The Surface Water Supply Index: Formulation and Issues

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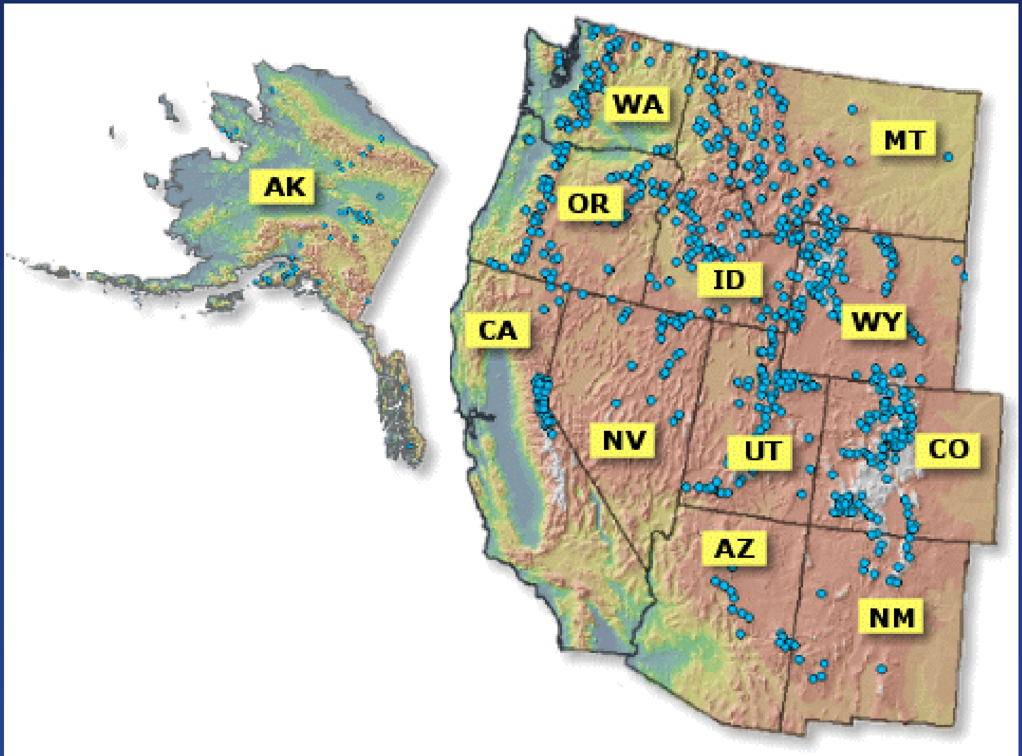
Snow Survey and Water Supply Forecasting Program

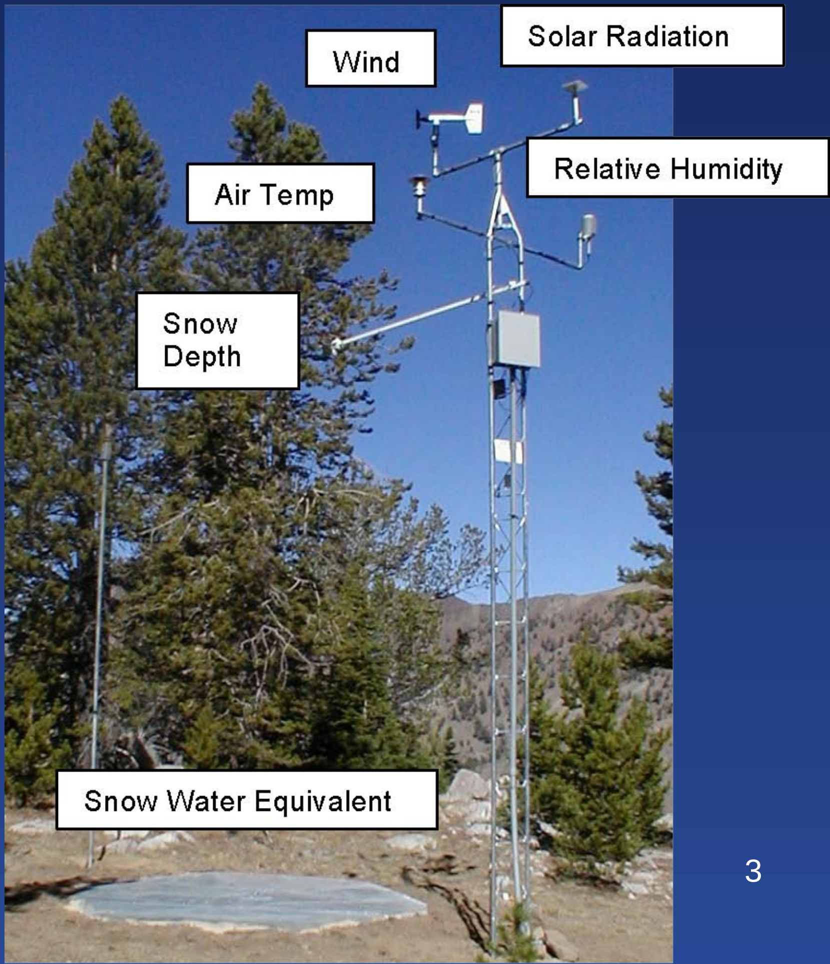
- Data collection
- Water supply forecasts
- Climate services



SNOTEL Network

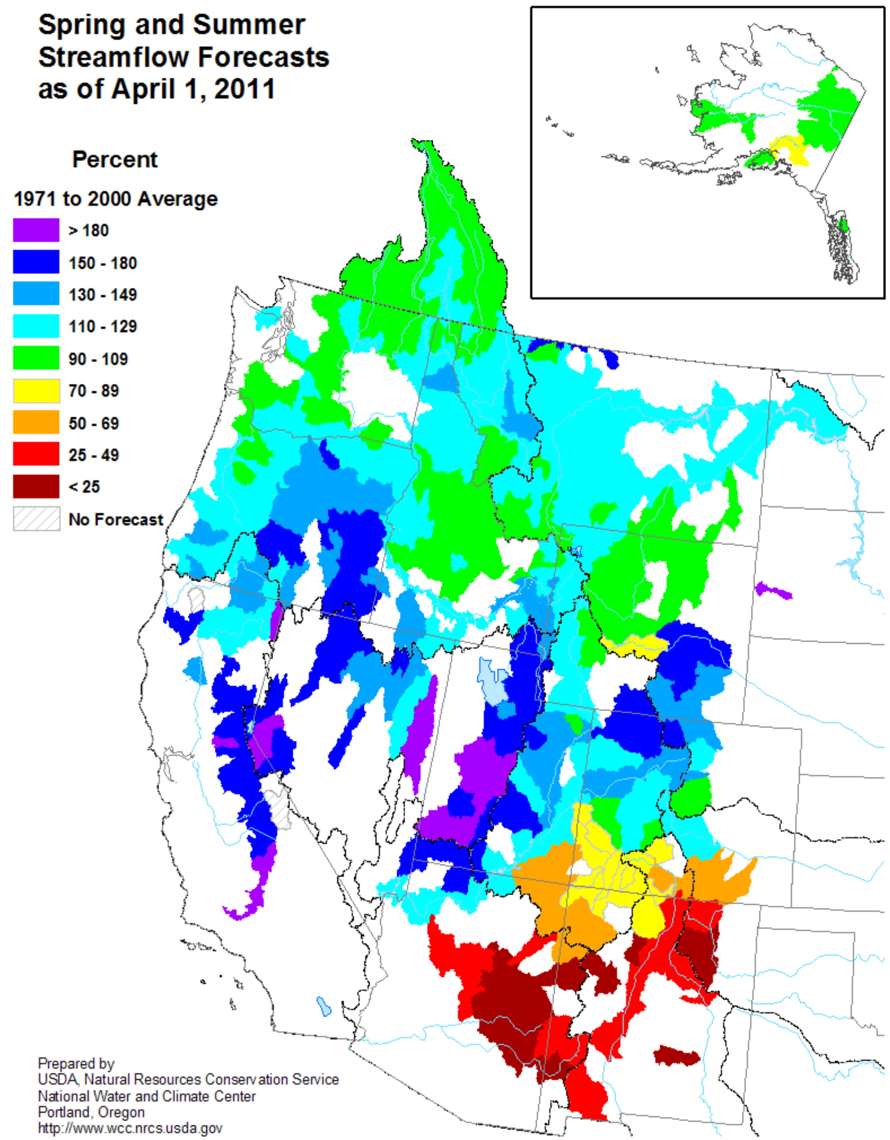
Currently over 800 sites
in 13 western states

http://www.wcc.nrcs.usda.gov/snow



Water Supply Forecasting

- Seasonal streamflow volume
- Published January through June
- Cooperative effort with National Weather Service
- Over 700 forecast points in western US



Purpose of SWSI

- Original purpose: "... be an indicator of basinwide water availability..., be predictive, and permit comparison of water supply conditions between basins..." (Shafer and Dezman, 1982)
- Used where Palmer Drought Index does not adequately reflect conditions in snow-dominated regions
- Used where primary source of agricultural water supply for irrigation is surface water
- Used as monitoring and triggering index for state drought plans (e.g., Colorado: http://cwcb.state.co.us/water-management/drought/Pages/StateDroughtPlanning.aspx)

History of SWSI

- Originally developed in early 1980s in Colorado (Shafer and Dezman, 1982)
- Original formulation, with variations, also adopted in Montana and Oregon
- Procedure reviewed by NRCS in cooperation with Colorado Climate Center in early 1990s
- Revised formulation based on streamflow volume forecasts published by Garen (1993)
- New formulation, with variations, adopted in Idaho, New Mexico, Montana, Colorado

Original Formulation

$$SWSI = \frac{aP_{snow} + bP_{prec} + cP_{strm} + dP_{resv} - 50}{12}$$

- Based on probability distributions of monthly time series of individual component indices
- Rescaled weighted sum of non-exceedance probabilities (in percent) from individual components
- Ranges from -4.2 to +4.2 (to have similar values as the Palmer index)
- Weights determined subjectively or from normalizing procedure but not optimized to predict a certain variable

Revised Formulation

$$SWSI = \frac{P_{fcst+resv} - 50}{12}$$

- Single probability of summed expected streamflow (over an appropriate time horizon) and current reservoir storage
- Component weightings are done implicitly within the streamflow forecast
- Streamflow forecast component varies throughout the year and switches to upcoming year at beginning of water year

Display of SWSI

NRCS state offices display the SWSI in different ways -- as tables, graphs, maps -- for example:

Montana:

http://nris.mt.gov/NRCS/swsi/Monthly.asp

Idaho:

http://www.id.nrcs.usda.gov/snow/watersupply/swsi-main.html

Oregon:

http://www.or.nrcs.usda.gov/snow/watersupply/swsi.html

SWSI Values and Labels

Extremely Dry:	-4.2 to -3.0	14% non-exceedance
Moderately Dry:	-2.9 to -2.0	26% "
Slightly Dry:	-1.9 to -1.0	38% "
Near Average:	-0.9 to 1.0	62% "
Slightly Wet:	1.1 to 2.0	74% "
Moderately Wet:	2.1 to 3.0	86% "
Extremely Wet:	3.1 to 4.2	100% "

Tabular Display of SWSI -- Montana

Montana April 2011 SWSI Values:

Marias River above Tiber Reservoir	1.2
Tobacco River	2.4
Kootenai River below Libby Dam	2.6
Fisher River	2.1
Yaak River	1.3
North Fork Flathead River	2.5
etc.	

Tabular Display of SWSI -- Idaho

Clearwater River at Spalding SWSI

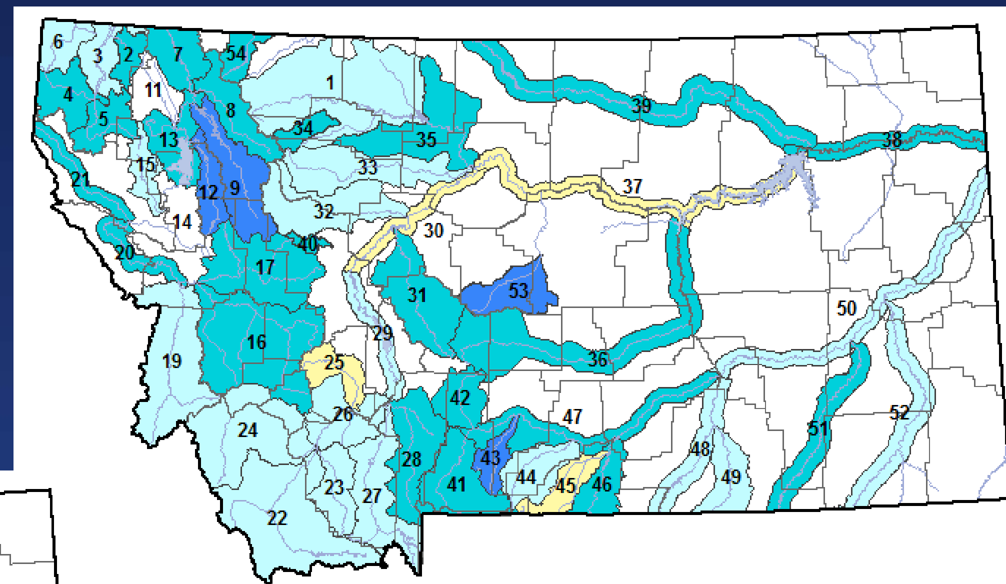
	Period	Data Type	Years	# of Years	
13342500 Clearwater River at Spalding	Apr-Sep	strm	1972-2010	39	Units KAF
13340950 Dworshak Reservior	31-Mar	resv	1972-2010	39	Units KAF

ENSO Classification
SE Strong El Nino - EN Mild El Nino - N Neutral - LN Mild La Nina - SL Strong La Nina

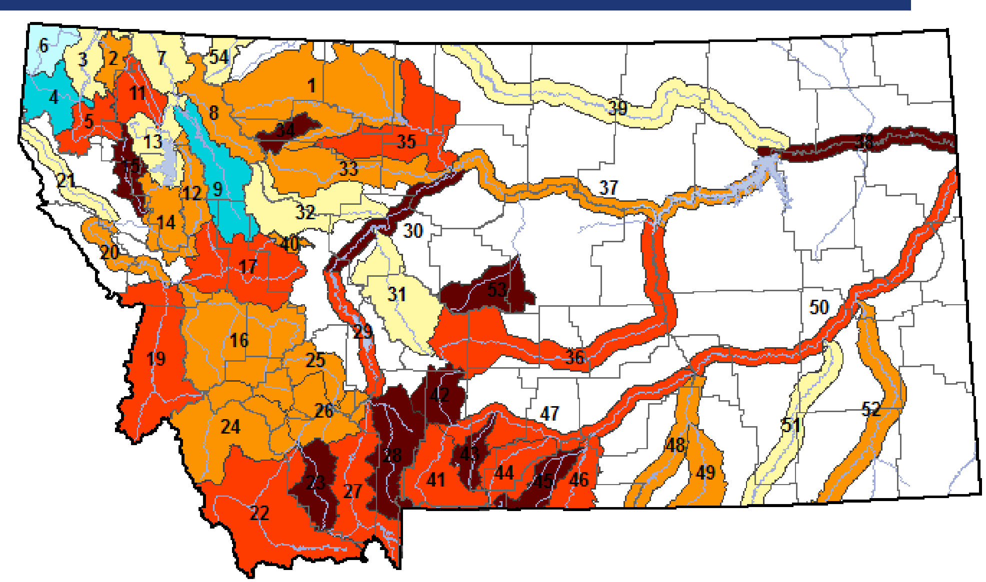
2010 Provisional Data

Historic Rank	Year	ENSO	Streamflow Apr-Sep	Reservoir 31-Mar	Streamflow + Reservoir Sum	Non-Exceedance Probability	SWSI	Current Year Rank
1	1974	SL	12655	1631	14286	0.98	4.0	
2	1997	N	12723	1466	14189	0.95	3.8	
3	1972	LN	12322	1140	13462	0.93	3.5	
4	1975	LN	10780	1469	12249	0.90	3.3	
5	1976	SL	10714	1458	12172	0.88	3.1	
6	**2008**	N	9901	2143	12044	0.85	2.9	
	2011 10% Chance Exceedance Forecast	**SL**	**10400**	**1619**	**12019**	**0.84**	**2.8**	**7**
7	1984	N	9163	2644	11807	0.83	2.7	
8	1982	N	10077	1622	11699	0.80	2.5	
9	1996	N	9537	2027	11564	0.78	2.3	
10	**2002**	N	9171	2175	11346	0.75	2.1	
	2011 30% Chance Exceedance Forecast	**SL**	**9380**	**1619**	**10999**	**0.74**	**2.0**	**11**
11	**2009**	N	8391	2513	10904	0.73	1.9	
	2011 50% Chance Exceedance Forecast	**SL**	**8900**	**1619**	**10519**	**0.71**	**1.8**	**12**
12	1999	SL	8761	1555	10316	0.70	1.7	
13	1993	EN	7323	2888	10211	0.68	1.5	
14	**2003**	EN	7083	3119	10202	0.65	1.3	
15	1978	SE	8331	1858	10189	0.63	1.0	
16	1981	N	7033	3045	10078	0.60	0.8	
	2011 70% Chance Exceedance Forecast	**SL**	**8420**	**1619**	**10039**	**0.59**	**0.7**	**17**
17	1990	N	7601	2401	10002	0.58	0.6	
18	**2006**	N	7564	2404	9968	0.55	0.4	
19	1989	SL	7876	1991	9867	0.53	0.2	
20	1991	N	7193	2568	9761	0.50	0.0	
21	**2004**	N	7259	2374	9633	0.48	-0.2	
22	1979	N	7610	1909	9519	0.45	-0.4	
23	1985	N	7768	1671	9439	0.43	-0.6	
24	**2000**	N	7100	2265	9365	0.40	-0.8	
25	1980	N	6948	2395	9343	0.38	-1.0	
26	1998	SE	6740	2575	9315	0.35	-1.3	
27	1995	SE	6237	3076	9313	0.33	-1.5	
28	1986	N	6623	2639	9262	0.30	-1.7	
	2011 90% Chance Exceedance Forecast	**SL**	**7370**	**1619**	**8989**	**0.29**	**-1.8**	**29**
29	1983	SE	6204	2457	8661	0.28	-1.9	
30	**2010**	EN	6343	2309	8651	0.25	-2.1	
31	**2005**	EN	5043	3083	8126	0.23	-2.3	
32	**2007**	EN	5289	2804	8093	0.20	-2.5	
33	1988	SE	5704	1952	7656	0.18	-2.7	
34	1994	SE	4823	2682	7505	0.15	-2.9	
35	1992	EN	4300	3094	7394	0.13	-3.1	
36	**2001**	LN	5089	2139	7228	0.10	-3.3	
37	1987	N	4301	2827	7128	0.08	-3.5	
38	1973	SE	4034	2505	6539	0.05	-3.8	
39	1977	EN	4080	2166	6246	0.03	-4.0	

Map Display of SWSI -- Montana

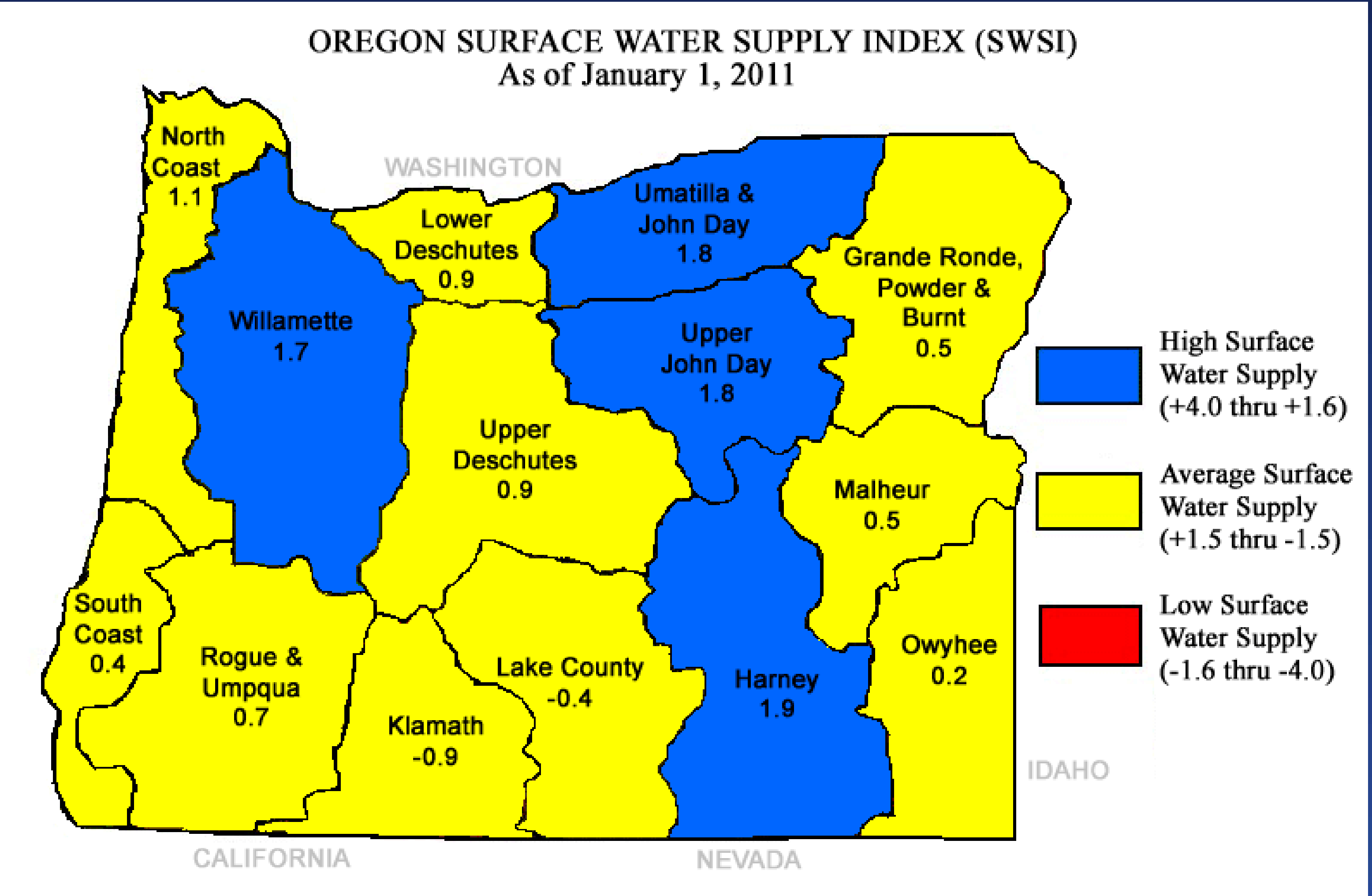


April 2011

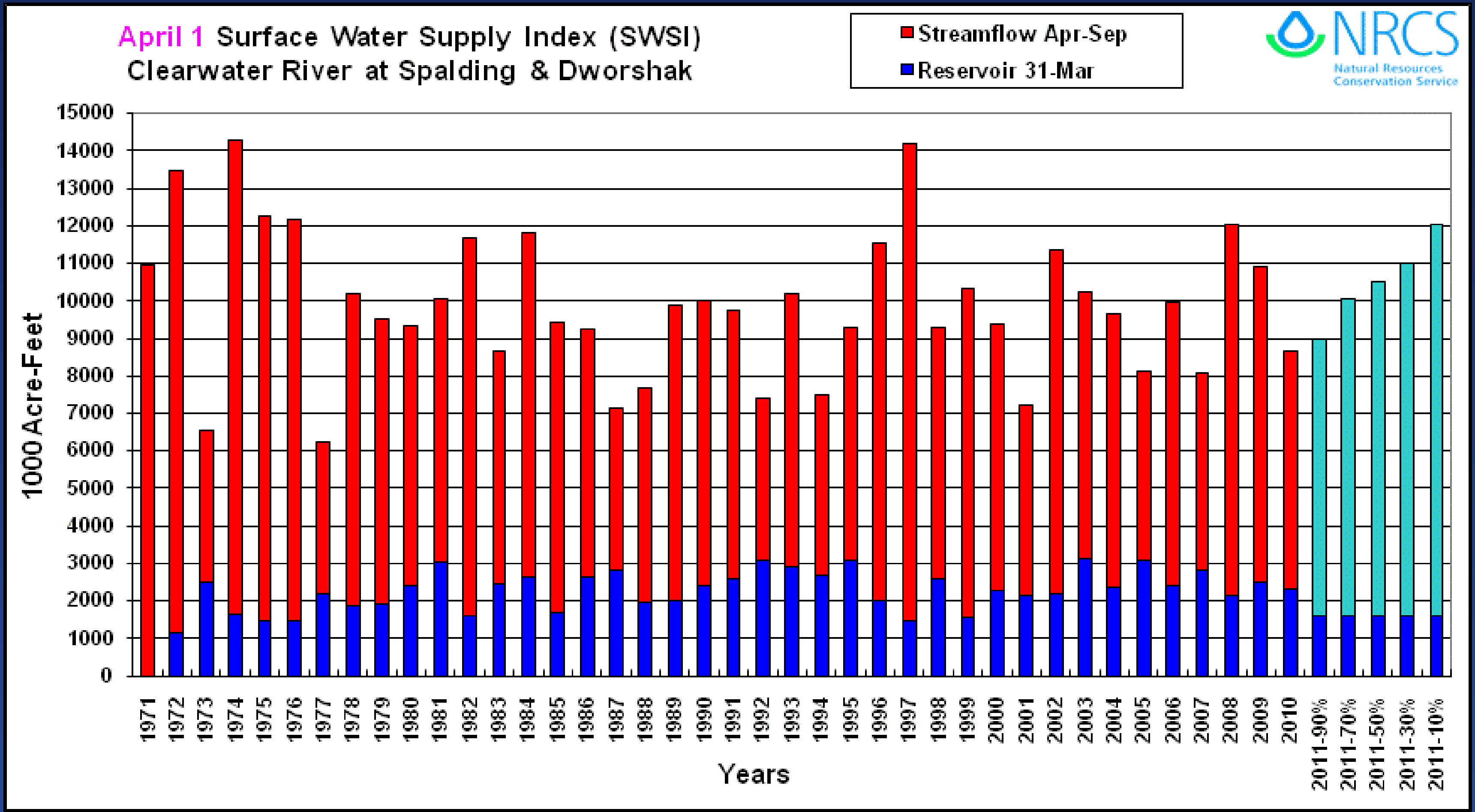


April 2007

Map Display of SWSI -- Oregon



Graph of SWSI Input Data -- Idaho



SWSI Issues

- Criterion variable
- Statistical formulation
- "Forecast" vs. "current conditions"
- Seasonal or year-around
- Numerical behavior
- Reservoir storage
- Individual components vs. combined variable

Criterion Variable Definitions

January	Apr-Sep fcst + Res	Apr-Sep fcst + Res
February	Apr-Sep fcst + Res	Apr-Sep fcst + Res
March	Apr-Sep fcst + Res	Apr-Sep fcst + Res
April	Apr-Sep fcst + Res	Apr-Sep fcst + Res
May	May-Sep fcst + Res	May-Sep fcst + Res
June	Jun-Sep fcst + Res	Jun-Sep fcst + Res
July	Jul-Sep fcst + Res	Res
August	Aug-Sep fcst + Res	Res
September	Sep fcst + Res	Res
October	Apr-Sep fcst + Res	Res
November	Apr-Sep fcst + Res	Res
December	Apr-Sep fcst + Res	Res

Criterion Variable Issues

- Do we need an explicit definition of "surface water supply"? That is, do we know what we mean by this term?
- Do the changes in the criterion variable as the year progresses make sense?
- Is it necessary that the same criterion variable be used throughout the region or country?

Original Formulation Issues

$$SWSI = \frac{aP_{snow} + bP_{prec} + cP_{strm} + dP_{resv} - 50}{12}$$

- Weights determined subjectively or from normalizing procedure but not optimized to predict a certain variable
- Probability properties not maintained
- No explicit criterion variable
- Discontinuity when snow enters and leaves

Revised Formulation Issues

$$SWSI = \frac{P_{fcst+resv} - 50}{12}$$

- Dependent on streamflow forecasts
- Requires unofficial forecasts or redefinition of criterion variable during non-forecast season (July-December) to compute year-around
- Discontinuities when criterion variable changes, such as summer and at beginning of water year

"Forecast" vs. "Current Conditions"

- What does "current conditions" mean with respect to surface water supply?
- Snowpack has an inherent lag therefore is implicitly predictive
- Three of the four components are typical predictor variables for streamflow forecasts
- Does previous month's or current streamflow mean anything?
- Diagnostic components vs. prognostic forecast

Seasonal vs. Year-Around

- What does "surface water supply" mean at each time of the year? This determines the criterion variable.
- Should we make unofficial forecasts during the summer and fall, or should we redefine the criterion variable?

Numerical Behavior Issues

- Statistical properties -- distribution of index in general and seasonally
- Forecast-based SWSI will not reach extreme values if streamflow forecast is highly uncertain
- Discontinuities: original SWSI when snow enters and leaves; revised SWSI at new water year and during summer months
- Setting of trigger levels -- should be based on frequency of occurrence
- Large changes in SWSI can result from small volume changes for low-variance distributions

Numerical Behavior Issues (cont.)

- Expression as rescaled non-exceedance probability, number of standard deviations, or non-exceedance probability itself (i.e., is frequency information inherent or obscured in index value?)
- Should SWSI formula denominator be 10 instead of 12 so that the range is -5 to +5, and the frequency of the value is transparent? (e.g., -3.0 → 20% non-exceedance probability)
- Should SPI be rescaled to do the same?
- People think linearly, even if index is nonlinear

Reservoir Storage Issues

- Large vs. small
- Newer reservoirs with short period of record
- Changing management over the years
- Can we even apply a probability-based index to reservoirs?
- Reservoir purpose -- some are not for "water supply" (e.g., flood control)

Mathematical Alternatives

- Specific criterion variable vs. vaguer wet/dry index
- Multivariate probability distribution
- Principal components analysis
- Combined variable vs. separate components

Separate Component Indices

	Feb 1974	Apr 1977	Jan 1988
Snowpack	2.9	-3.2	-3.9
Precipitation	2.7	-4.0	-3.6
Ant. streamflow	2.8	-3.5	-3.9
Reservoir	1.4	0.0	-3.7
Fcst. streamflow	3.6	-3.5	-3.1
SWSI	3.7	-3.4	-3.4

General Index Issues

- Combining very different and noncommensurate variables is highly problematic
- Need a clearly defined quantity to be indexed (e.g., SPI)
- Numerical behavior and statistical properties of index need to be clear and well-understood
- Meaning of index needs to be clear
- Needs to be a well-conceived rationale for connecting specific values of index to decisions and responses (e.g., taking into account frequencies of occurrence, etc.)

Final Remarks

- Many questions, many issues, many discussions over the years -- some things have been clarified, and some things are still unclear and unresolved, or at least no general consensus has been reached
- Sometimes there is a mismatch between (naïve?) expectations and technical realities of an index's behavior
- How much understanding should we expect of people for them to use a drought index appropriately?

References

Garen, D. C. (1993). Revised surface water supply index for western United States. Journal of Water Resources Planning and Management, 119(4):437-454.

Shafer, B. A. and L. E. Dezman (1982). Development of a surface water supply index (SWSI) to assess the severity of drought conditions in snowpack runoff areas. Proceedings of the Western Snow Conference, 164-175.

Conclusion

Questions?

Comments?