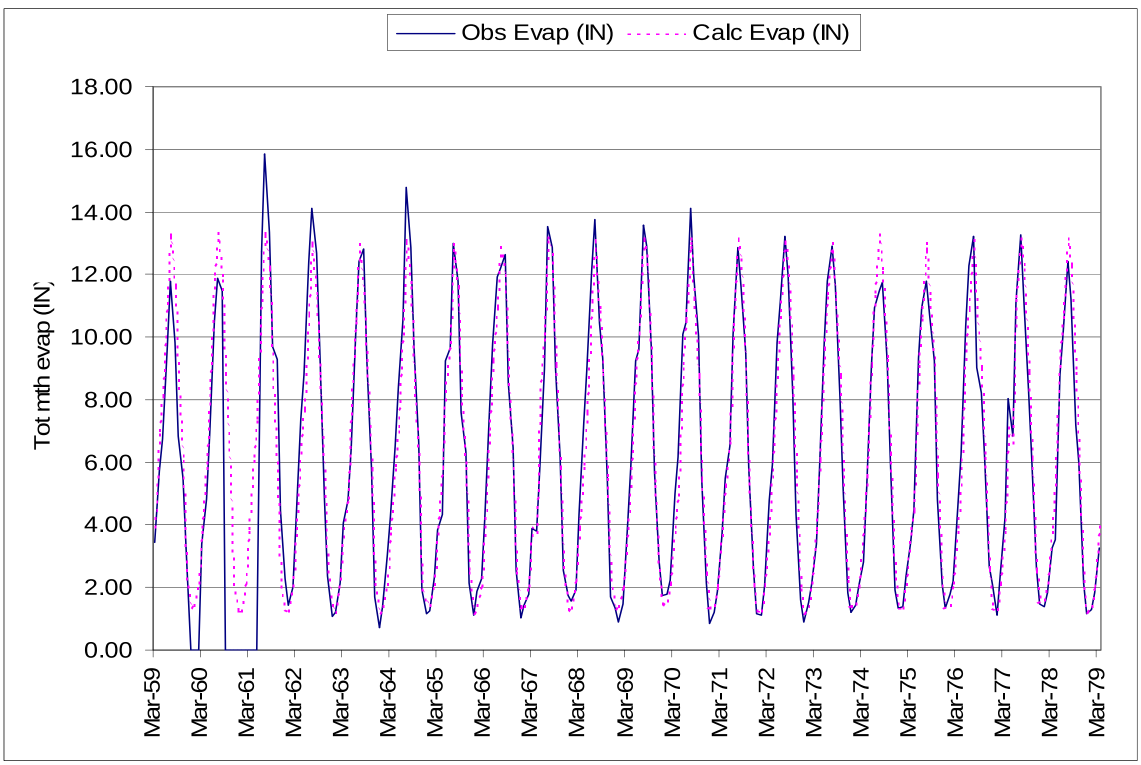

Figure 8: New Hogan Observed and Calculated Evaporation

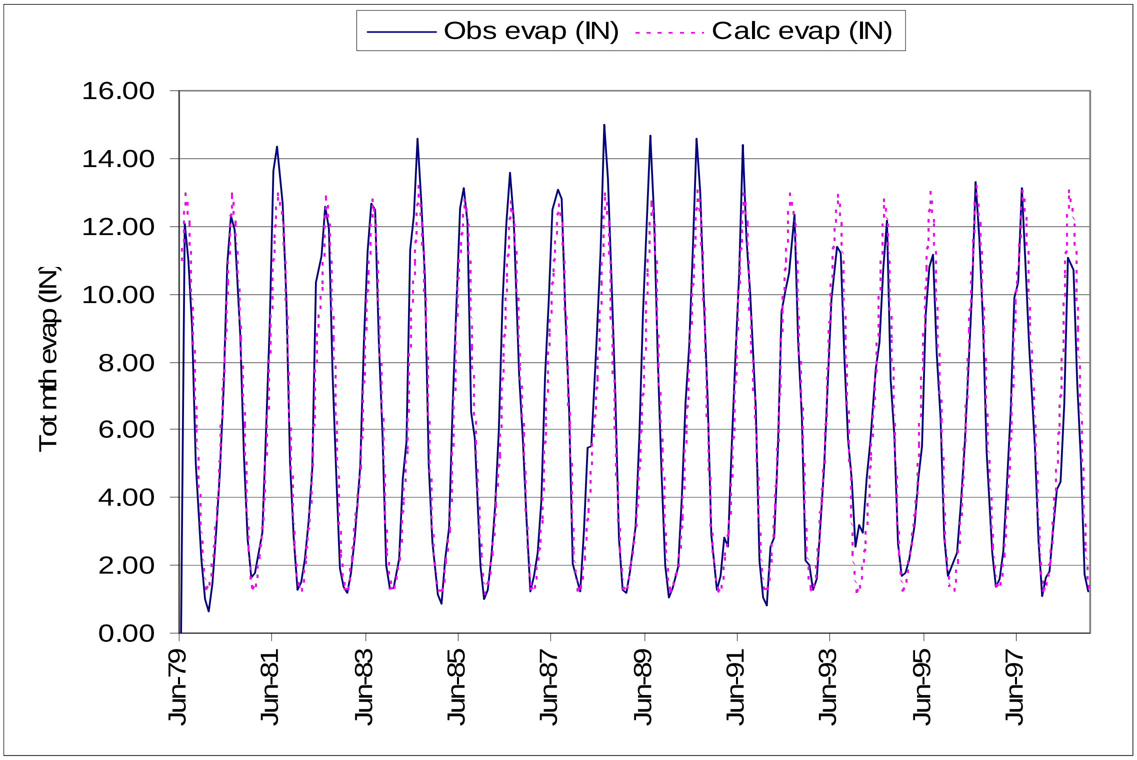

Figure 9: New Melones Observed and Calculated Evaporation

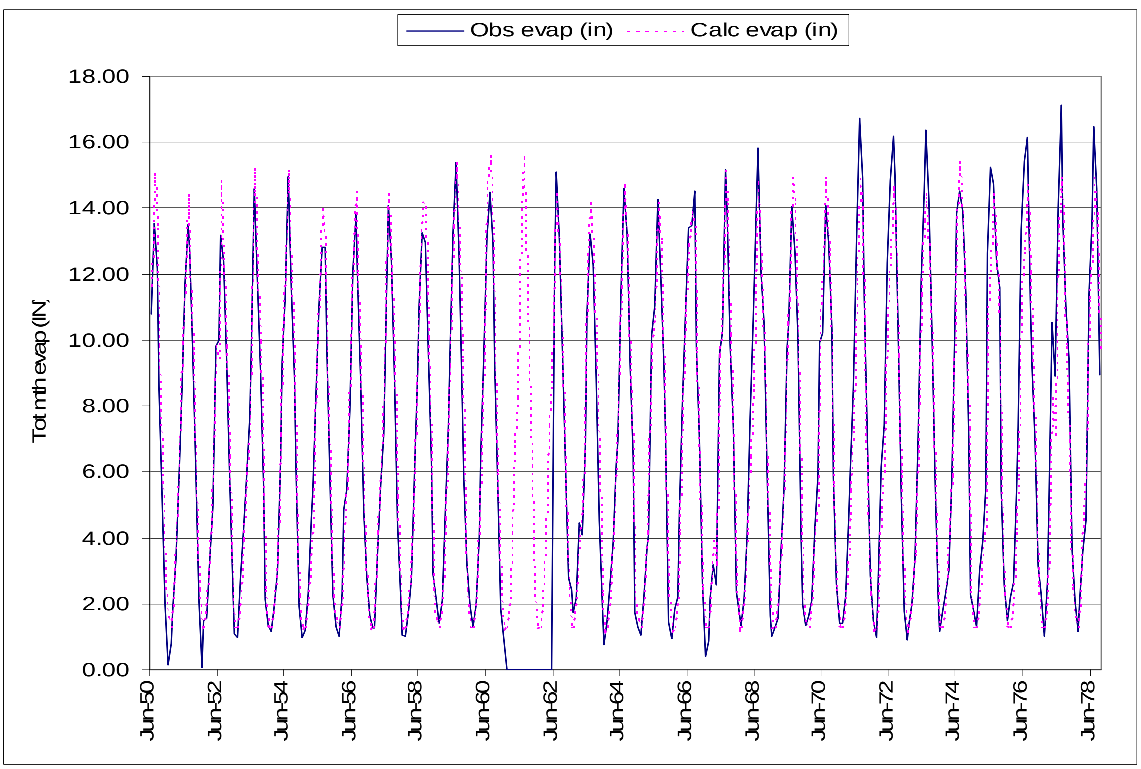

Figure 10: New Don Pedro/Lake McClure Observed and Calculated Evaporation

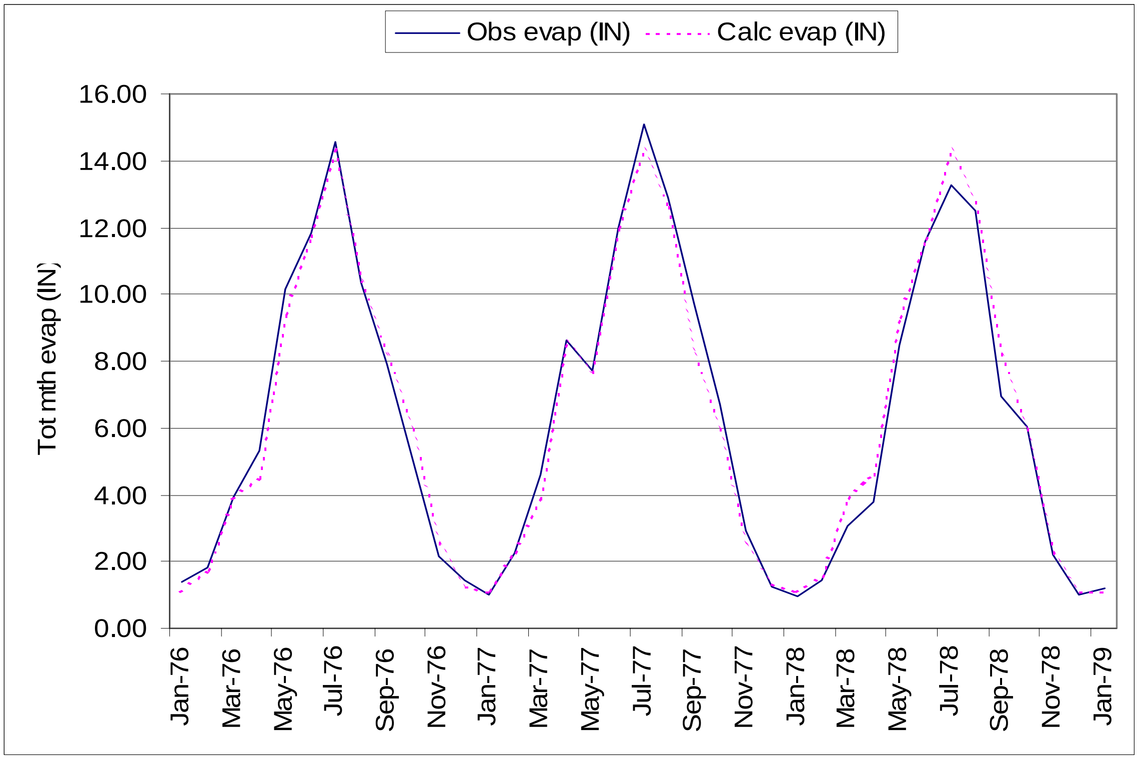

Figure 11: Eastman Observed and Calculated Evaporation

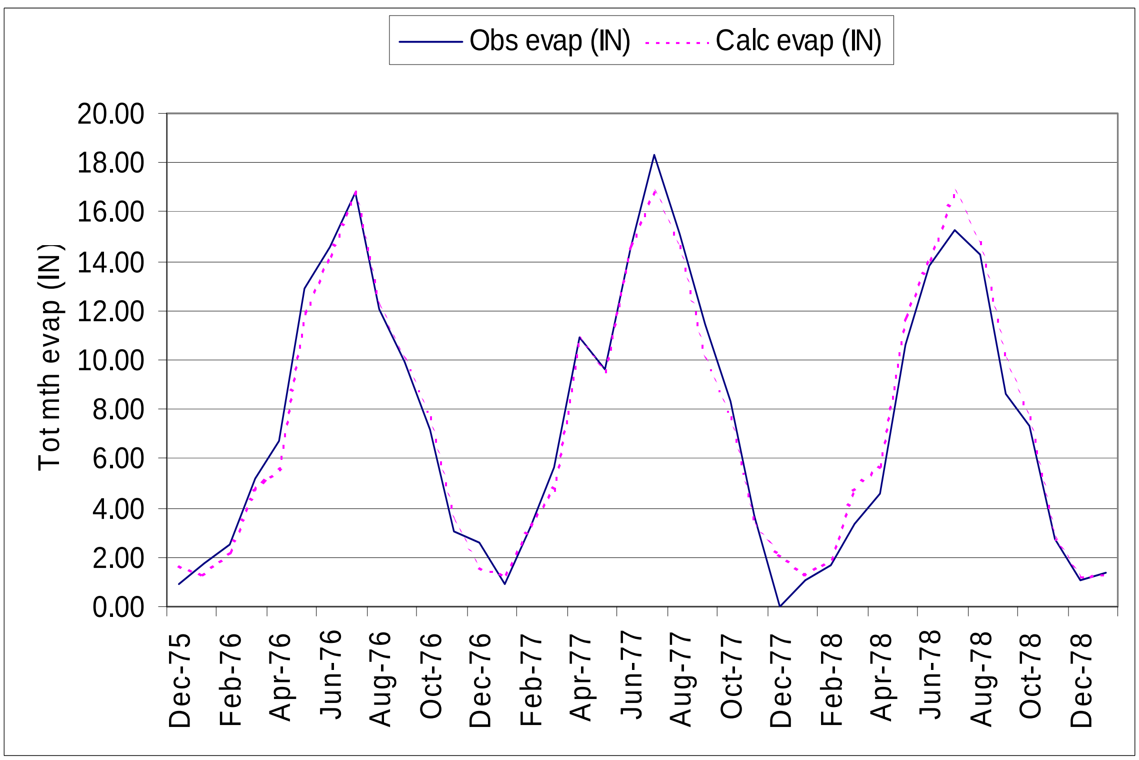

Figure 12: Hensley Observed and Calculated Evaporation

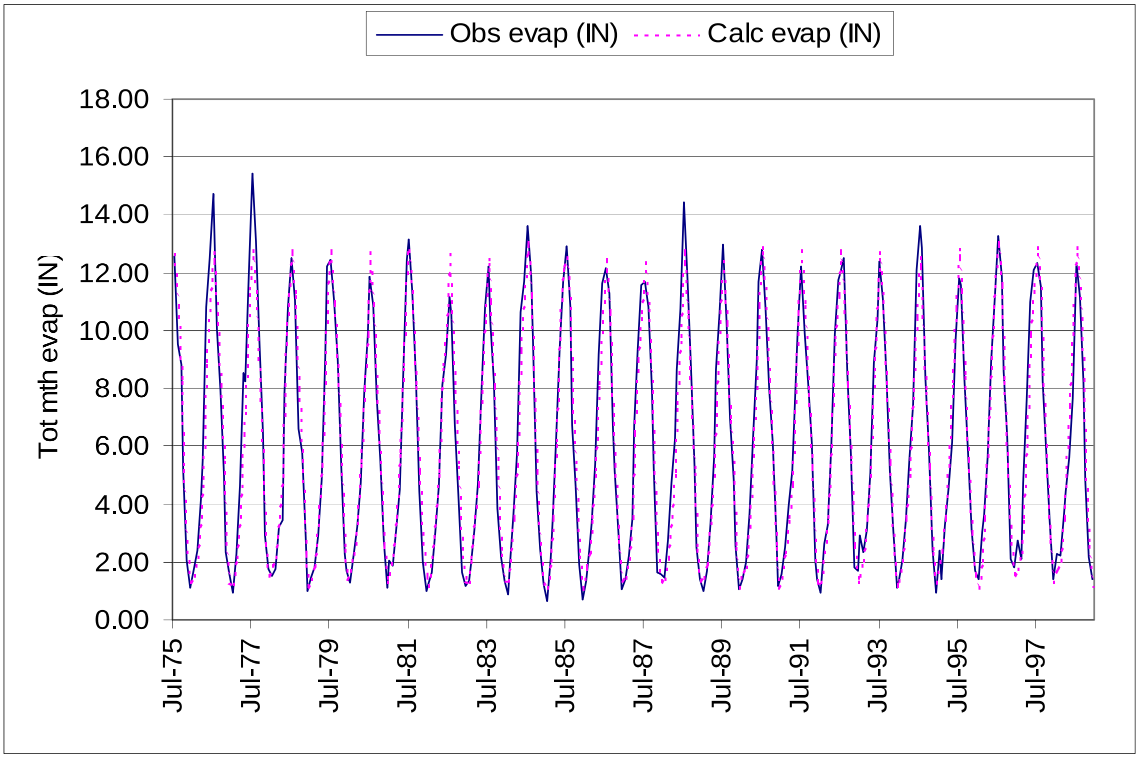

Figure 13: Millerton Observed and Calculated Evaporation

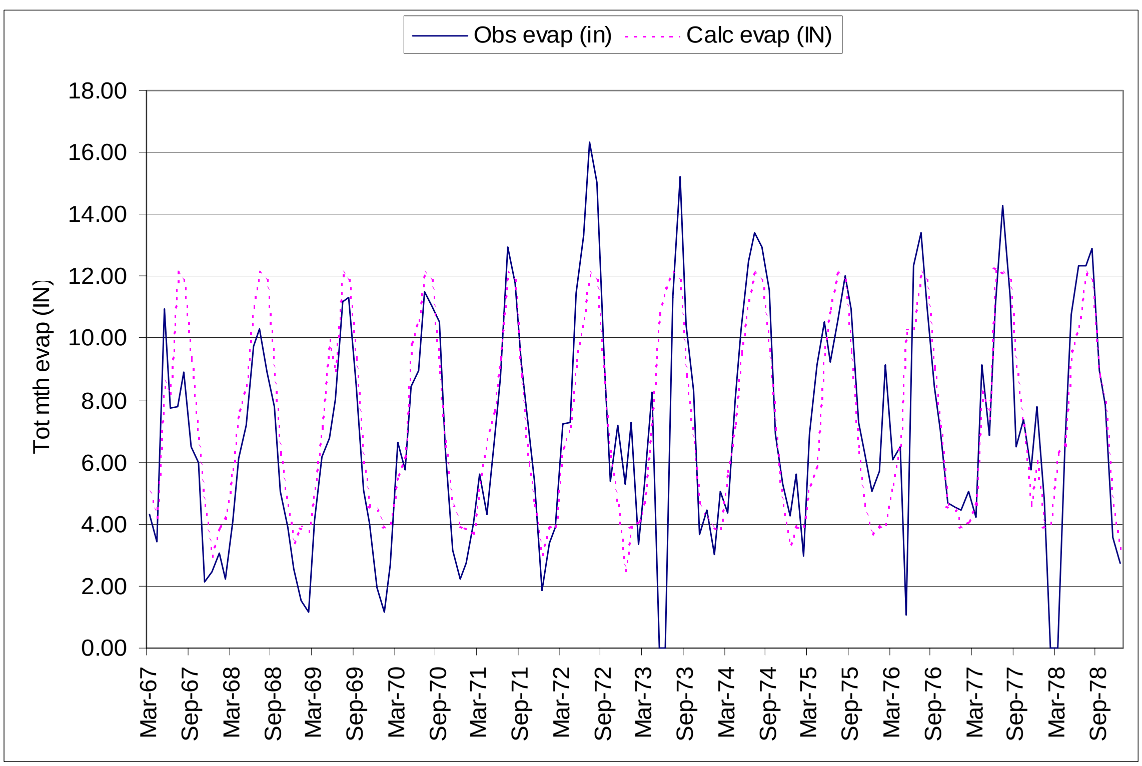

Figure 14: Pyramid Observed and Calculated Evaporation

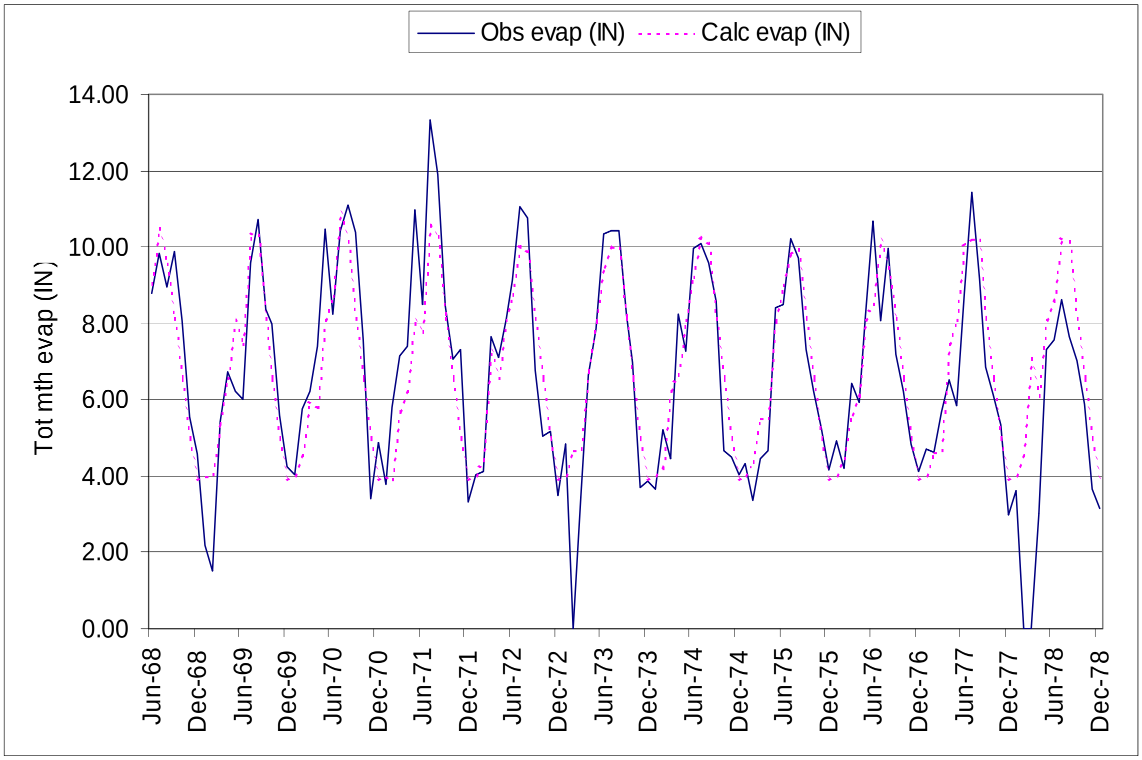

Figure 15: Castaic Observed and Calculated Evaporation

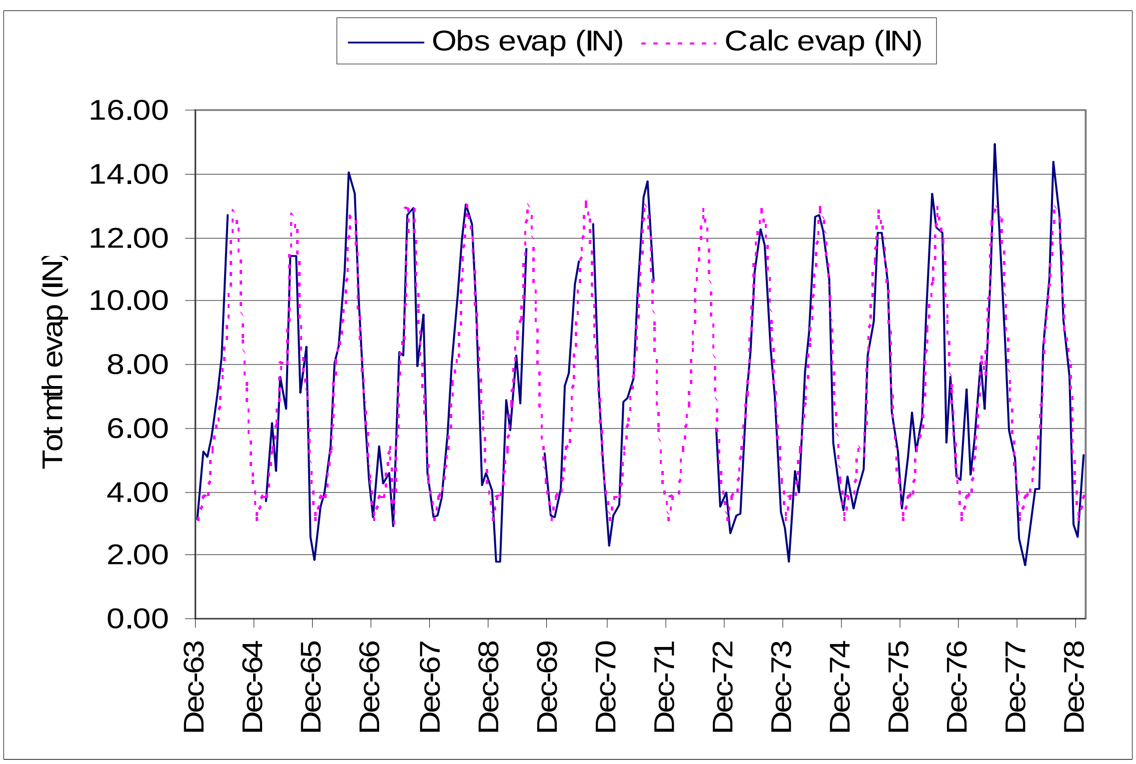

Figure 16: Perris/Silverwood Observed and Calculated Evaporation