Hydrologic Projections for the Bear River

Joe Barsugli

Western Water Assessment

University of Colorado at Boulder

Climate Change Adaptation Workshop for Natural Resource Managers in the Bear River Basin

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- Acknowledgements: Alan Hamlet (Univ. of Washington), Jeff Deems (WWA), Kevin Werner (NOAA/CBRFC), Eve Davies (Pacificorp)

Precipitation Climatology -- Bear River Basin

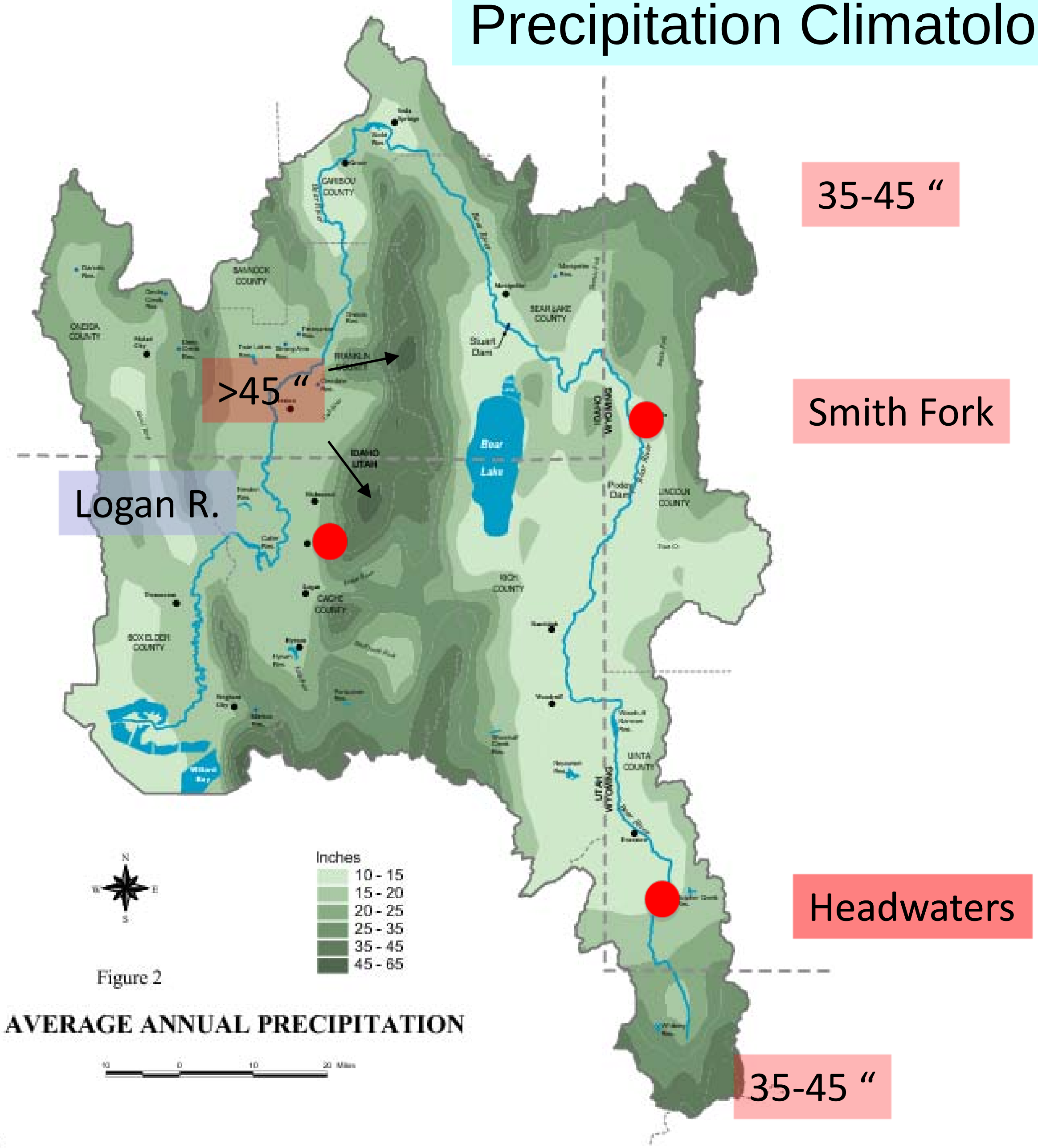
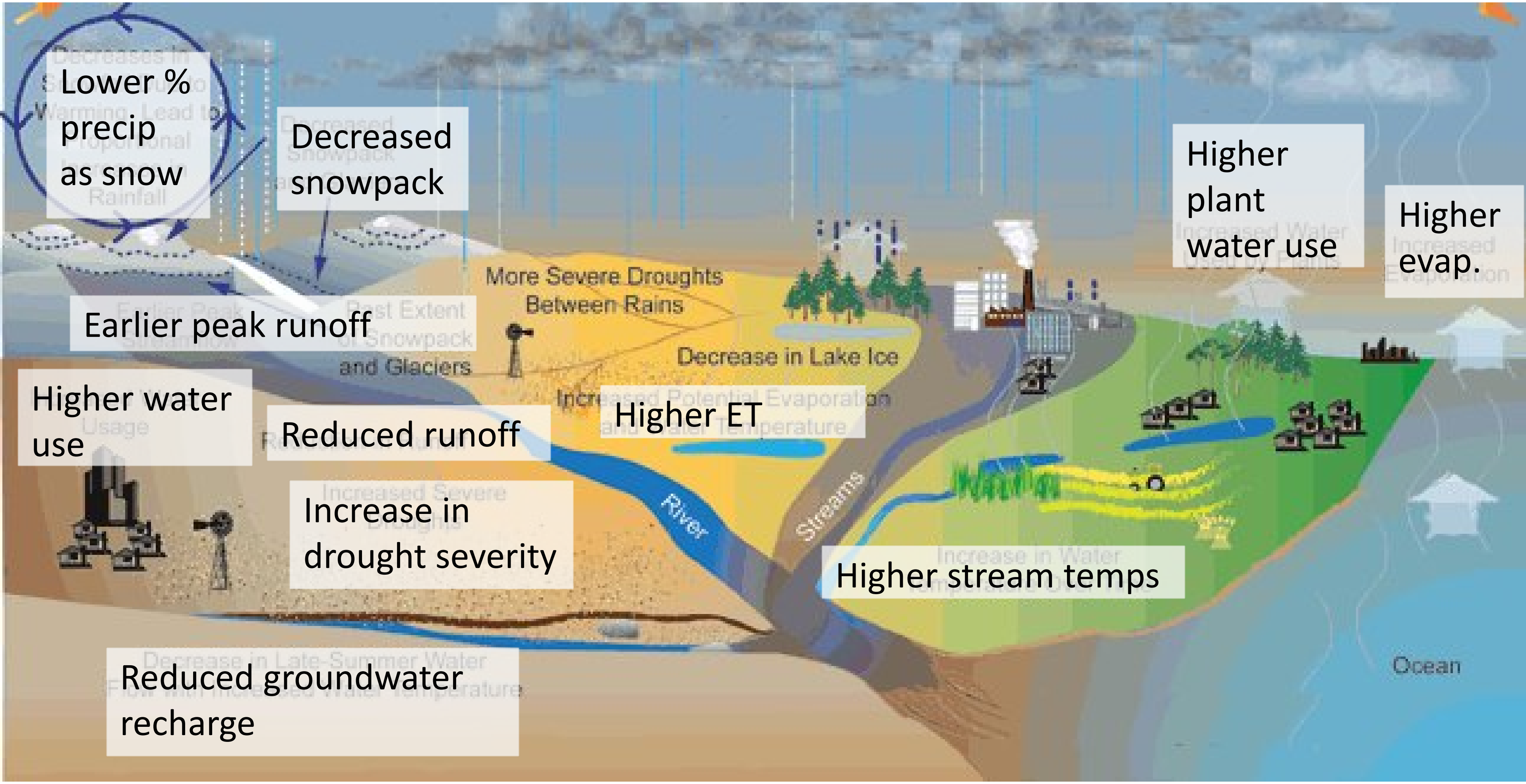


Figure 2

AVERAGE ANNUAL PRECIPITATION

Source: Bear River Plan, Utah DWR

Impacts to water cycle given additional warming…



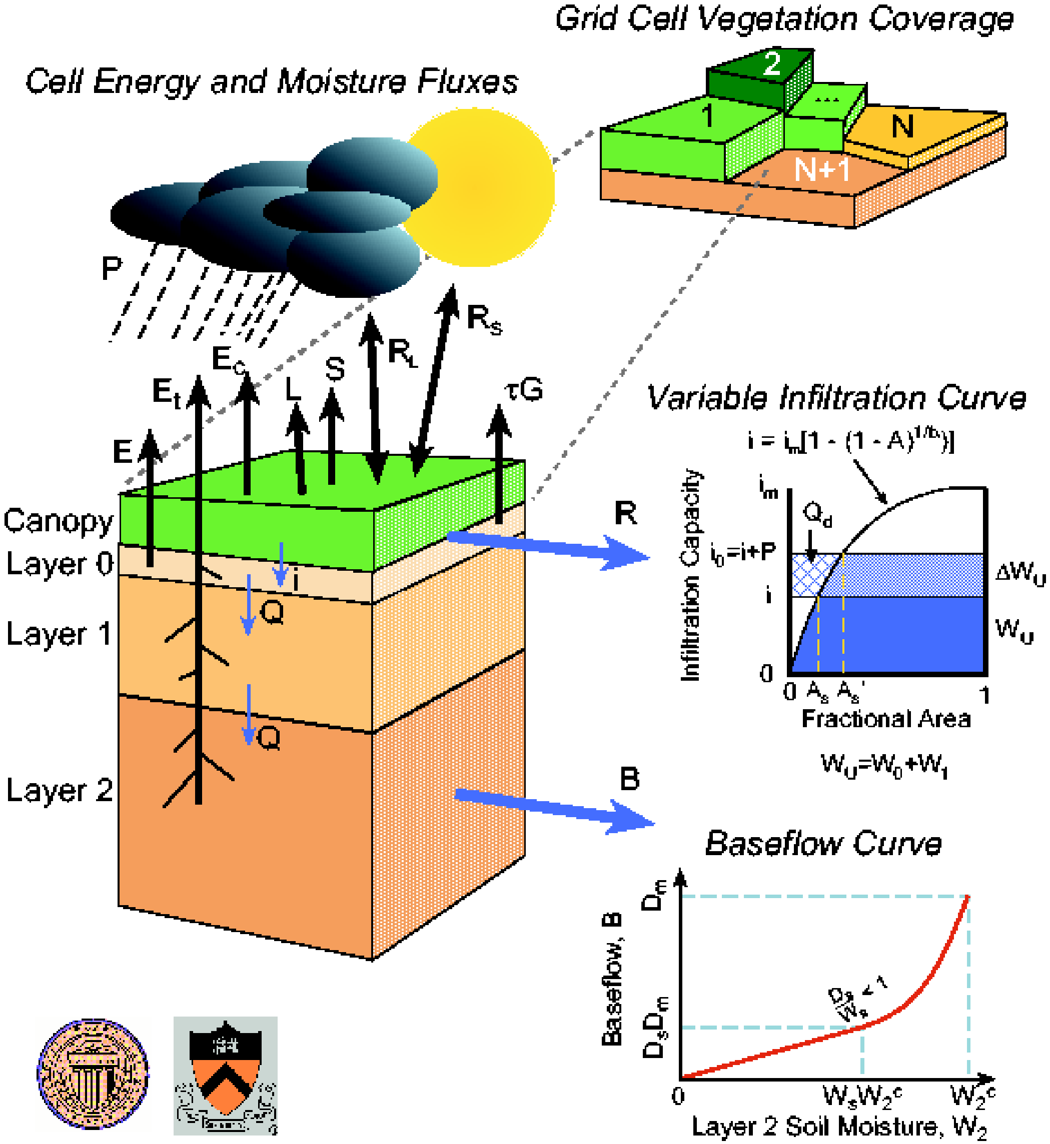
Variable Infiltration Capacity (VIC) Hydrology Model

Publicly available land-surface/soil hydrology model with runoff routing to stream network

Simulates "natural" streamflows and changes given Linda's climate change scenarios

Thanks to Alan Hamlet (Univ. of Washington) for sharing his version of the VIC model and his sage advice on interpreting the output.

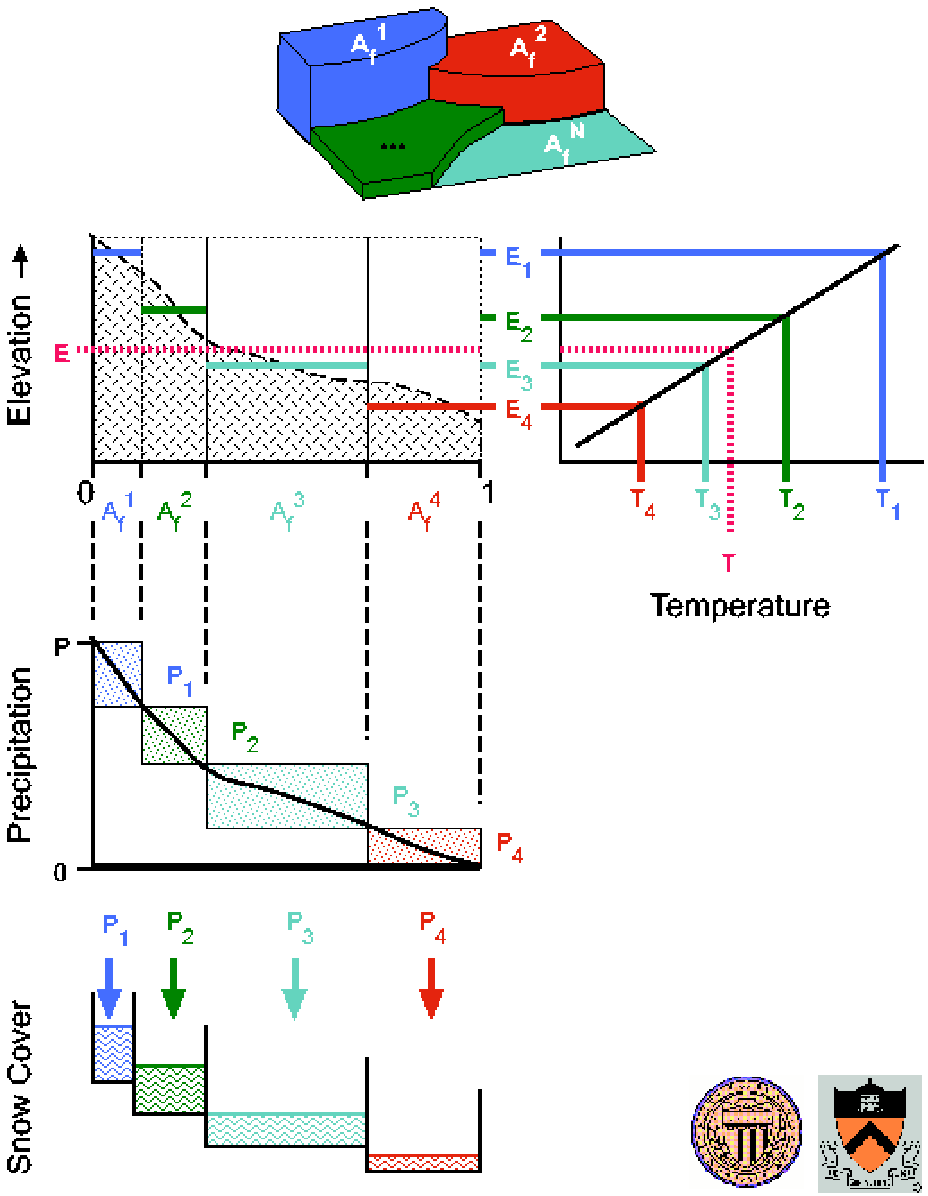
Variable Infiltration Capacity (VIC) Hydrology Model



- Publicly available land-surface/soil hydrology model with runoff routing to stream network
- Simulates "natural" streamflows
- 1/8 degree gridcells (about 10x14 km)
- Uncalibrated. A standard set of infiltration and baseflow parameters are chosen, and not calibrated to observed hydrographs. Main effect is on runoff timing, particularly on day-to-week timescale.
- "Water balance" mode. Simplified energy balance is computed based on daily values except for snow, which uses 3-hour timestep.

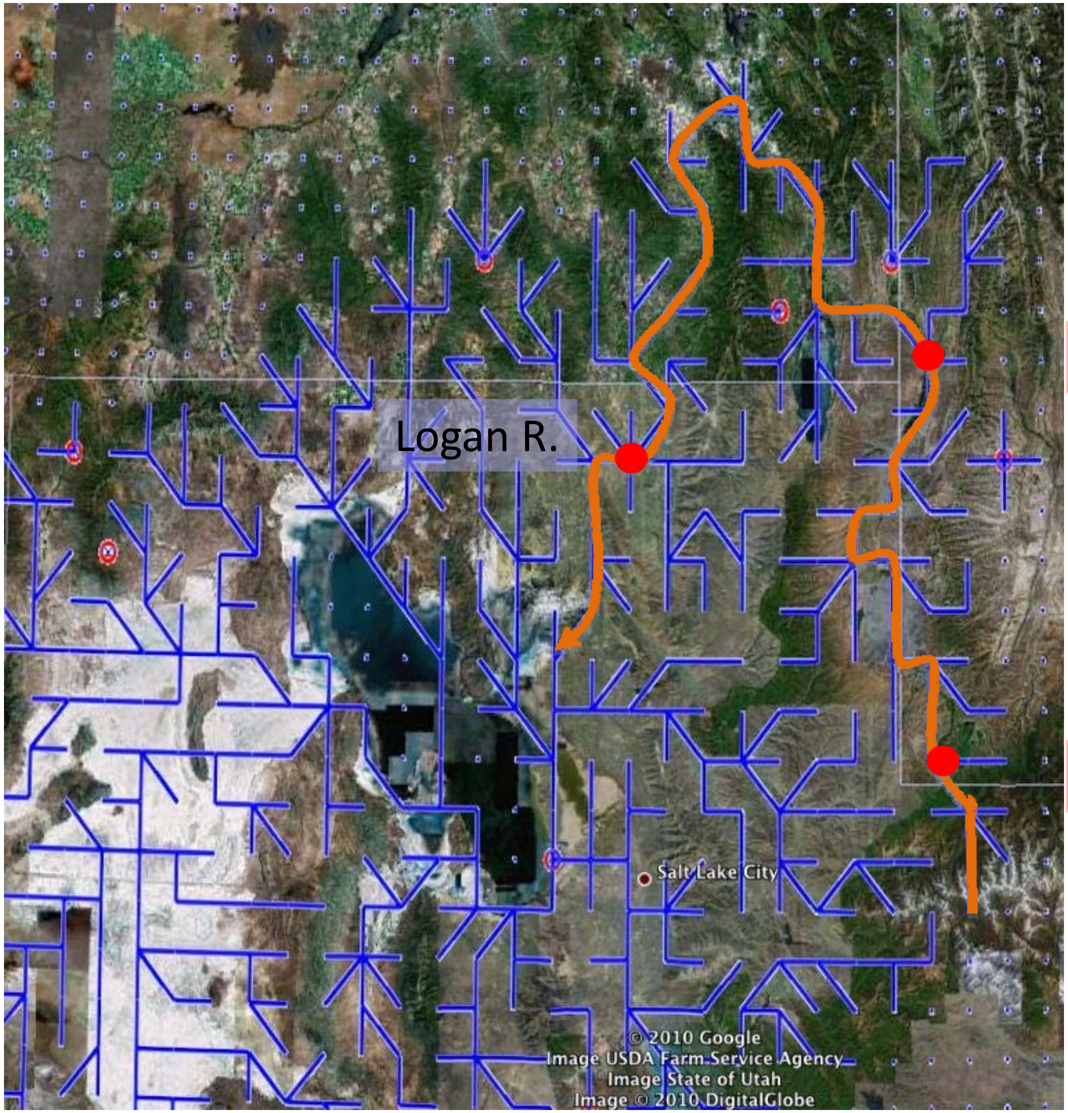
VIC Model Details

VIC Snow Elevation Bands



- Up to 5 elevation bands in each gridcell for snow model
- Temperature lapse rate used to extrapolate to elevations bands
- Precipitation is distributed as rain or snow depending on temperature
- Snowpack evolution/melt also determined on individual bands.
- Daily Precipitation, Maximum and Minimum Temperature input from gridded dataset (Hamlet and Lettenmaier, 2005)

VIC Routing Model: Bear River



•Runoff and baseflow in each cell is routed by the stream network

Smith Fork

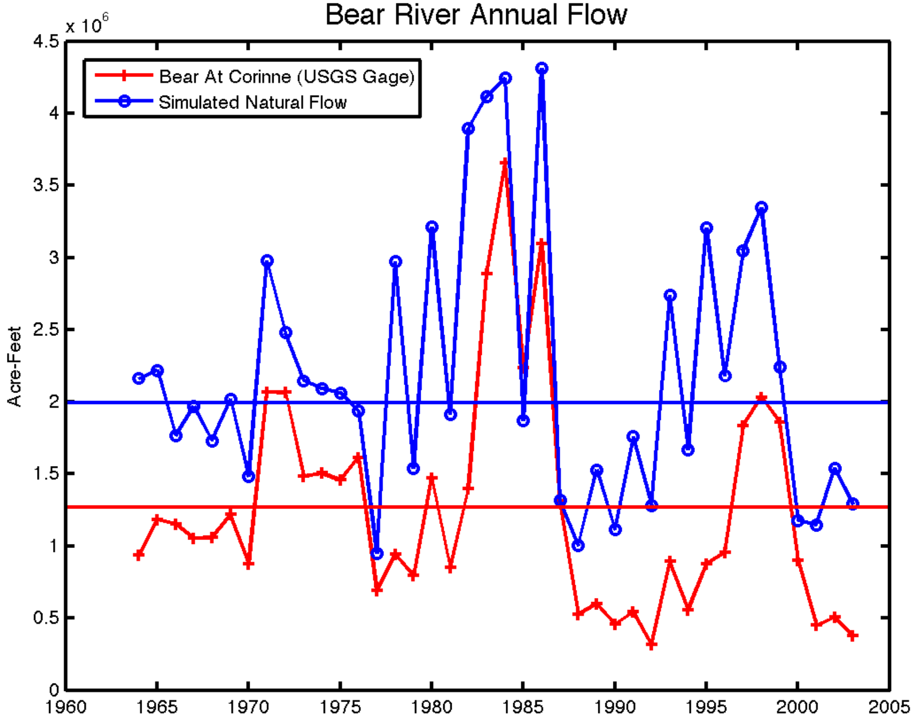
Headwaters

CAUTION!!!

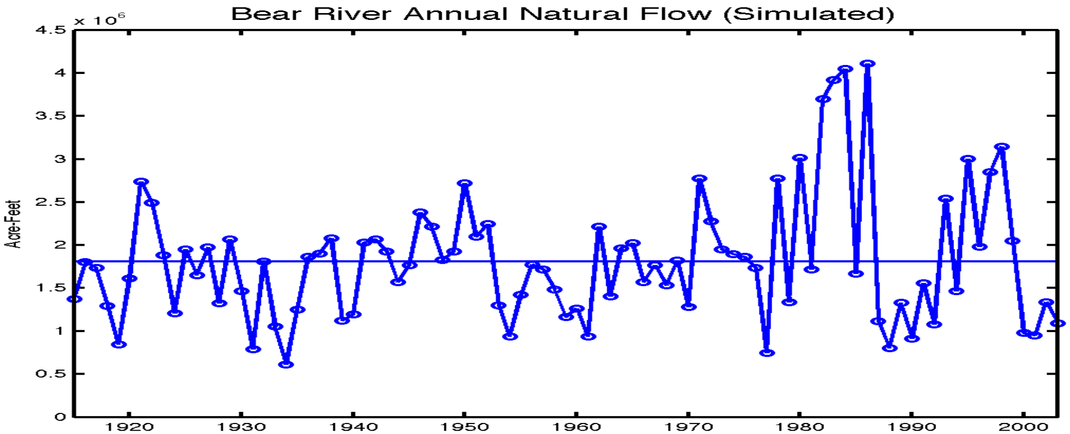
•Streams are not coupled to the shallow (soil) groundwater

•Groundwater flow is not modeled

Comparison of Modeled with Gaged Streamflow: Bear River Total Flow

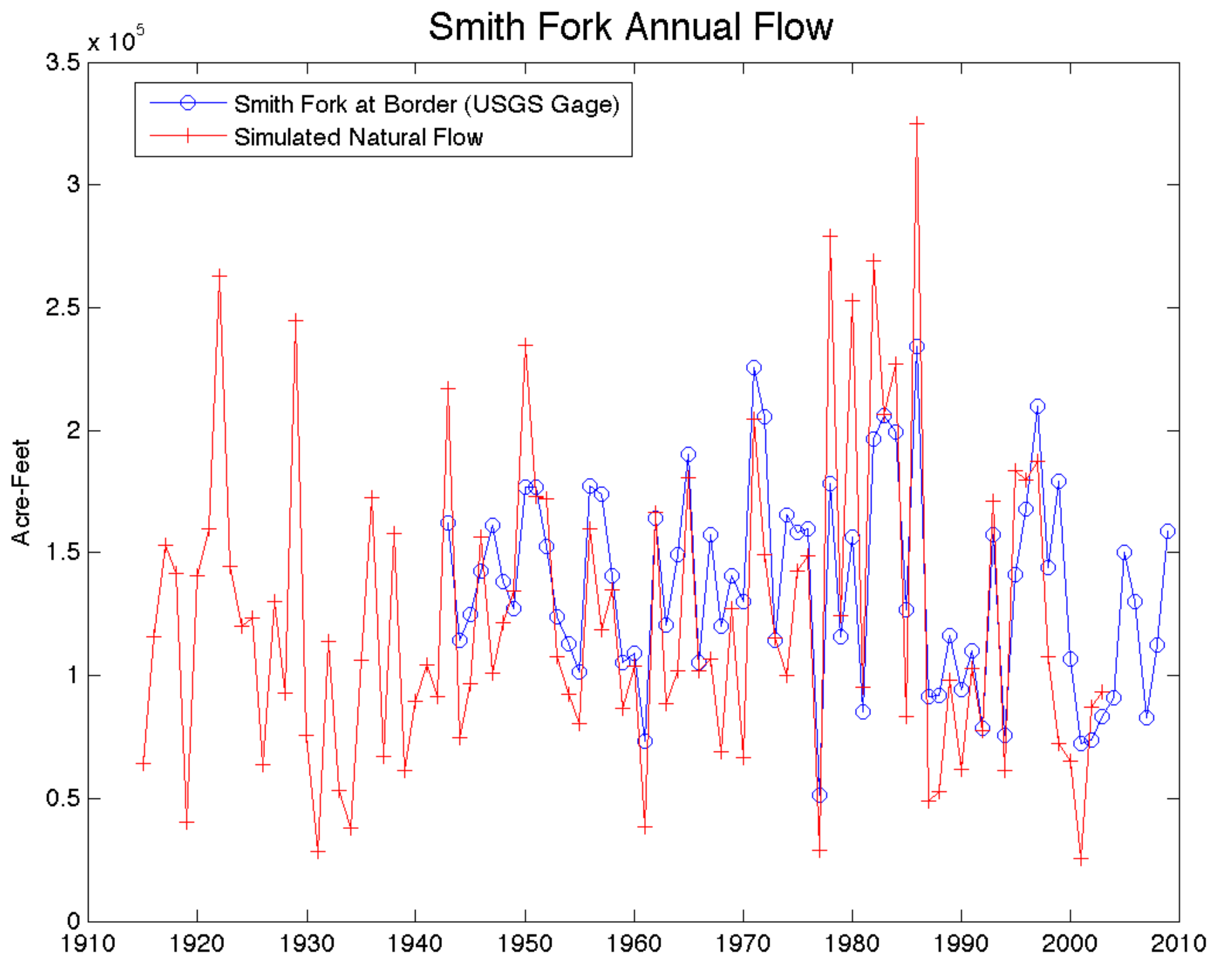


- •Expect gaged flow to be lower than modeled “natural” flow due to diversions and consumptive use.
- •1964-2003 modeled: 2.0 million acre-feet per year
- •1964-2003 gaged flow: 1.3 MAF



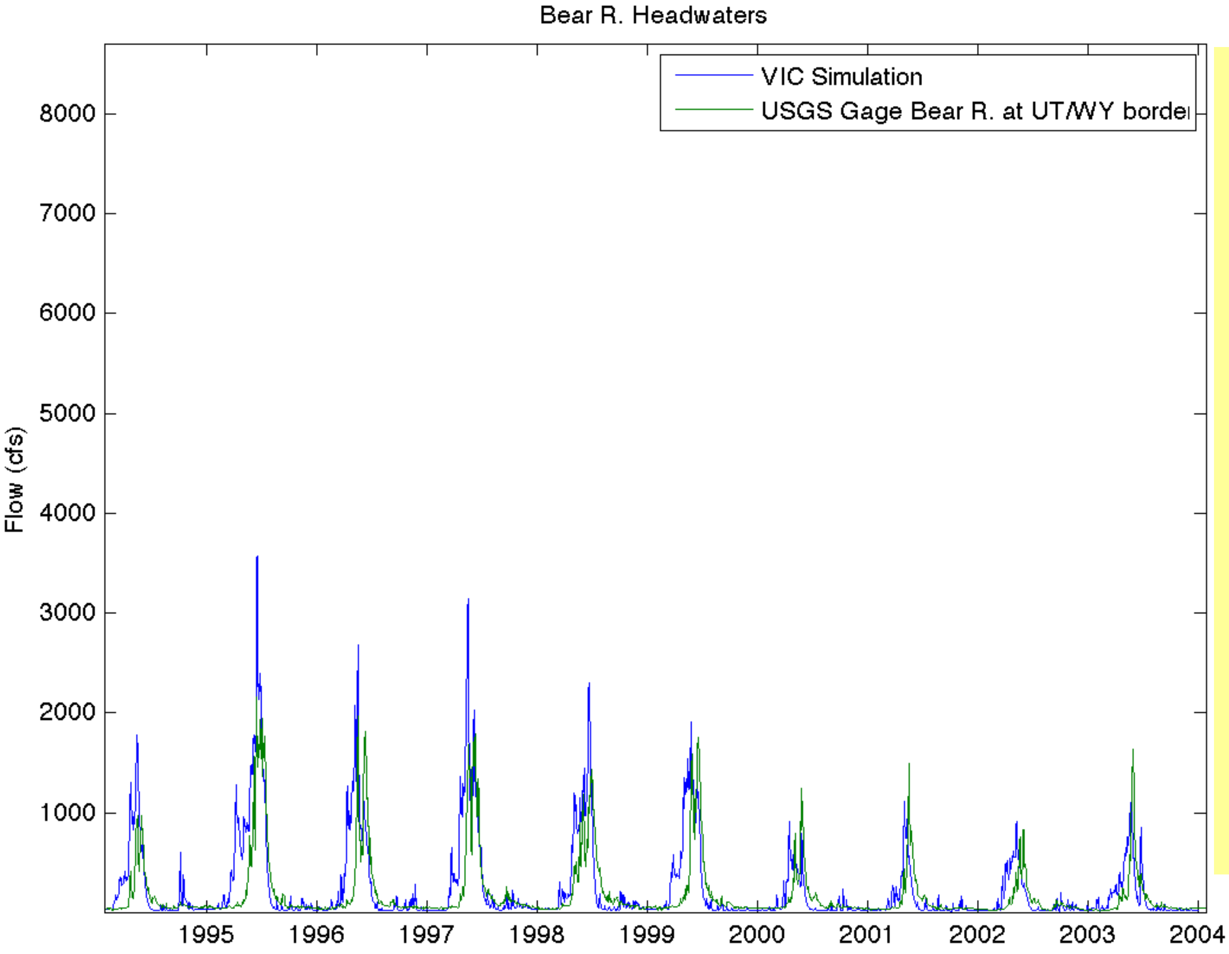
- •Long term mean of around 1.8 million acre-feet per year (modeled)
- •Estimates of yield of the basin are around 1.8 - 2 million acre-feet.

Comparison of Modeled with Gaged Streamflow: Smith Fork



- Only small diversions and storage above gage, so it reflects "natural" flows
- Long-term means well modeled
- Model misses some wet and dry years -- likely due to deficiencies in gridded meteorological data.

Comparison of Modeled with Gaged Daily Streamflow: Bear River Headwaters



- Spring runoff comes earlier in the model and drops off faster.
- Peak flow overestimated in many years.
- Model captures differences between wet and dry years.
- Overall magnitude of flows is well represented in the model

Climate-altered hydrology: The Delta Method

Baseline run: observed daily sequence of precipitation (P) and temperature (T)

"Delta" run:

$T \rightarrow T_{obs}+\Delta T$

$P \rightarrow P_{obs}*(1+\Delta P/P)$

"Deltas" are specified monthly from climate scenarios given by Linda Mearns

Interpretation:

- These are sensitivity experiments.
- Does NOT explicitly model changes in extremes or changes in frequency of wet/dry days.

Sensitivity to changes in Temperature and Precipitation Separately

	+1C	+2C	+10%
Bear River total	-5%	-10%	+22%

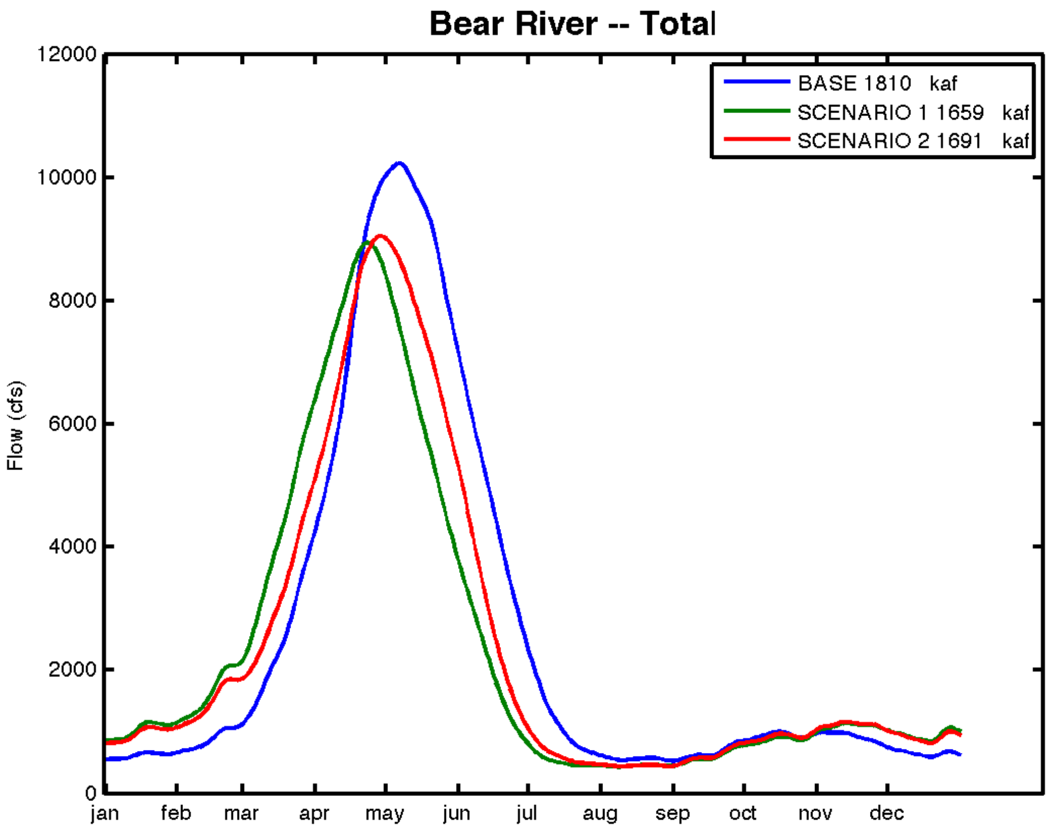
•Idealized scenarios in which only one variable is changed. The same changes are applied in each month.

•Colorado River at Lees Ferry shows similar sensitivity to temperature and precipitation changes in the VIC model . Other hydrology models differ in their sensitivity ranging from from 5 - 9%.

Climate Change Scenarios

Annual Streamflow (KAF)	Historic Simulation	Scenario 1	Scenario 2
Uinta Headwaters (BEARH)	187	153 (-18.2%)	162 (-13.4%)
Smith Fork (SMITH)	130	124 (-4.6%)	120 (-7.7%)
Logan River(LOGAN)	411	384 (-6.6%)	392 (-4.6%)
Bear River total (BEARC)	1810	1659 (-8.3%)	1691 (-6.6%)

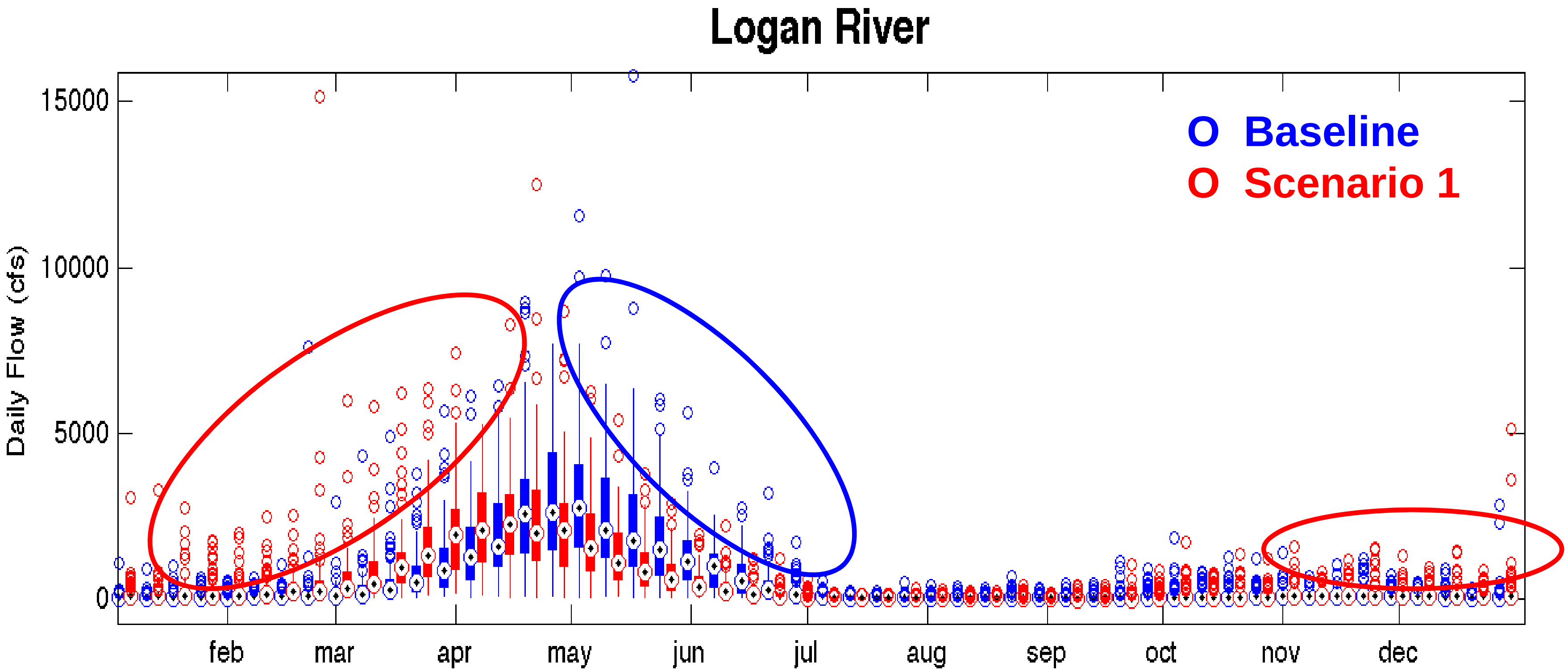
Streamflow Timing



Hydrograph feature	Scenario 1	Scenario 2
Rising limb	2 weeks earlier	1 week earlier
Peak	2 weeks earlier	1 week earlier
Receding limb	3 weeks earlier	2 weeks earlier

Changes in Daily Flows

•Box shows 25th and 75th percentiles for each week of the year. Extremes and outliers are shown by the "whiskers" and by circles.
•Higher average and peak flows in late Fall, Winter and early Spring due to snow events becoming rain events in a warmer climate
•Earlier melt means smaller late spring/early summer peak flows



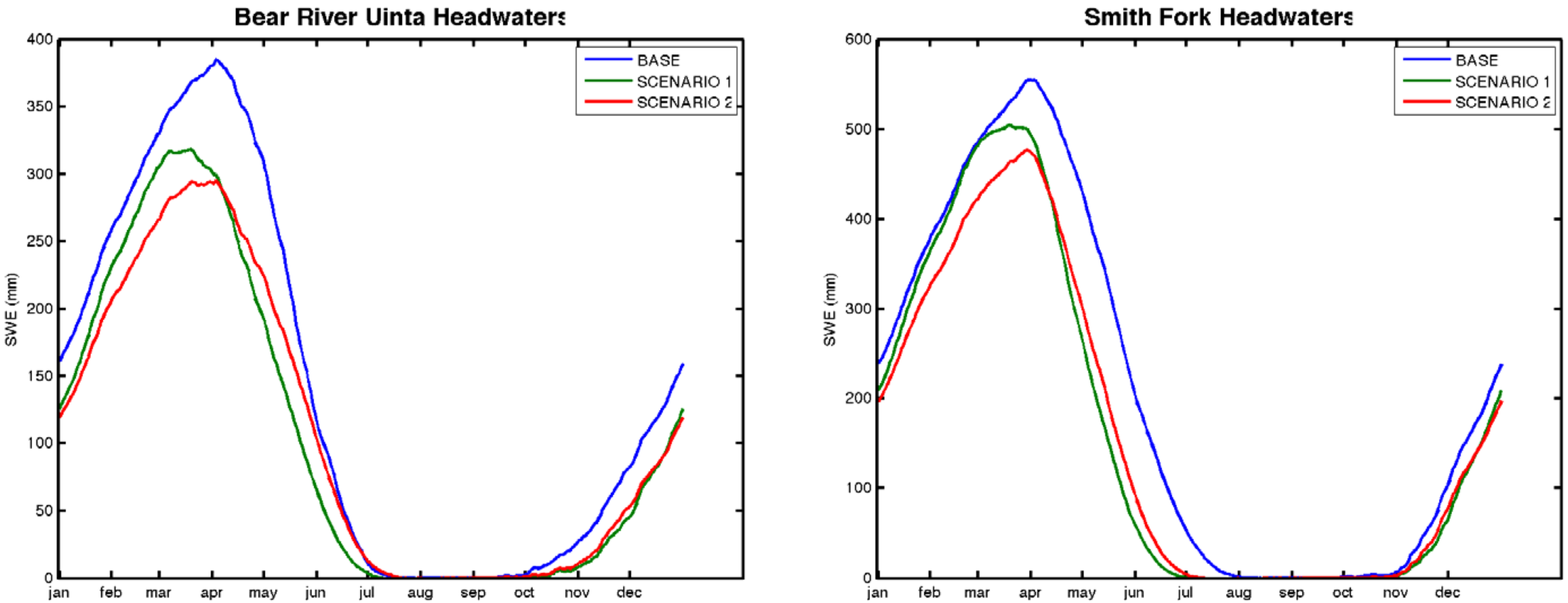
Summertime Streamflow

- Lowest daily flows reduce by around 10-15%. (Low flows driven mainly by lower precipitation). Similar result for "7Q10".
- 90th percentile (high) flows during Summer greatly diminished (Both evapotranspiration and low precipitation contribute)
- Simulation of low flows could be improved by calibrating the runoff in headwaters basins.
- CAUTION! "Delta method" does not change number of wet vs. dry days. Confidence in qualitative changes, not quantitative.

Summertime Flows	Scenario 1	Scenario 2
Low flows (10th percentile)	-10%	-15%
High flows (90th percentile)	-25%	-50%
"7Q10 "	-8-15%	-15-20%

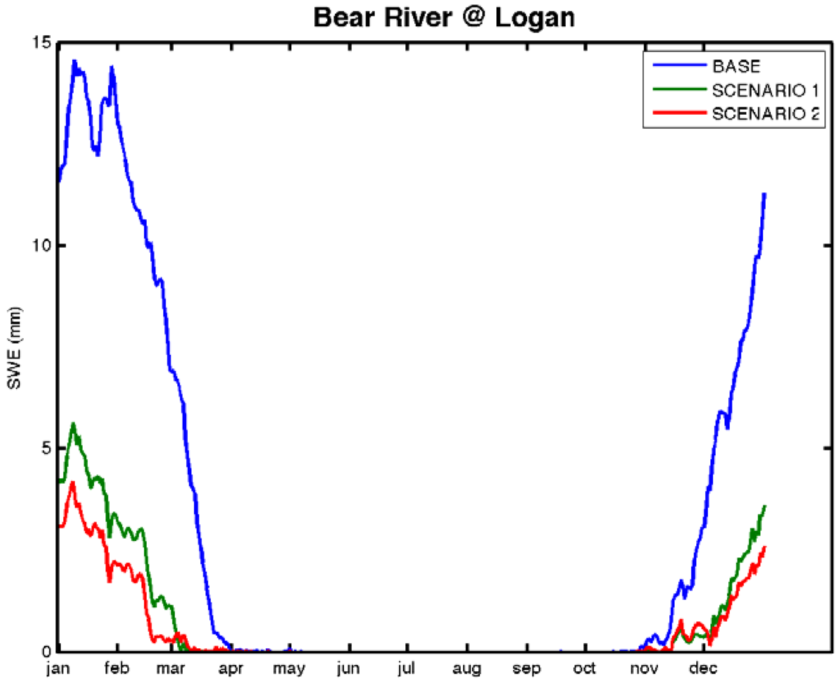
Snowpack (SWE) - High elevation basins

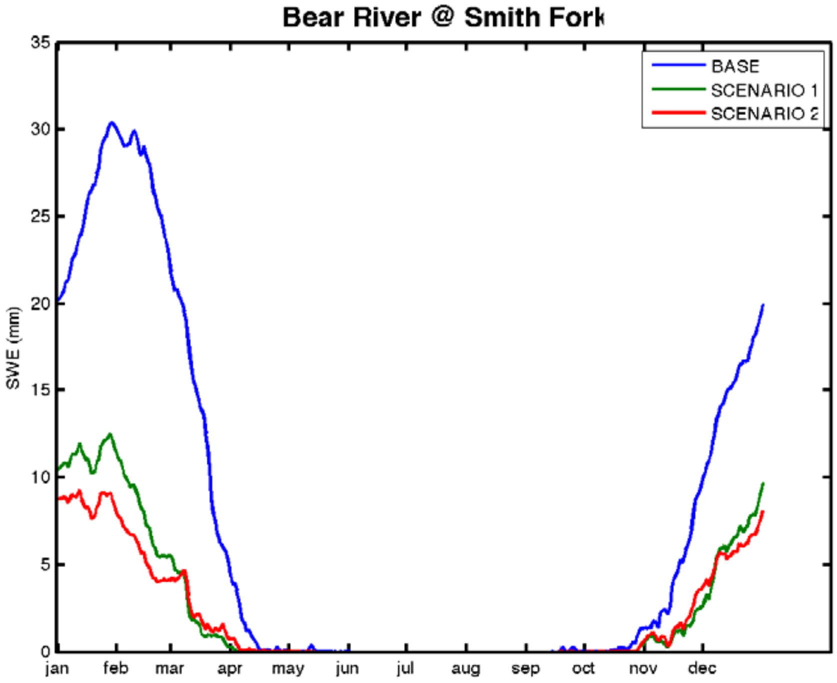
- Snowpack starts accumulating later and melts earlier
- Amounts depend on seasonal changes in precipitation
- The two scenarios are similar in the peak snowpack because of compensating seasonal changes



Snowpack (SWE) -- Lower elevation sites

•Lower elevation sites see a more pronounced reduction in average snowpack





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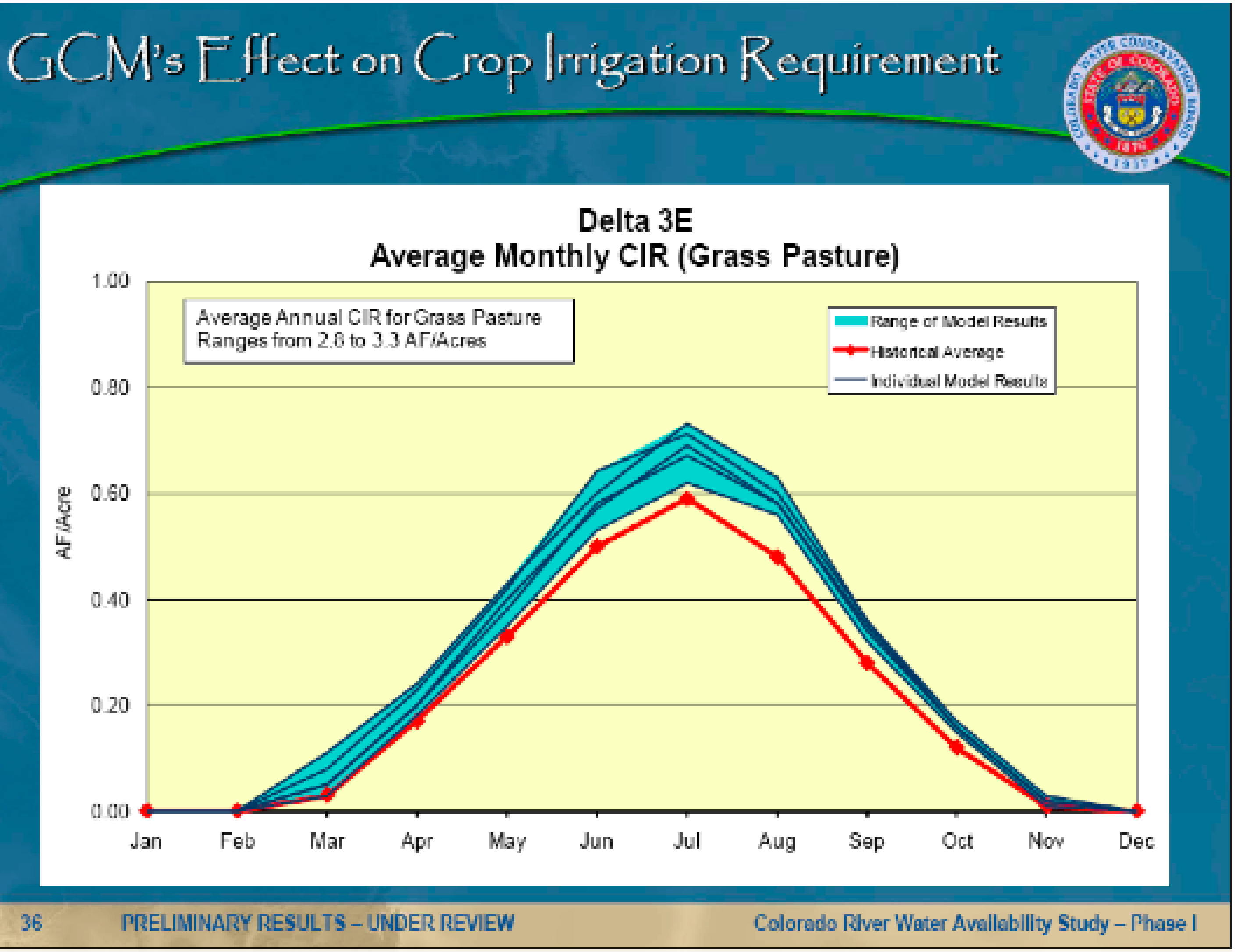
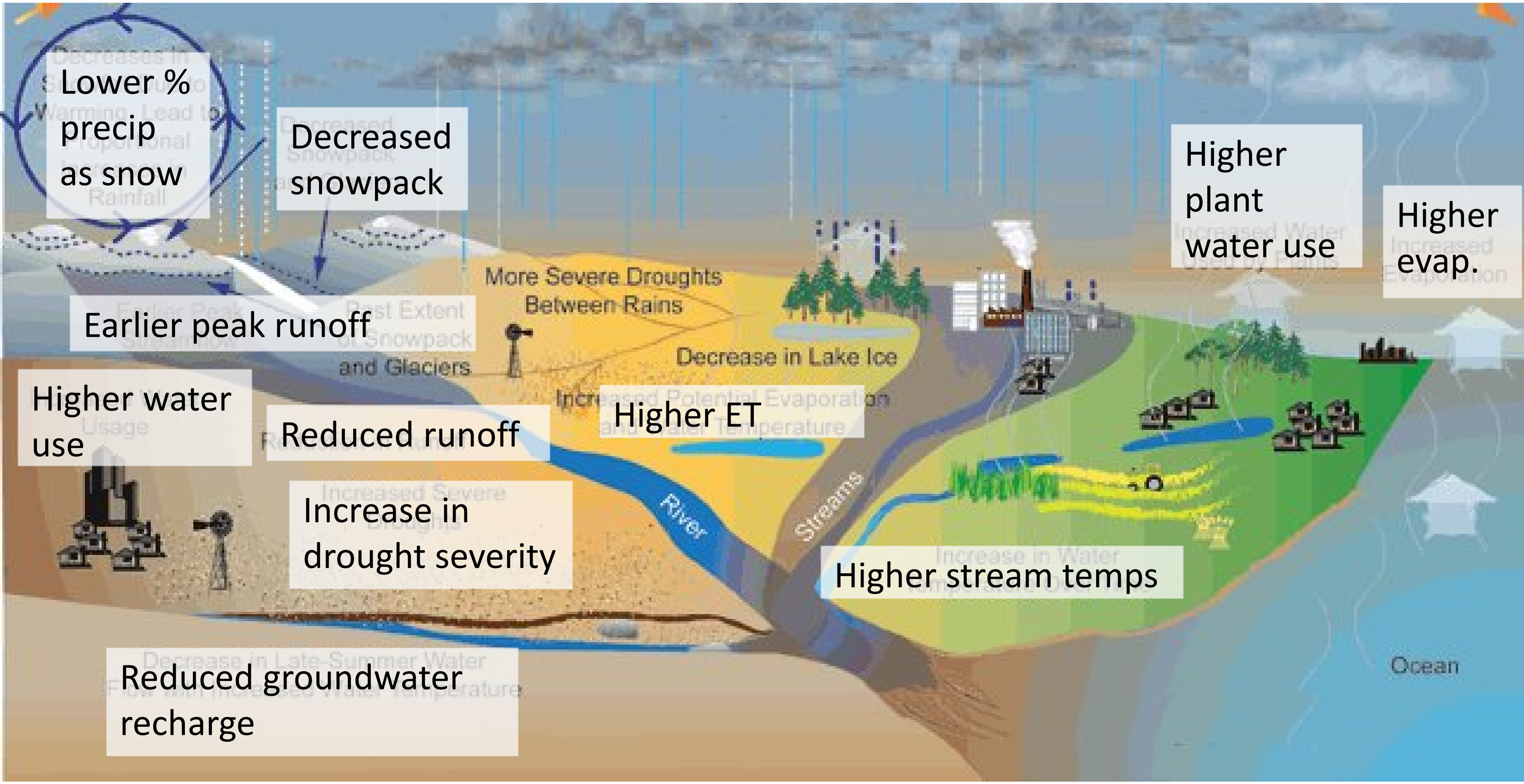
Increased Agricultural Demand-- an example from Colorado



- Colorado River Water Availability Study (CRWAS) -- under review
- Demand rises earlier
- Demand is a function of temperature **and** precipitation
- Additional demand may not be met

Recap....


Lower % precip as snow
Decreased snowpack
Earlier peak runoff
More Severe Droughts Between Rains
and Glaciers
Decrease in Lake Ice
Higher plant water use
Higher evap.
Higher water use
Reduced runoff
Higher ET
Increase in drought severity
River
Streams
Higher stream temps
Reduced groundwater recharge
Ocean

END