

Town of Star Valley Ranch
PREDICTING MAXIMUM SNOW WATER EQUIVALENT

Special Report Number 2 January 29, 2007

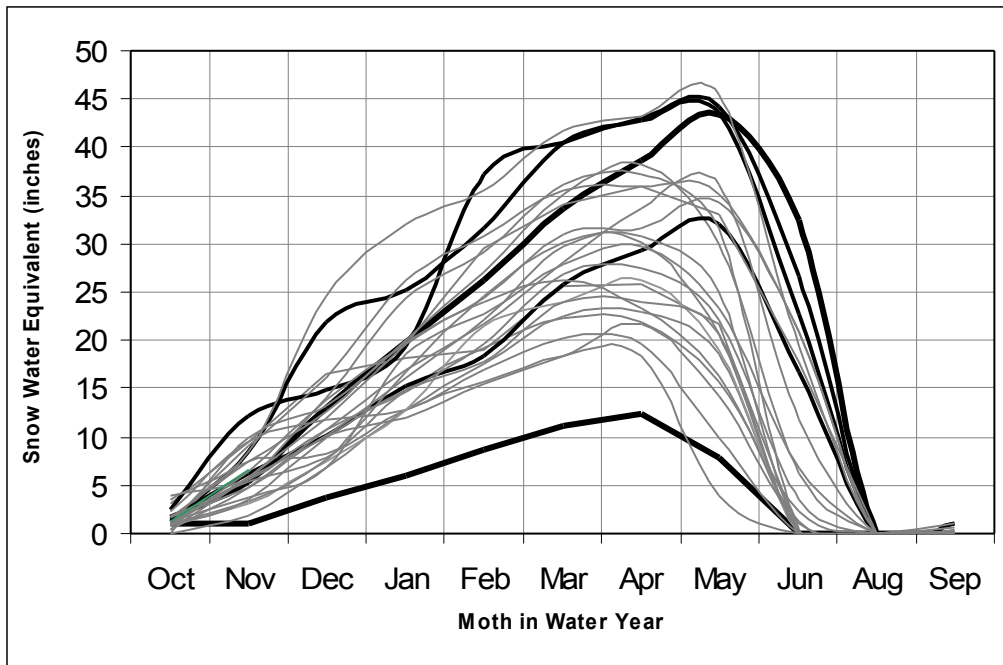


Figure 1. Snow water equivalent curves for the 24 year record at Willow Creek. Some years are in bold to illustrate the nearly linear annual increase in SWE as well as some irregularities in the increase.

SOME BASICS

The US Department of Agriculture maintains Snotel stations in the Mountain West. Their purpose is to measure mountain precipitation and temperature throughout the year, but particularly during the winter, and to automatically relay this data via satellite to USDA meteorologists. They use this data to estimate the quantity of irrigation water available to the valleys during the following summer. A Snotel station is located at Willow Creek, which is just south of Bedford at an elevation of 8300 feet. One instrument measures the amount of water contained in the snow that is the snow water equivalent or SWE. The SWE is less than the total snow fall or snow depth.

INTRODUCTION

Mountain snow acts as a water reservoir that accumulates winter precipitation and releases it in the spring when it percolate into the ground eventually to feed springs and recharge aquifers or it flows over the ground and through the soil into local rivers for the spring floods. Mountain snow water keeps the rivers, springs, and aquifers in the Town of Star Valley Ranch filled with water all year. The earlier the Town is aware of the potential maximum amount of snow water, the sooner it can plan for either a water shortage or abundance during the following summer.

This report presents the result of a statistical analysis that uses the amount of snow water accumulation during early winter to predict the maximum amount of water stored in the snow in April. The amount of water stored in the snow is known technically as the snow water equivalent of SWE. The report ends with a prediction of the discharges from Prater and Green Canyon Springs during July of this summer.

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In Special Report Number 1, the relationship between SWE and discharge from Prater and Green Springs was determined and equations developed that predict the summer discharges for these springs once the April SWE is known. In this report, statistical methods are developed to predict the April SWE using the SWE for each of the months of December, January, and February.

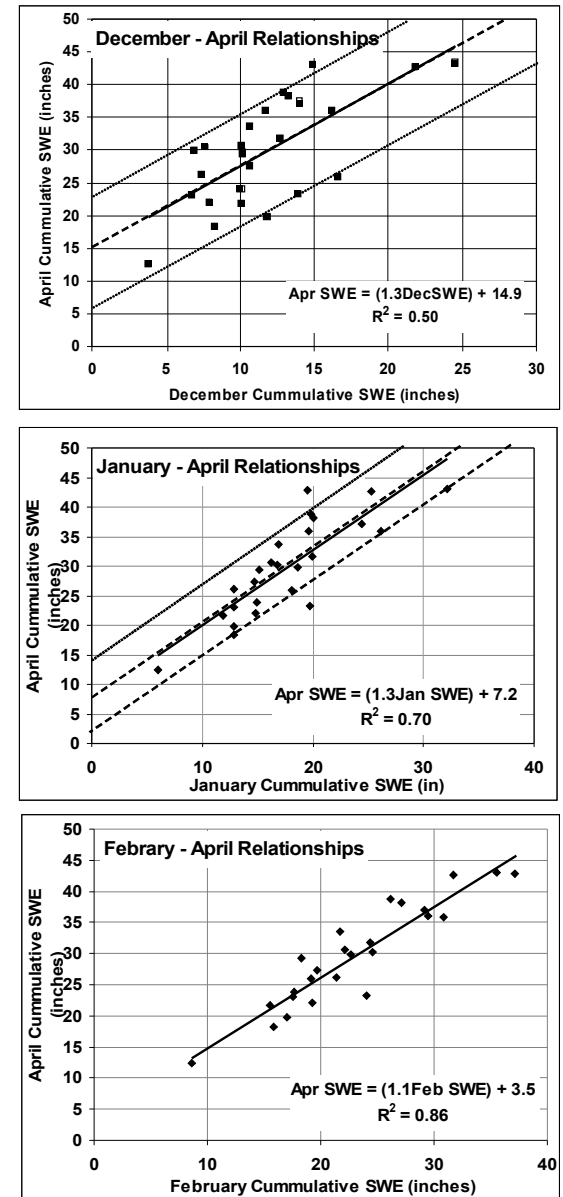
STATISTICAL PREDICTION

As shown in **Figure 1**, which illustrates the increase in SWE through out the winter months until melting begins in late April or May, the SWE increases in nearly a straight line from October to a peak in March or April. Some lines rise very steeply when the early winter snow is heavy and wet while other lines rise gently when these months have little or dry snow. The steepness of the line controls the April SWE when the spring snow melt begins. Linear regressions quantify these relationships and provide the desired predictions.

Figure 2 shows the relationship between the SWE in December, January, and February and the final SWE during April for each of the 24 winters of record. The data form a scatter of points that rise from October toward April SWE in a straight line. The regression equation for each relation appear in the lower right of the graph with its R^2 (R^2 expresses the goodness of the fit; the higher the R^2 , the better the fit).

The relationships in **Figure 2** demonstrate that heavy snows in early winter usually predict a high SWE for April. **Figure 3** is a plot of the amount of SWE contributed each month. The 25 year record indicates that winter months with more than seven inches of SWE are rare in the Salt River Range and the largest increase in SWE occurs in December through February. A few winter months have exceptionally heavy February or March snow and in these cases, the predictions from early winter would underestimate the April SWE.

Figure 2. Relationship between April SWE and the SWE in early winter at the Willow Creek Snotel Station from 1982 to 2006. The dashed line is the projection of the trend beyond the data and the dotted lines are the error of prediction. The error of prediction decreases from December to February while the amount of explanation (R^2) increases from 50% to 86%. R^2 is amount of variation in April SWE that is explained by the variation in the early winter SWE.



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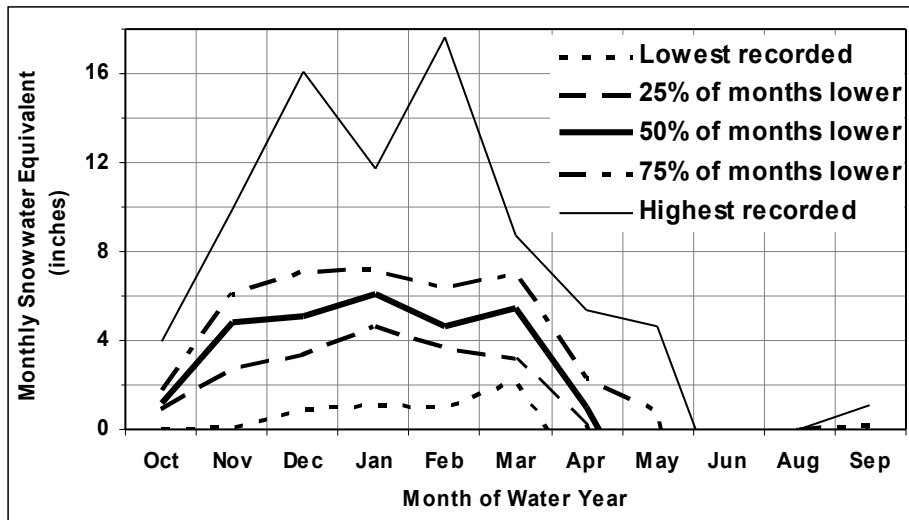


Figure 3. Amount of SWE accumulation for each winter month at the Willow Creek Snotel Station between 1980 and 2006. Monthly SWE tends to be constant around five inches from December through March and declines to less than two inches in April. Monthly SWE is usually (less than 75% of the time) below seven inches between November and March with the unusually high accumulations occurring in December and February.

SUMMER 2007: An Example

The relationships developed here and combined with the relationship between July SWE and July discharge from Prater and Green Canyon Springs to estimate the water supply from the springs available this summer. A test of the predictions is possible if spring discharges are measured this summer. Even if no measurements are made, the abundance or scarcity of spring discharge will become apparent over the course of the summer.

Table 2 shows the observed December and January SWE's, their predicted July discharge, and the predicted July discharge for Prater and Green Springs. The predicted 2007 July discharges are expressed as a percent of the observed 2006 July discharges. The results suggest that Star Valley Ranch should prepare for a dry summer.

Table 1 summarizes the data used in the analysis. It includes the observed SWE in December, January, February and April, the predicted April SWE based on each early winter regression, the differences between predicted and observed, and a summary of each month's record. The differences between the observed and the predicted SWE's define the error in prediction. The maximum difference is the error of prediction, which is rarely achieved. The errors that occur less than 75% of the time are a good estimator of the error associated with the April SWE prediction.

DISCUSSION

The analysis presented here is based on a 24 year record from a Snotel station located south of Bedford. The record is long for automated Snotel stations but short as far as capturing all the variations resulting from various weather cycles. For these two reasons the predictions should be treated as rough approximations. However, the error of prediction decreases with each month and by February the April SWE prediction is within a few inches of the observed (compare statistical summary in **Table 1**)

When the April SWE predictions are coupled with the prediction of July spring discharges (Special Report No. 1), the early winter SWE data can be used to estimate the spring discharges during the following summer.

Table 2. Predicted spring discharges for the summer of 2007 based on the relationships developed here and Special Report No. 1. The predicted 2007 discharges are compared to observed 2006 discharges and shown as a percentage of 2007.

Month	2007 SWE (in)	Predicted April SWE (in)	Predicted July Discharge (gpm)		2007 discharge as % of 2006 discharge	
			Prater	Green	Prater	Green
Dec	9.3	27	395	1281	70%	56%
Jan	13.7	25	365	1165	64%	51%

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Water Year ending in	Observed Cumulative Snow Water Equivalent (inches)				Predicted April Cumulative Snow Water Equivalent (inches)			Difference (Predicted - Observed)		
	Dec	Jan	Feb	Apr	Dec	Jan	Feb	Dec	Jan	Feb
1981	3.8	6	8.6	12.5	19.84	15	12.96	7.34	2.5	0.46

Table 1. Summary of data used in this report and the predictions resulting from the equations in Figure 2 with the differences between predicted and observed SWE. No SWE data were collected for water year 1982. The statistical summary at the bottom of the table indicates the range of values for the 24 year record.

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1983	13	19.8	26.2	38.7	31.8	32.94	32.32	-6.9	-5.76	-6.38
1984	21.8	25.3	31.7	42.7	43.24	40.09	38.37	0.54	-2.61	-4.33
1985	16.6	18.1	19.1	25.9	36.48	30.73	24.51	10.58	4.83	-1.39
1986	14.9	19.5	37.1	42.9	34.27	32.55	44.31	-8.63	-10.35	1.41
1987	8.3	12.9	15.8	18.3	25.69	23.97	20.88	7.39	5.67	2.58
1988	6.8	12.9	17.5	23	23.74	23.97	22.75	0.74	0.97	-0.25
1989	13.3	20.1	27.1	38.2	32.19	33.33	33.31	-6.01	-4.87	-4.89
1990	7.9	14.8	19.3	22	25.17	26.44	24.73	3.17	4.44	2.73
1991	10.2	15.2	18.3	29.3	28.16	26.96	23.63	-1.14	-2.34	-5.67
1992	11.8	12.9	17	19.7	30.24	23.97	22.2	10.54	4.27	2.5
1993	10.7	16.9	21.7	33.6	28.81	29.17	27.37	-4.79	-4.43	-6.23
1994	7.4	12.9	21.4	26.2	24.52	23.97	27.04	-1.68	-2.23	0.84
1995	12.7	19.9	24.4	31.7	31.41	33.07	30.34	-0.29	1.37	-1.36
1996	16.2	26.2	30.8	35.9	35.96	41.26	37.38	0.06	5.36	1.48
1997	24.5	32.1	35.5	43.1	46.75	48.93	42.55	3.65	5.83	-0.55
1998	6.9	18.6	22.7	29.8	23.87	31.38	28.47	-5.93	1.58	-1.33
1999	11.7	19.6	29.5	36	30.11	32.68	35.95	-5.89	-3.32	-0.05
2000	7.7	16.8	24.6	30.2	24.91	29.04	30.56	-5.29	-1.16	0.36
2001	10.1	11.9	15.5	21.7	28.03	22.67	20.55	6.33	0.97	-1.15
2002	10	14.9	17.7	23.9	27.9	26.57	22.97	4	2.67	-0.93
2003	10.1	16.2	22.1	30.7	28.03	28.26	27.81	-2.67	-2.44	-2.89
2004	13.9	19.7	24	23.3	32.97	32.81	29.9	9.67	9.51	6.6
2005	10.7	14.7	19.7	27.4	28.81	26.31	25.17	1.41	-1.09	-2.23
2006	14	24.4	29.1	37.1	33.1	38.92	35.51	-4	1.82	-1.59
Minimum	3.8	6	8.6	12.5	19.84	15	12.96	-8.63	-10.35	-6.38
25% Lower	8.3	14.7	18.3	23.3	25.69	26.31	23.63	-4.79	-2.44	-2.23
50% Lower	10.7	16.9	22.1	29.8	28.81	29.17	27.81	0.06	0.97	-0.93
75% Lower	13.9	19.8	27.1	36	32.97	32.94	33.31	4	4.27	0.84
Maximum	24.5	32.1	37.1	43.1	46.75	48.93	44.31	10.58	9.51	6.6