A Proposed Prairie Water Supply Index for Drought

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Purpose of the Surface Water Supply Index (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

Courtesy David Garen, NRCS, USDA

History of Surface Water Supply Index

- Originally developed in early 1980s in Colorado
- Original formulation, with variations, also adopted by Montana and Oregon
- Procedure reviewed by NRCS in cooperation with Colorado Climate Center in early 1990s
- Revised formulation based on water supply forecasts published in 1993
- New formulation, with variations, adopted by Idaho, New Mexico, Montana, and Colorado
- Recent interest in expanding this index to Canada

Courtesy David Garen, NRCS, USDA

Original SWSI Formulation

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

- Rescaled weighted sum of individual component non-exceedance probabilities
- Ranges from -4.2 to +4.2
- Weights determined subjectively or from normalizing procedure but not optimized to predict a certain variable

Courtesy David Garen, NRCS, USDA

Revised Formulation

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

- Single probability of summed expected streamflow and current reservoir storage
- Component weightings are done within the streamflow forecast
- Streamflow outlook switches at beginning of water year

Courtesy David Garen, NRCS, USDA

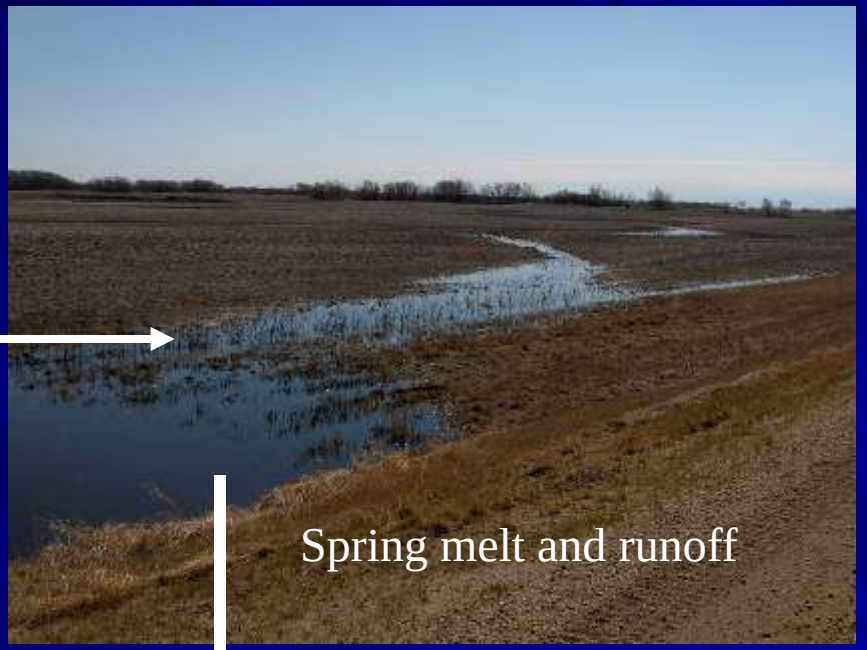
Advantages of Adopting SWSI to the Prairies

- Snowmelt is the primary source of surface runoff in the Canadian Prairies and provides most local streamflow and replenishment of wetlands, local reservoirs and lakes.
- An index for local surface water supply is attractive due to the lack of usable groundwater and distance from most farms to “exotic” water supplies from the mountain-fed Saskatchewan River system.

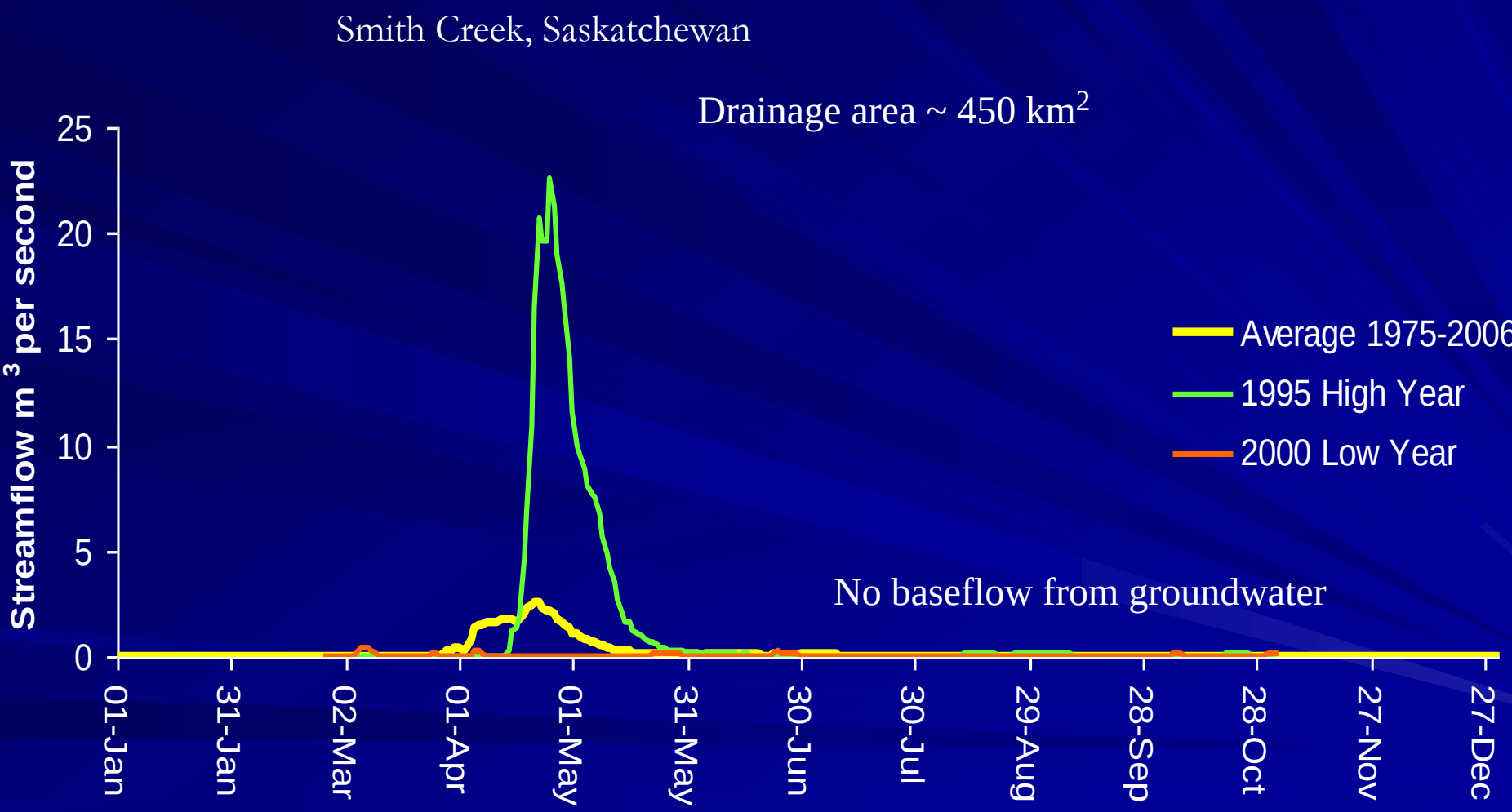
Problems with Adapting SWSI to the Prairies

- Mountains are not the source of runoff for most prairie streams (except Saskatchewan River system)
- Lack of reservoirs over many basins
- Lack of streamflow forecasts for many basins
- Dependence of runoff on frozen soil moisture as well as snowmelt
- Dependence of contributing area and streamflow generation on wetland/slough storage capacity

Prairie Runoff Generation



Prairie Streamflow fed by Snowmelt



Hydrological drought can be viewed as the absence of snowmelt……

Proposed Prairie Water Supply Index

$$PWSI = \frac{aP(SWE - INF - PondStorage) + bP(PRECIP)}{c}$$

- Snow accumulation (SWE) less storage in frozen soils via infiltration (INF) and in ponds via local runoff (PondStorage) gives winter inputs to spring water supply.
- Spring and summer precipitation (forecast) gives spring additions to water supply
- Use exceedence fraction for first term and seasonal forecast for second term.

Estimation of Terms

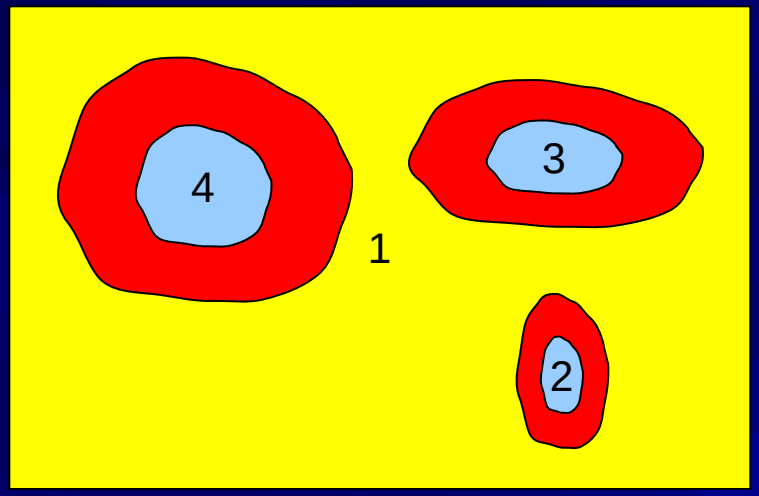
- SWE – from Cold Regions Hydrological Model and station data or from snow surveys or gamma airborne maps, or from MSC Passive Microwave maps
- INF – from soil texture maps and fall soil moisture estimates or from Cold Regions Hydrological Model and station data
- PondStorage – pond area from Radarsat or MODIS. Volume-area scaling from new GIS technique (Fang et al. 2010). Or from CRHM
- Precip – from seasonal forecast or 15 day ensemble forecasts.

Estimate Terms using Hydrological Model over Virtual Basin

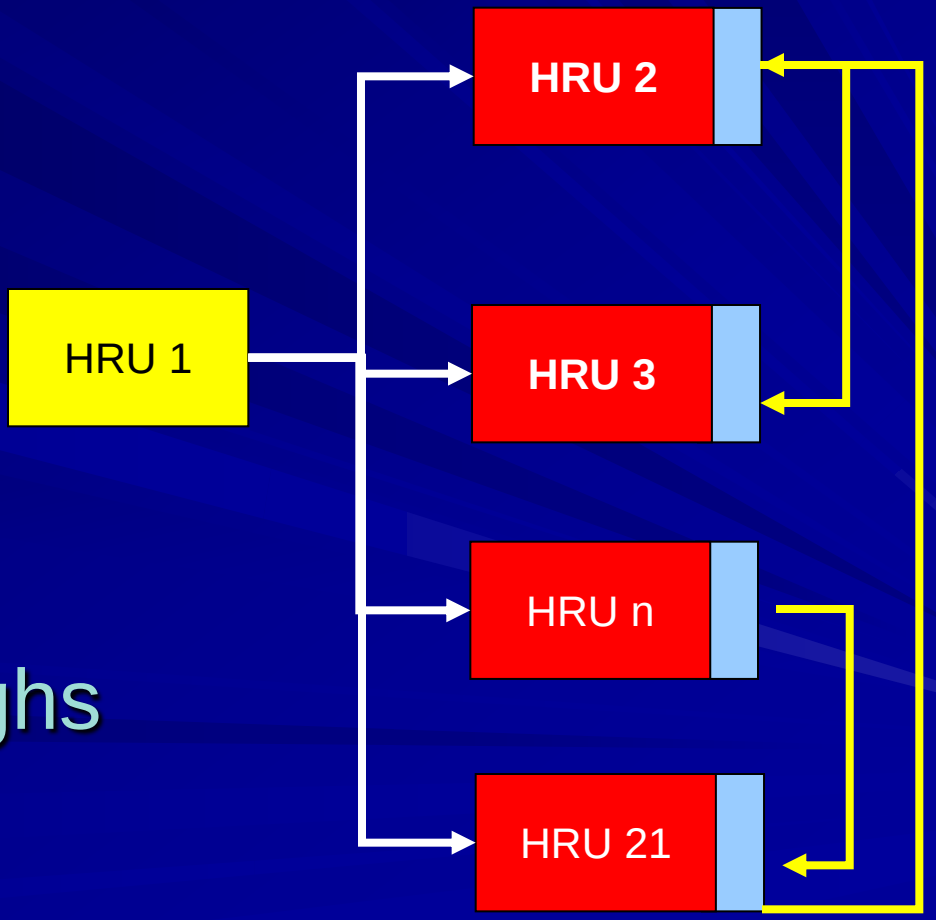
- Continuous model simulations using CRHM
  - Each location over 46 year period (1960-2005/06)
  - blowing snow transport,
  - sublimation,
  - Spring SWE,
  - Infiltration into frozen and unfrozen soils;
  - ET is calculated by the Penman-Monteith (1965,1981) method
  - soil moisture accounting and runoff to estimate actual evaporation during snow free period
- Virtual basin: typical land surface and ponds
- Meteorological forcing
  - Hourly: T, RH, Wind speed, Rainfall (Env. Canada); Qsi to drive net radiation estimates (Shook and Pomeroy)
  - Daily: snowfall (Env. Canada)

CRHM model of small prairie wetland basin

Small wetland complex

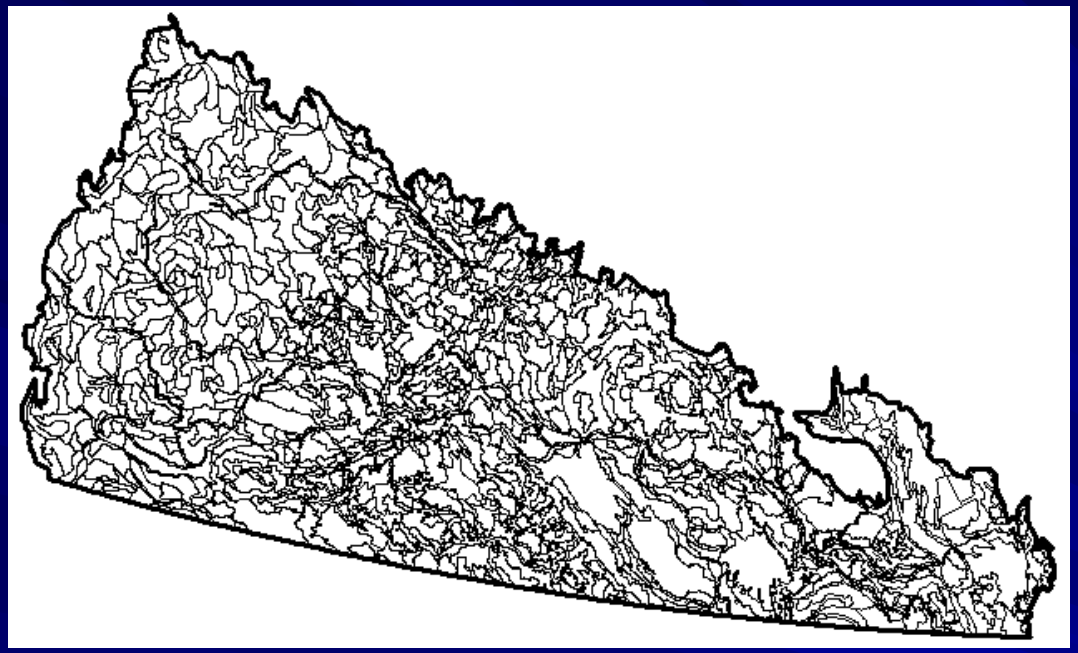


CRHM model



- HRU 1 is cropped
- HRUs 2-21 are sloughs

Soil Attributes: Texture



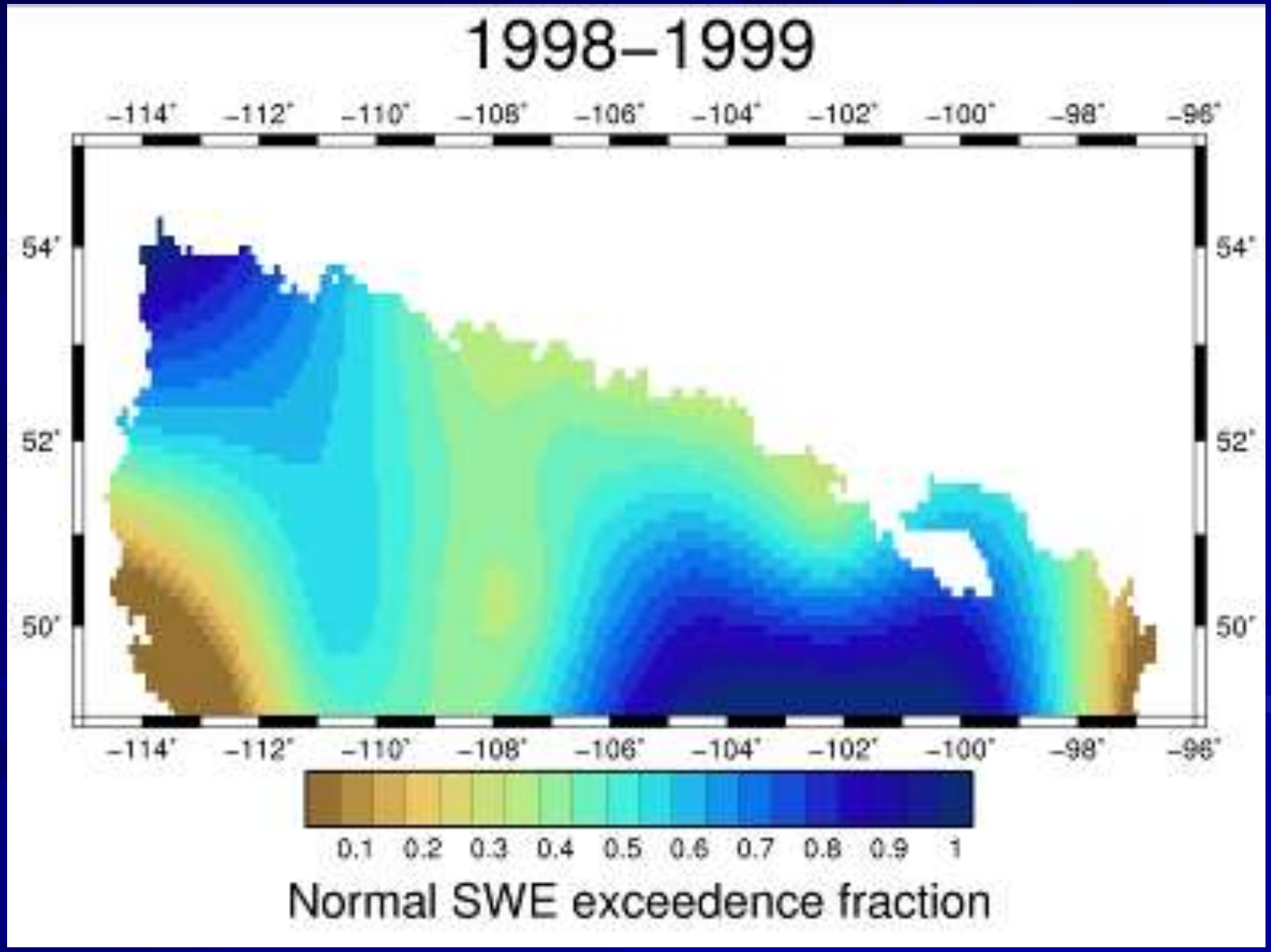
Polygons: Soil Landscapes of Canada 3.1.1 (2007)

Agriculture and Agri-Food Canada

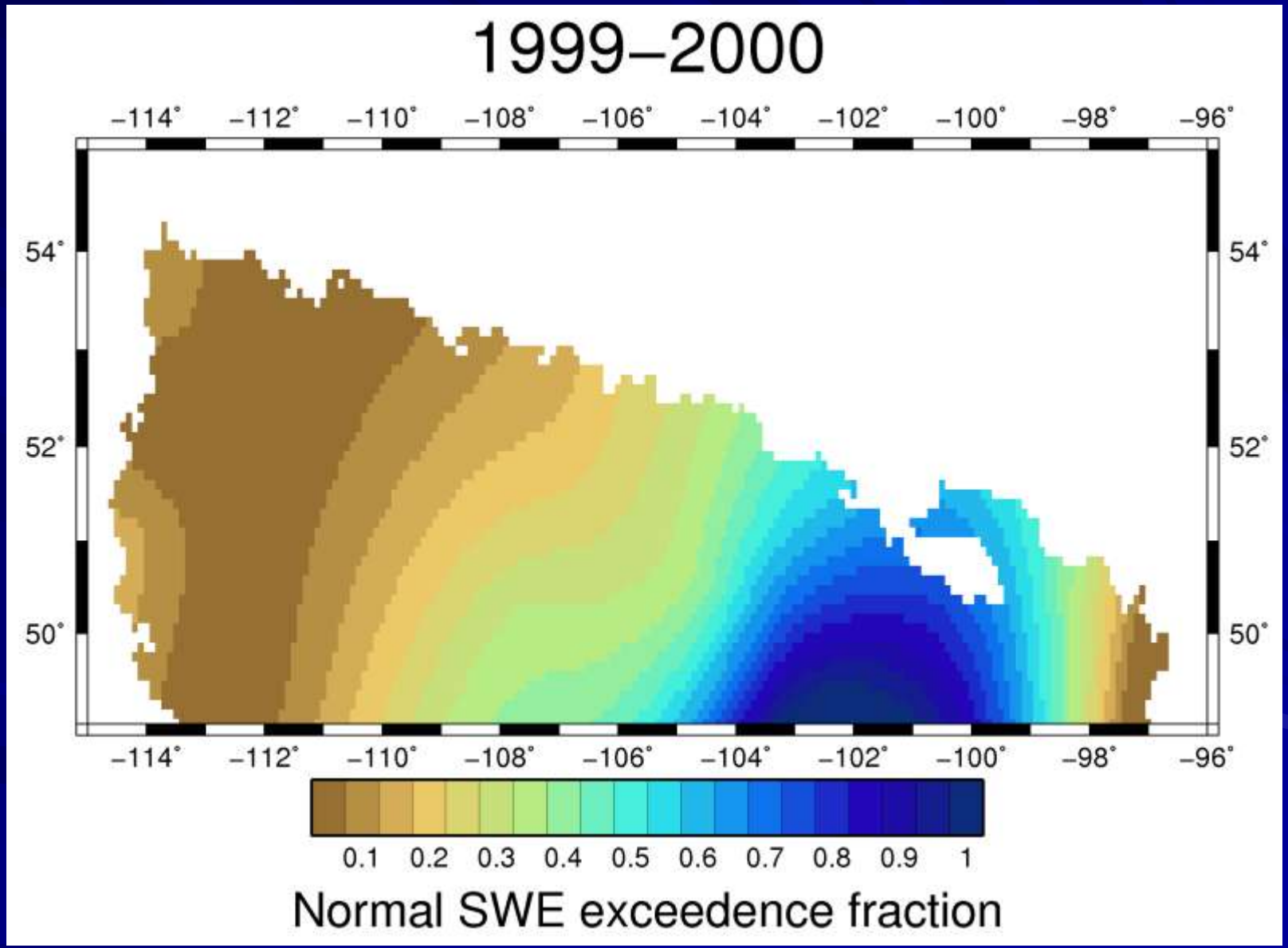
- Digital database of compiled soil survey maps at 1:1 million

- Determination of soil texture at any given polygon
  - Weighted average; % sand, silt, and clay of each soil layer in profile for every soil component located in the polygon
  - Typically: 1 m profile depth, 3-5 soil layers, 2 or more components

SWE on Grass, Pre-drought



SWE on Grass, Drought



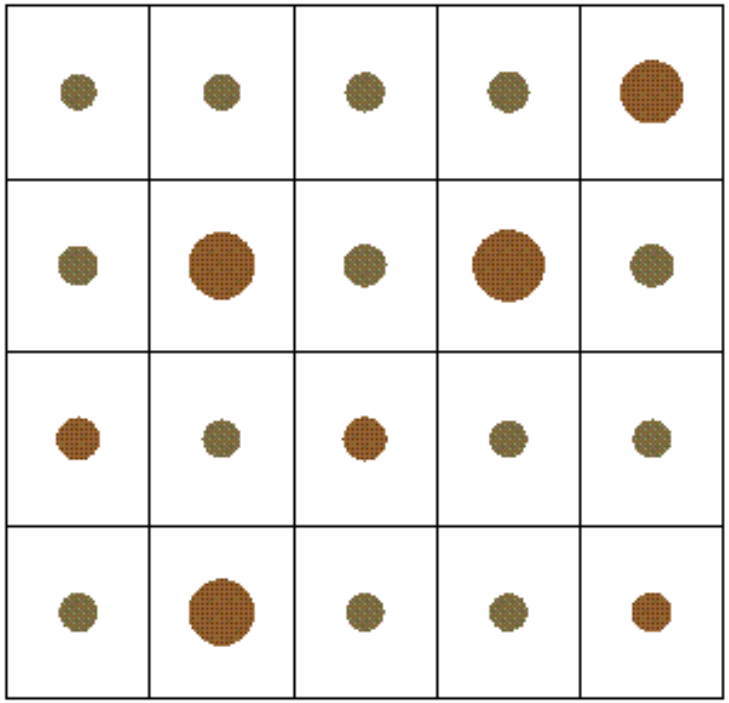
Pond Storage Variation

Empty

Full

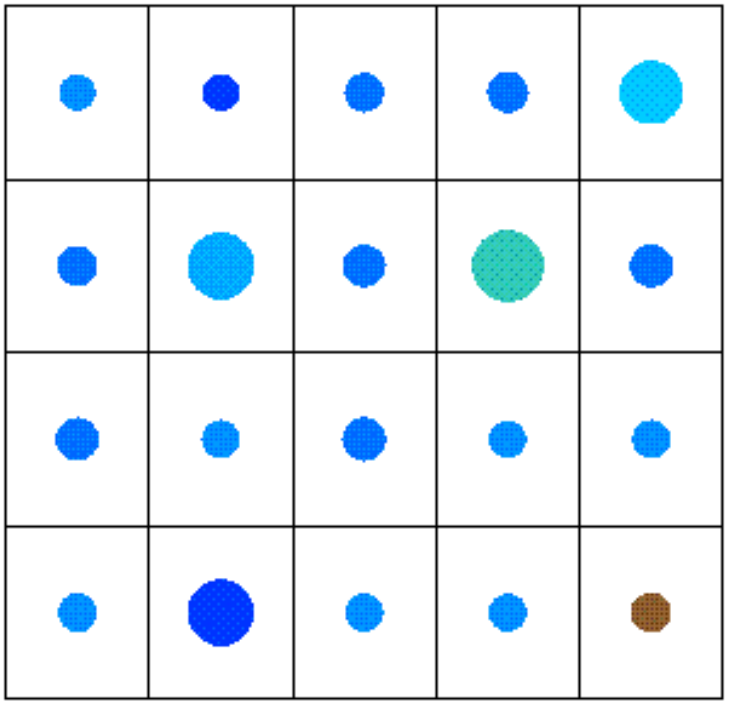
1-May-1999

Lethbridge
drought

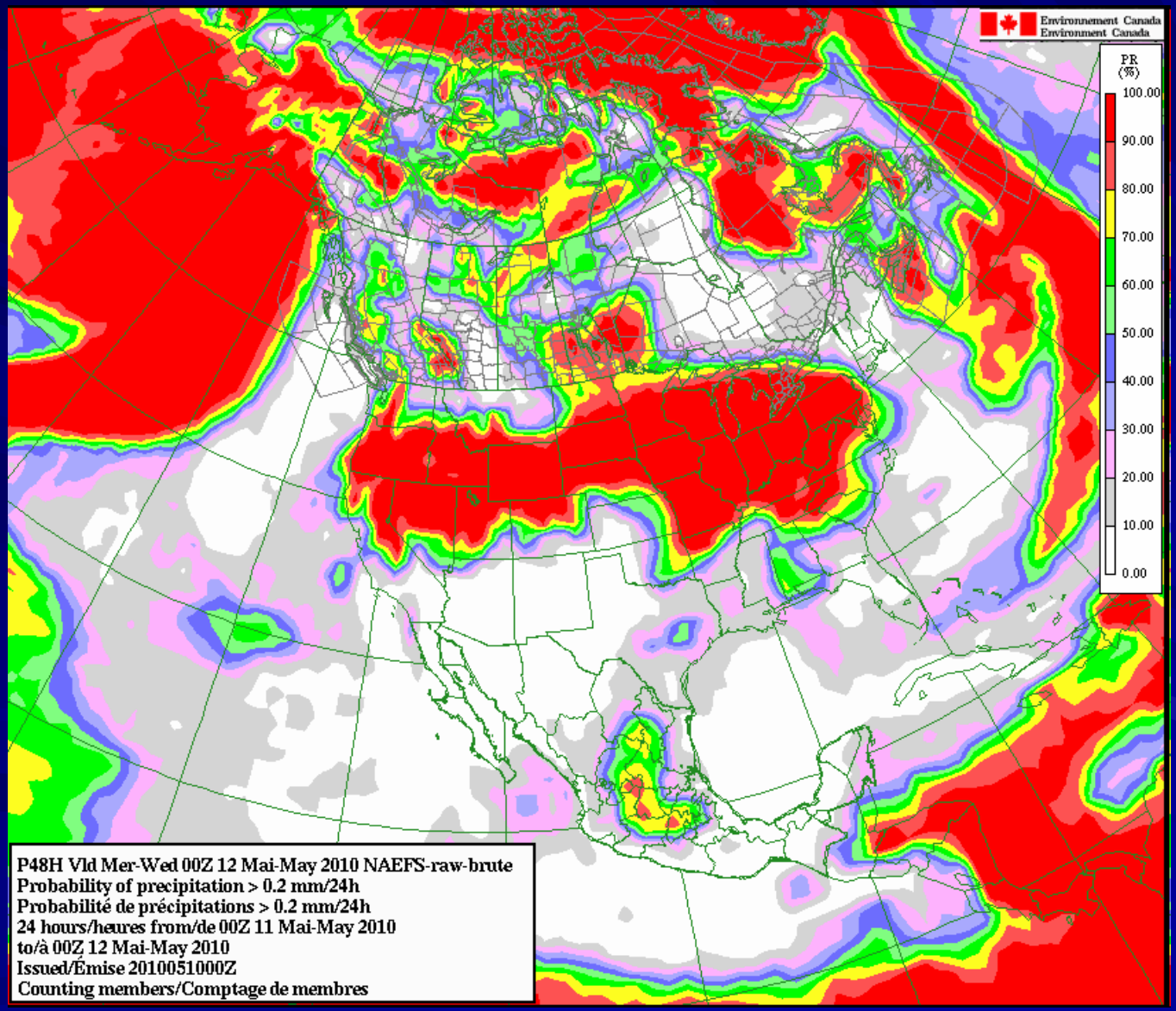


1-May-1999

Brandon
no drought



Precipitation Probability



Conclusions

- PWSI makes physical sense for the Prairies.
- PWSI can be estimated from data assimilation models or surface observations or remote sensing.
- It also needs probabilistic precipitation forecasts
- This proposed index needs trial calculations, and calibration to provide an easy to understand index that can be used to trigger drought responses for management of surface water supplies in the Prairies.