Ensuring Sufficient Water Supply for the Emerging Bioeconomy

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Purpose of Presentation

- Review water supply requirements for biofuel in Canada
- Assess where water supply might be a limiting factor
- Review nature of water availability
- Discuss options for the bioeconomy in water stressed regions
- Anticipate sensitivity of water supplies to
  - land use change,
  - drought and
  - climate change

Intensive Plant Growth for Biofuels

- Despite having much of the world's freshwater, Canada has water limitations to biofuel growth
- Highly productive crops will tend to use most or all available soil water in drier parts of Canada and reduce streamflow everywhere:
  Evaporation (incl. transpiration) ≈ Rainfall
  - Prairies
  - Interior BC valleys
  - SW Ontario
- Afforestation will reduce streamflow because of interception of rainfall and snowfall and increased infiltrability of soils.
  - Interception evaporation is not due to transpiration – water loss not related to biomass production
- Reduced streamflow is not necessarily consistent with improved water quality claims of biofuel industry

Biodiesel Processing

- Active Ion Purification (ion resin catalyst)
- No water added for wash process
- Able to process vegetable oils with acid values < 5%
- Example: Milligan’s Biodiesel, Foam Lake, SK
- BIODIESEL PRODUCTION HAS LITTLE WATER SUPPLY LIMITATION

Ethanol Processing

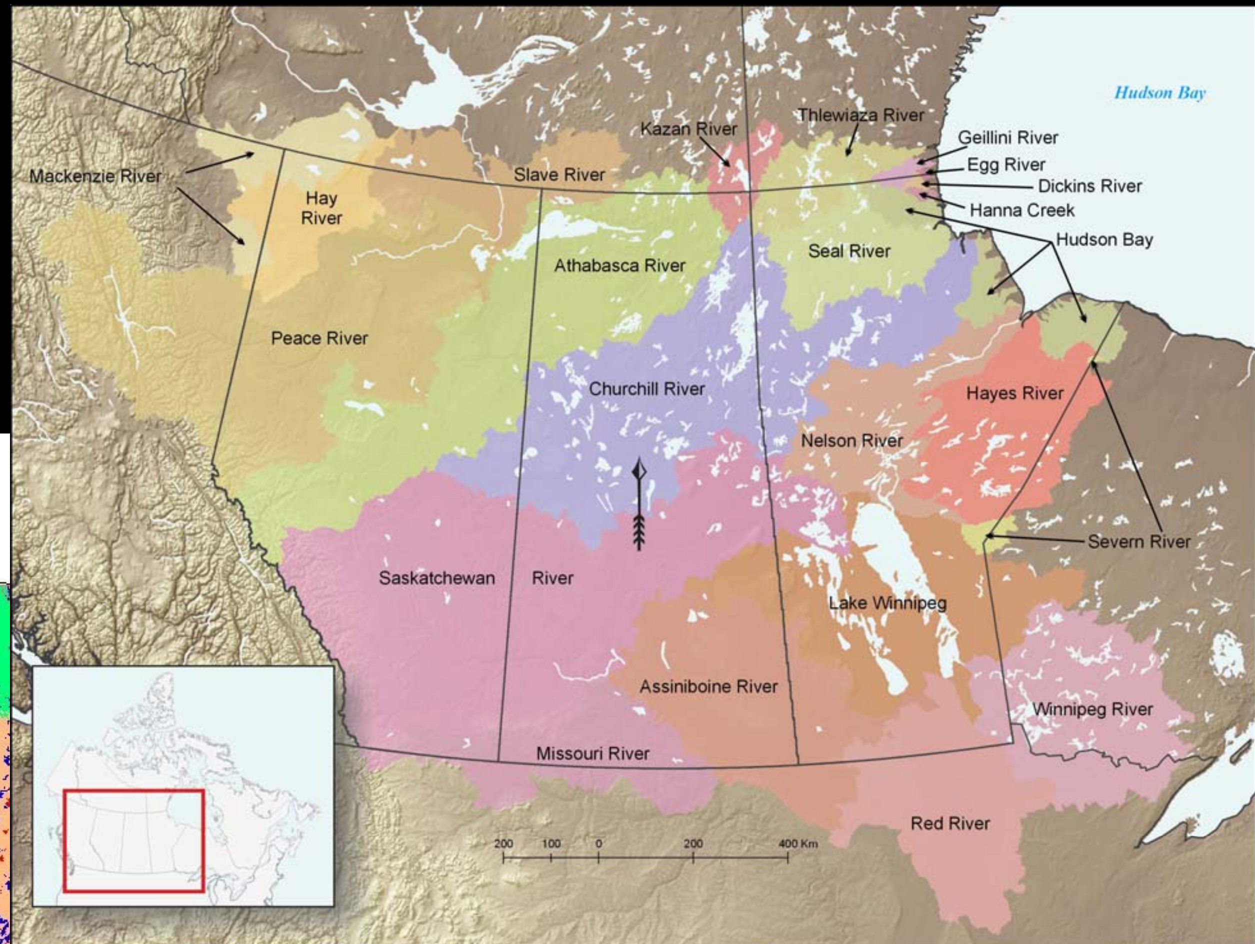
- Ground, sometimes steeped, grain ‘meal’ slurried with water to form ‘mash’
- Mash is processed and fermented
- Distillation: ethanol is concentrated to 190 proof ethyl alcohol then dehydrated to 200 proof.
- Water use from 3 to 10 litres water per 1 litre ethanol.
- Carbon use is smaller when water use is higher
- 80 million litres ethanol/year = 800 million litres water use/year for average plant.

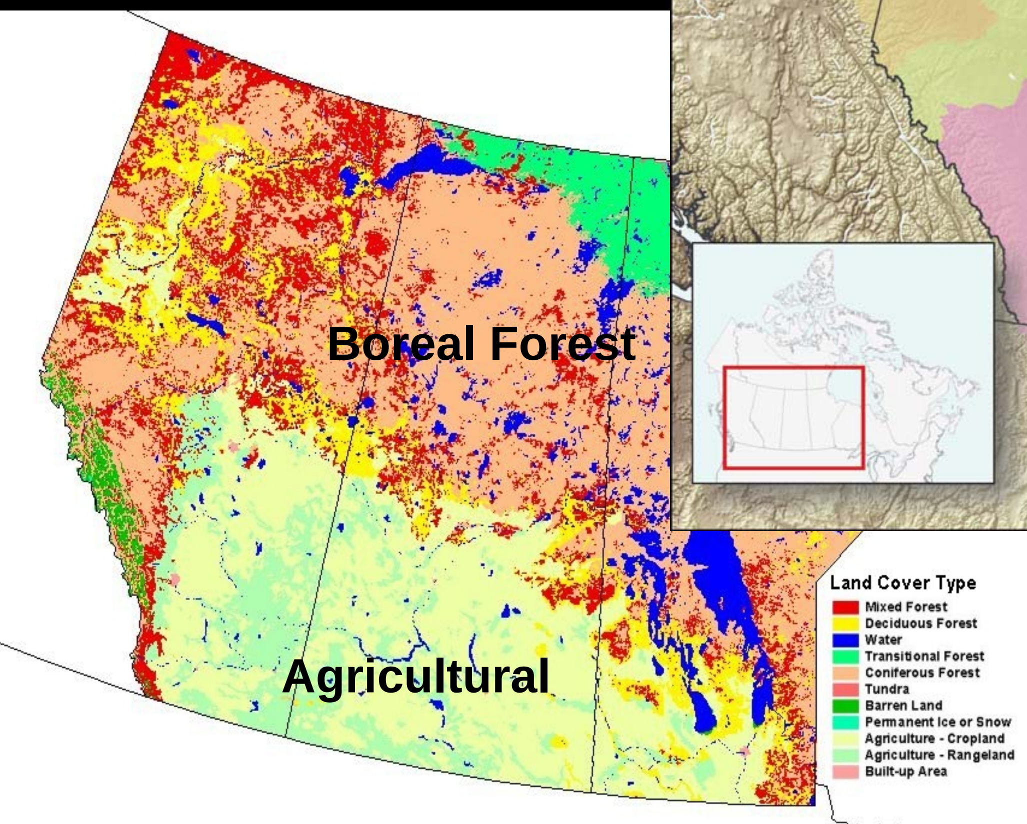
Ethanol Plant Water Requirements

- One ethanol plant uses 800 million litres/year =
- 800,000 m^3/year =
- 2,200 m^3/day =
- 0.025 m^3/s per plant.
- If plant density is 1 plant per 100 km^2, then ~100 km^2 gross basin area draining to plant
- Equivalent to 8 mm/year of runoff via streamflow for plant water use.
- This is easily accomplished across Canada except for parts of the Prairies – the 'Palliser Triangle'.
- However, the Prairies are an excellent source of grain for ethanol and so the water supply for Prairie ethanol plants must also be considered……….

Case Study: THE CANADIAN PRAIRIES

Landcover tied to climate & soils with distinctive land atmosphere interactions





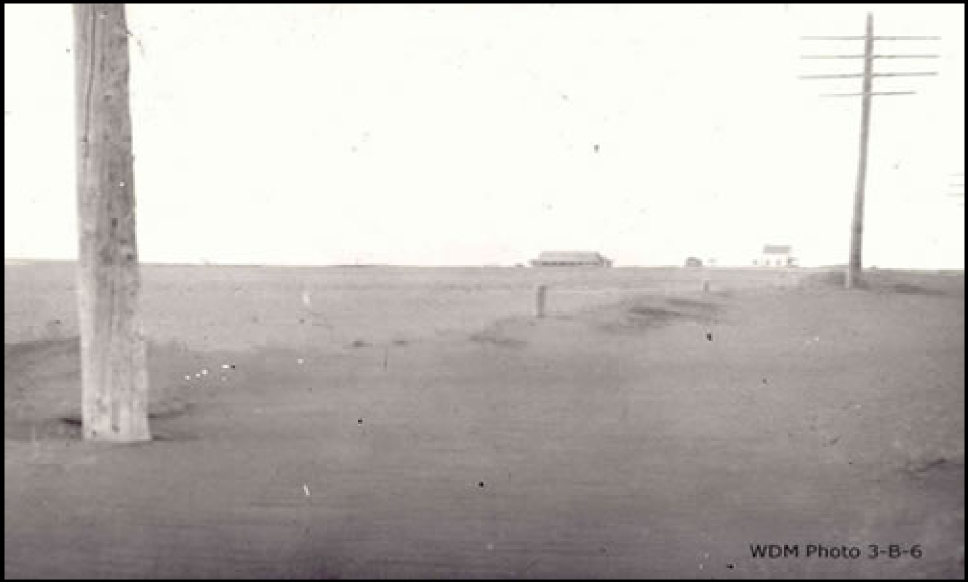
Water flows west to northeast through major ‘exotic’ rivers that derive most water from mountain runoff

Distinctiveness of Prairie Hydrology

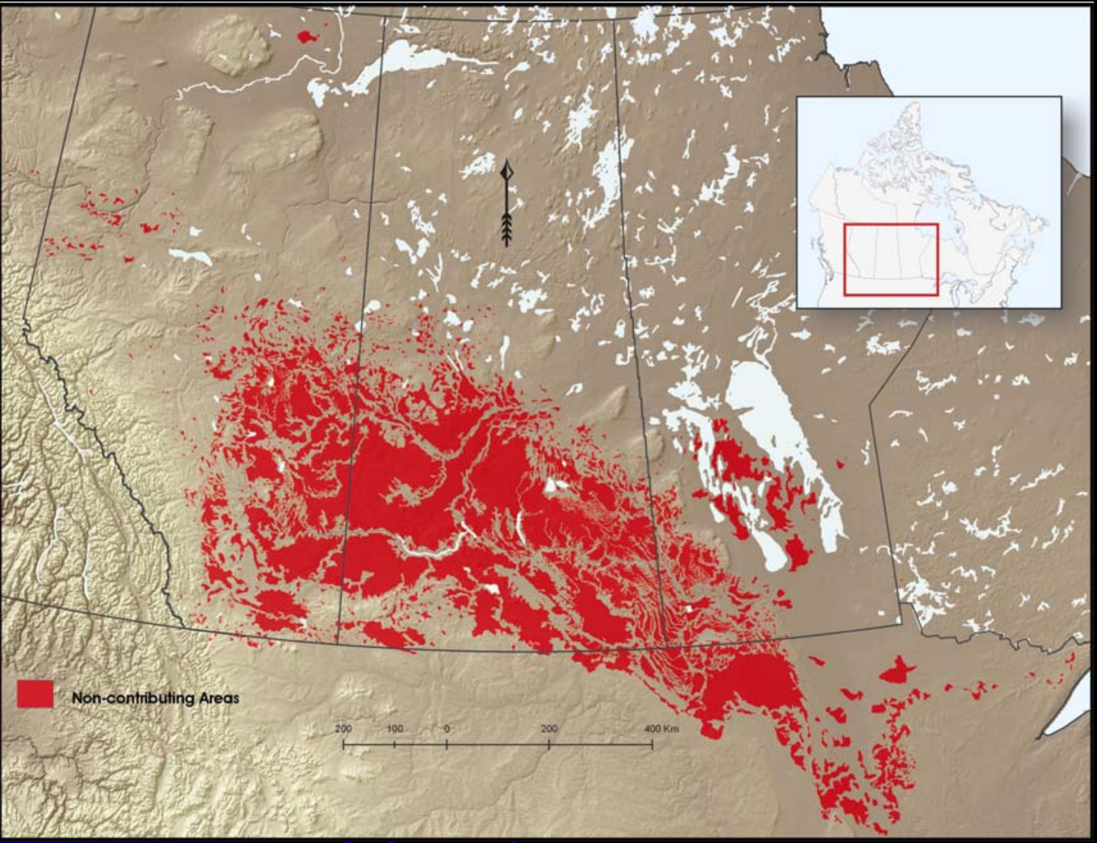
- Dry – relatively small precipitation, water deficit, low moisture reserves
- Cold – long frozen season, snow cover, frozen soils
- Flat – gentle topography, poorly defined drainage
- Extreme –
  - Inter-annual – sequences of drought and floods
  - Intra-annual – dry and wet years
  - Episodic – intense snowstorms, snowmelt and rainfall, intense heat, rapid growing season, unreliable streamflow

"Saskatchewan, Saskatchewan, there's no place like Saskatchewan; we sit and gaze across the plain and wonder why it never rains…"

- These words from the song *Saskatchewan* were written during the 1930s.



PRAIRIE HYDROLOGY – Limited Contributing Areas for Streamflow

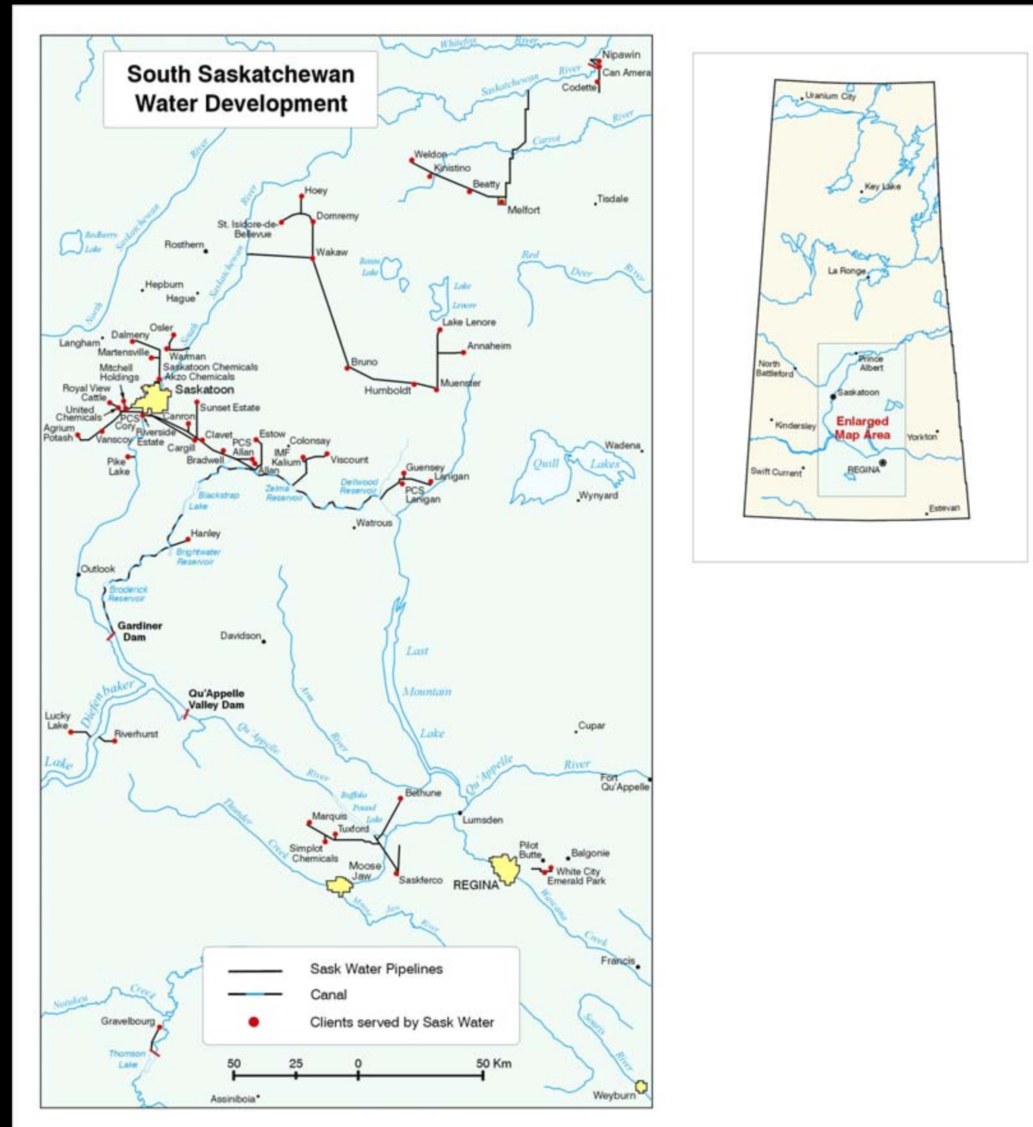


Non-contributing areas for streamflow extensive in Canadian Prairies

Localized hydrology affected by poor drainage, storage in small depressions

Water Use in Southern Prairies

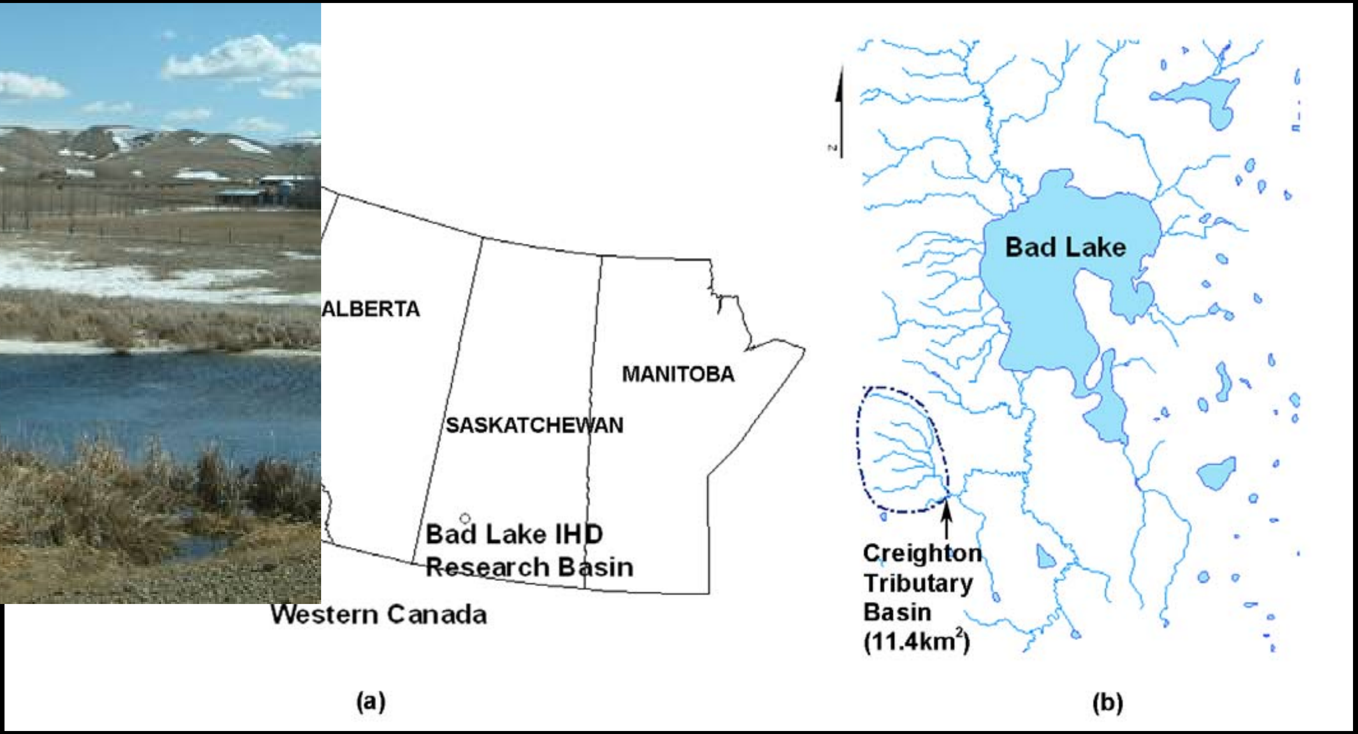
- Precipitation on average 350 mm
- Grain Growing
  - 125 mm soil water reserves needed
  - 175 mm spring rainfall needed
  - Roughly 300 kg/ha increased wheat yield for each extra 25 mm of water added
- Agricultural, municipal, industrial & aquatic use – require surface and groundwater in excess of crop use
- South Saskatchewan River: <1% of flow originates from Saskatchewan, but 70% of population use the river



What About Locally Produced Water Supplies?

- Because of frozen soils and rapidly melting snowcovers in the spring, 80% - 90% of prairie runoff is produced from snowmelt
- Snowmelt runoff is strongly controlled by snow drift location and size, soil moisture and mid winter thaws.
- In wet years, there is often excess water to dryland cereal grain growing needs – this water could potentially be used for ethanol production, but how reliable is it?
- Hydrological computer simulations may tell us something about the reliability of local prairie water supplies

Creighton Tributary, Bad Lake as a typical Prairie Basin

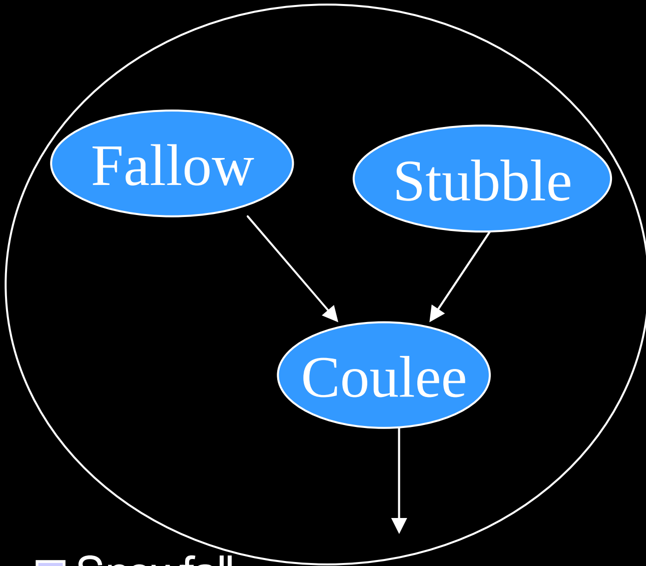


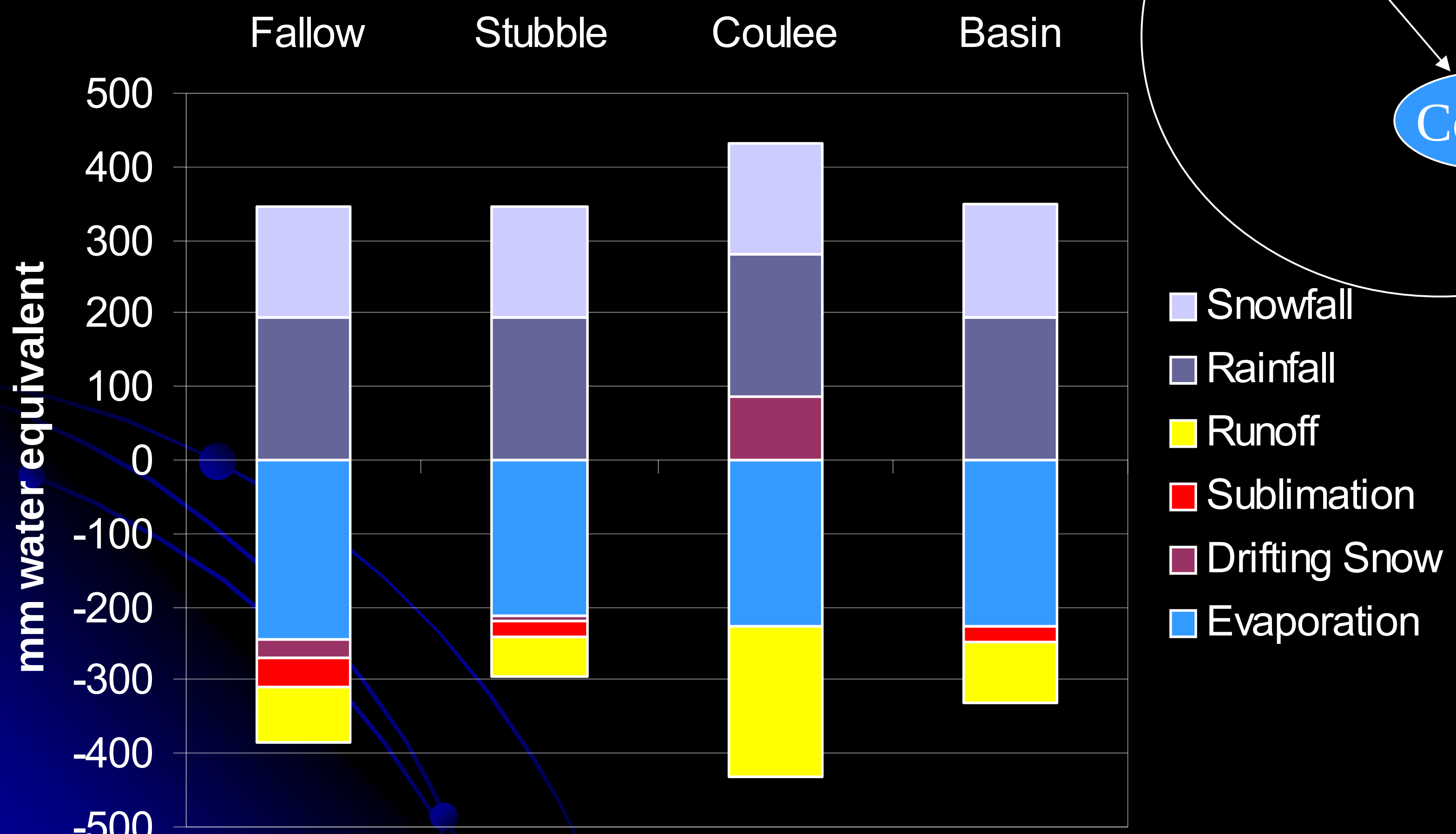
Moderately well drained plateau of grains and fallow drains into a coulee
Semi-arid to sub-humid climate
Typical drainage and landcover for much of southern prairies

Prairie Basin Water Balance

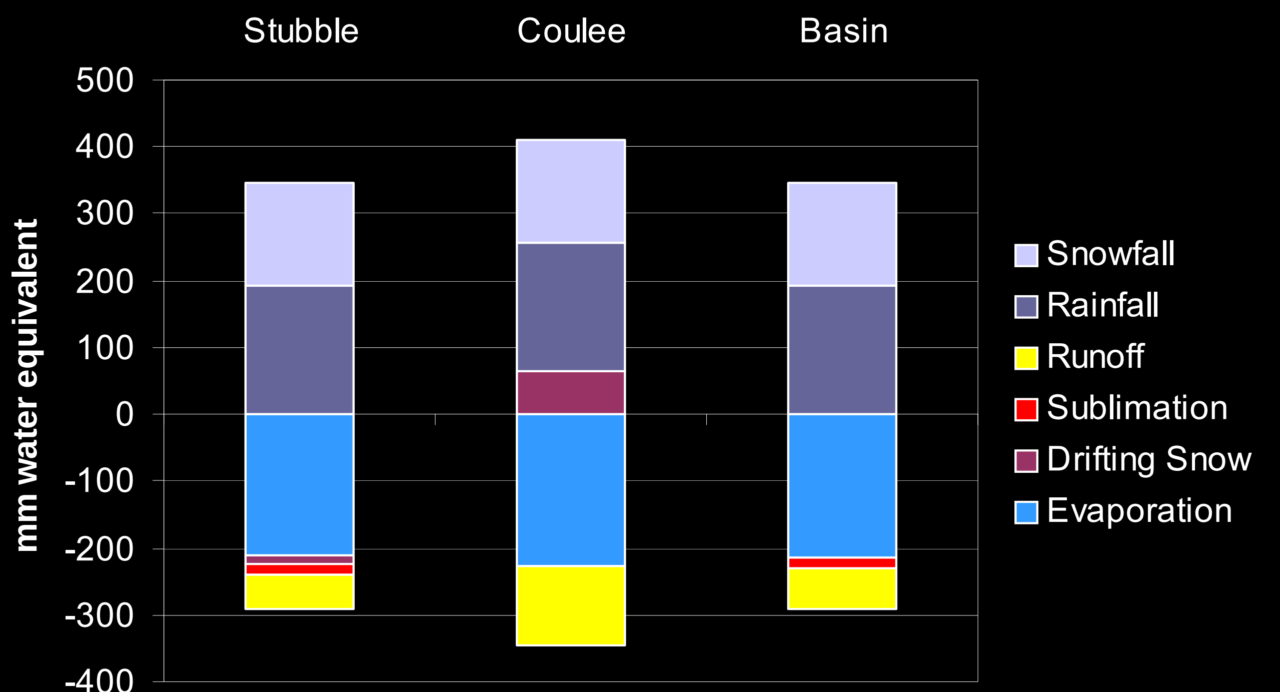
Creighton Tributary, Bad Lake early 1970s

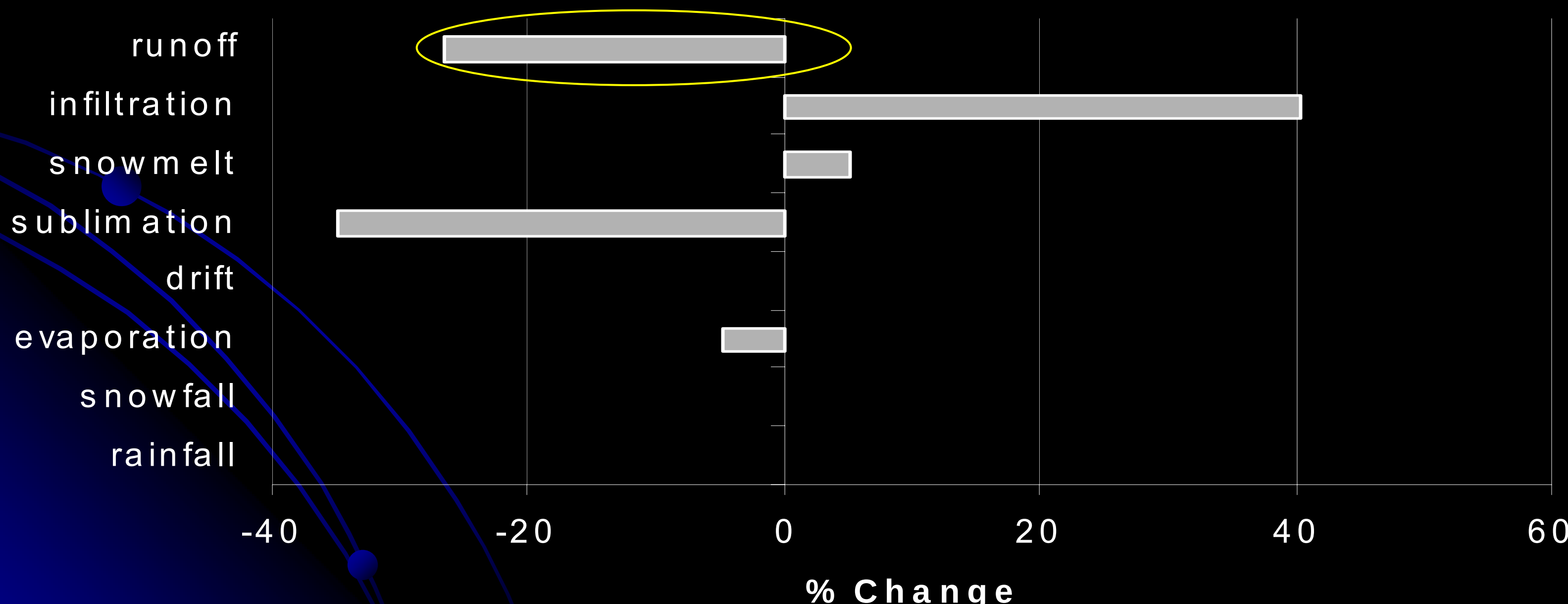
30% Summer Fallow
15% Grassland Coulee





2006: Continuous Grain Cropping

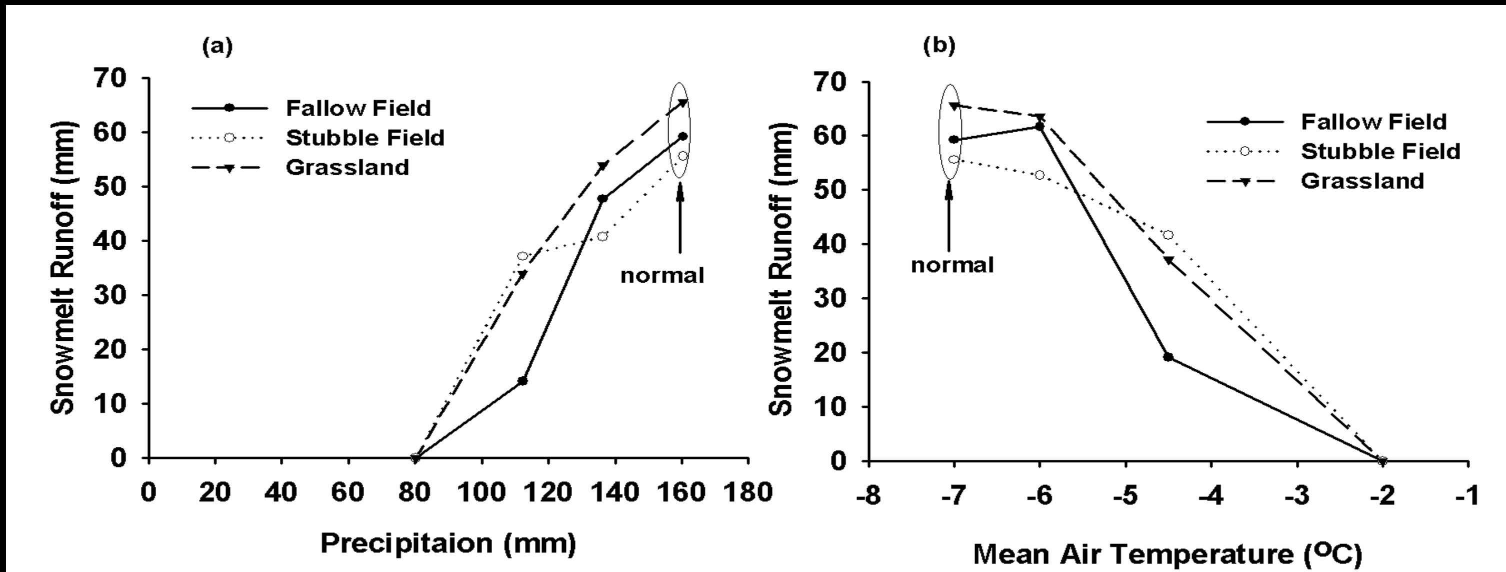




Implications of Land Use Changes

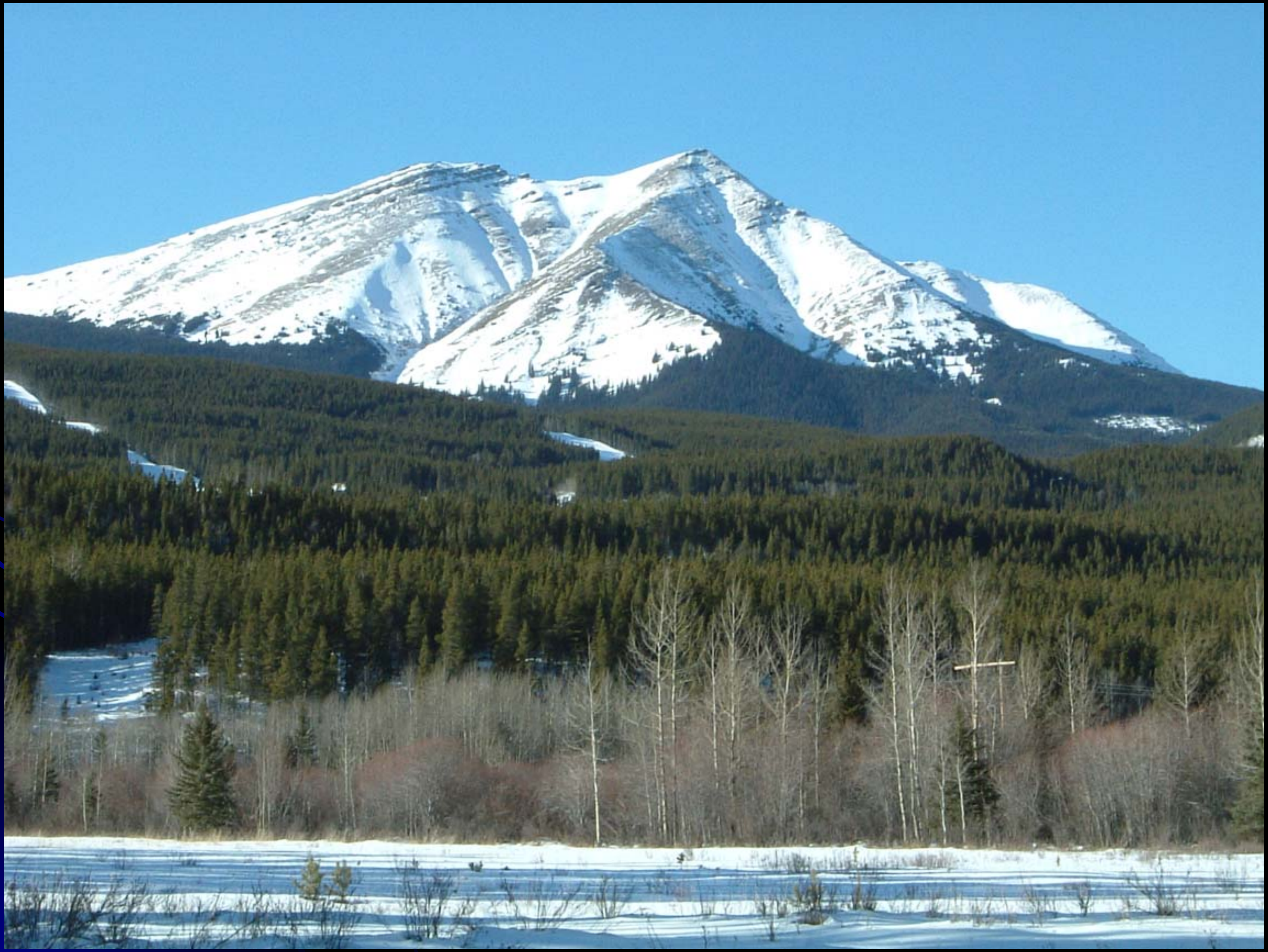
- *By making agriculture more effective at using rainfall and snowmelt we have substantially reduced the 'excess' water that formed runoff.*
- Local runoff feeds streams, fills small lakes, recharges groundwater
- Can we have both optimised dryland agriculture for biofuels and local water supply for ethanol plants???

Drought Restricts Spring Runoff Generation

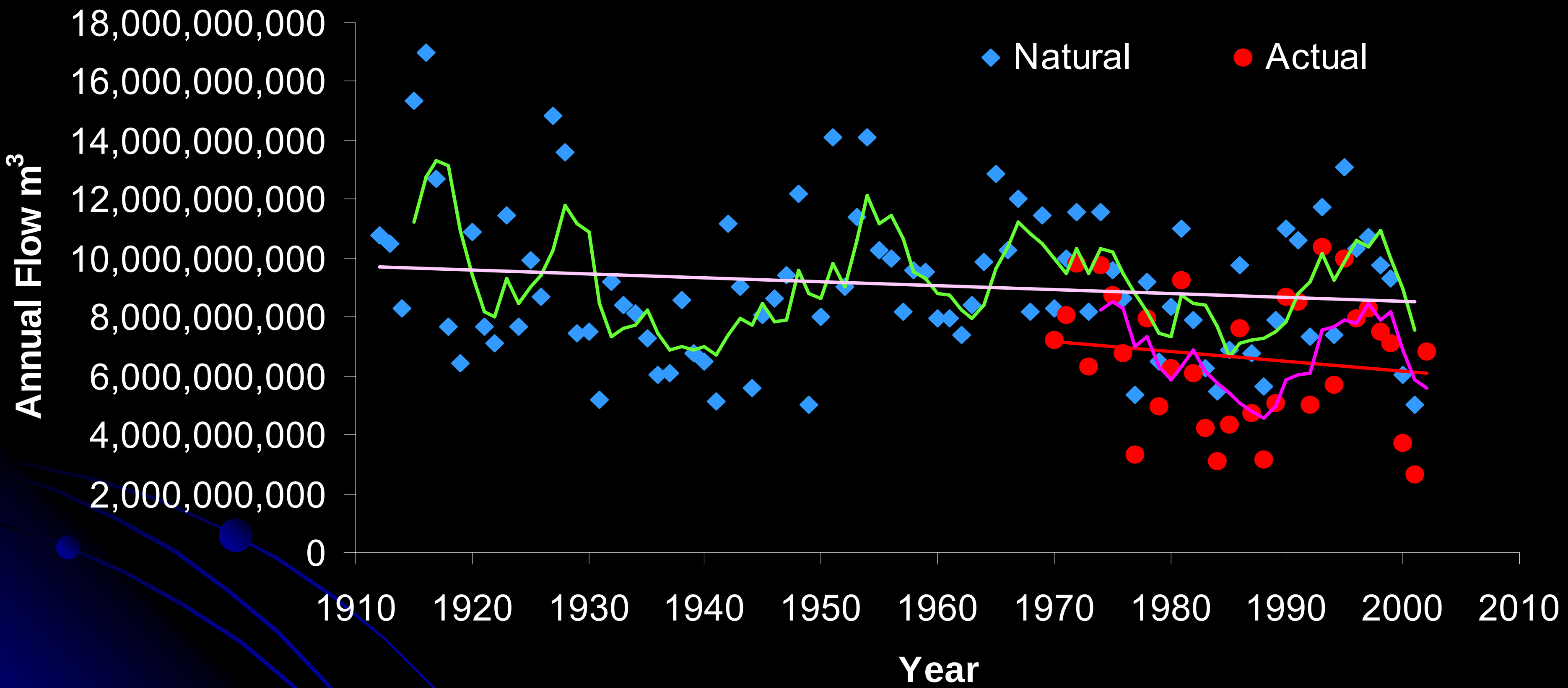


- Local Prairie water supplies inherently unreliable during drought
- Unlikely to support sustainable biofuel processing industry
- Competition between agricultural production and water runoff for streamflow and biofuel processing
- Implication is that little is left for wetlands, ecosystem services

Rocky Mountains, source of most Canadian Prairie surface water



Naturalized Flow of South Saskatchewan River entering Lake Diefenbaker



Decline of ~1.5 billion m^3 over ~90 years (~ -15%) in natural flow
Decline of ~1.1 billion m^3 over ~30 years (~ -15%) in actual flow
Upstream consumption of naturalized flows up to 7%-42% in last 15 years

What is Reducing Natural River Flow?

- Not glaciers: glacier melt contribution to Bow River at Calgary ~ 0.6%, or less.
- Lowest snowfall years associated with lowest river flows – mountain snowpack
- 15% flow decline likely a climate change effect.

What is Reducing Actual River Flow?

- Irrigation – responsible for most water use (75%)
- Municipal/industrial – relatively small effect (17%)
- Alberta water use consumes 25% of natural flows, but up to 42% in drought years

Conclusions

- Biofuel economy will affect and be limited by the hydrological cycle
  - Reduced streamflow in afforested basins
  - Reduced soil moisture and streamflow in intensive agricultural basins
- Low streamflow and water storage potential in southern Prairies will limit ethanol plant size and number
- Droughts cause cessation of prairie runoff – unreliable water source for biofuel processing
- Prairie biofuel production must rely on Saskatchewan River system – Rocky Mountain water
- Rocky Mountain waters are declining: example SSR flow is down ~40% since settlement due to consumption and climate change.
- **Consumption of water for biofuel primary production, forest interception loss & ethanol processing will reduce water availability for ecosystem services and human use and may degrade water quality in some cases**

Thank You!

- pomeroy@usask.ca
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