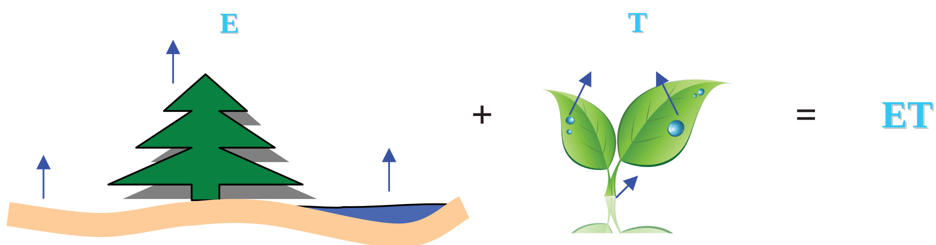
Evaporation and Evapotranspiration in Alberta – The Morton Method

FACTS AT YOUR FINGERTIPS

Evaporation (E), Transpiration (T) and Evapotranspiration (ET)

ET= E+T

Evaporation is the process whereby liquid water is converted to water vapor and removed from the evaporating surface, such as lakes, rivers, pavements, soils and wet vegetation. *Transpiration* is the process of water loss from plants. *Evapotranspiration* is the loss of water from the earth's surface through the combined processes of evaporation and transpiration.



Terminologies

Provincially averaged annual evaporative loss in Alberta

PE: 929 mm
PET: 902 mm
SLE: 677 mm
AET: 364 mm

- ***Potential Evaporation (PE):*** the rate of evaporation, under existing atmospheric conditions, from a surface of water that is chemically pure and has the temperature of the lowest layer of the atmosphere.
- ***Shallow Lake Evaporation (SLE)***: the evaporation from a water surface sufficiently large that the effects of the upwind shoreline transition zone can be ignored and the seasonal sub-surface heat storage is insignificant.
- ***Potential Evapotranspiration (PET):*** the amount of water evaporated (both as transpiration and evaporation from the soil) from an area of continuous, uniform vegetation that covers the whole ground surface and that is well supplied with water.
- ***Actual or Areal Evapotranspiration (AET):*** the amount of water lost to evapotranspiration from the soil– plant continuum by an actively growing plant or crop.

Average Provincial Water Balance & Evaporation in Alberta (1980-2009)

P=Precipitation, R= Runoff, G=Groundwater Recharge, Estimated actual evapotranspiration from water balance =P-R-G

The actual evapotranspiration in Alberta is about 74% of its total precipitation

	PE*	PET*	SLE	AET	P	R	G	P-R	P-R-G
Min (mm)	794	769	598	298	300	0	0	52	19
Max(mm)	1245	1196	840	446	1407	531	125	854	835
Mean (mm)	929	902	677	364	502	98	41	416	373
Std.Dev. (mm)	94	89	59	27	121	110	22	58	57
Volume (billion m^3)	616	598	449	241	333	65	27	275	247

**Note that, the PET or PE is an indication of the environmental demand for evapotranspiration or evaporation. A value of PET or PE greater than the actual precipitation will dry out the soil, unless more precipitation occurs.*

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Spatial Distribution of Evaporative Losses in Alberta

PE, PET and SLE show highest evaporative amounts at the south-east corner of Alberta. In contrast, as south-east Alberta is mostly dry, it shows lower AET

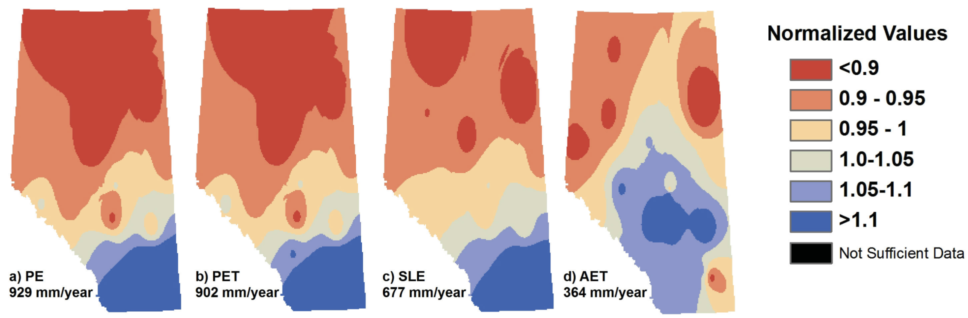


Figure: Spatial distribution of mean annual evaporative losses over Alberta for 1980-2009 (normalized by corresponding mean values for Alberta).

Factors Affecting Evaporation (E) and Evapotranspiration (ET)

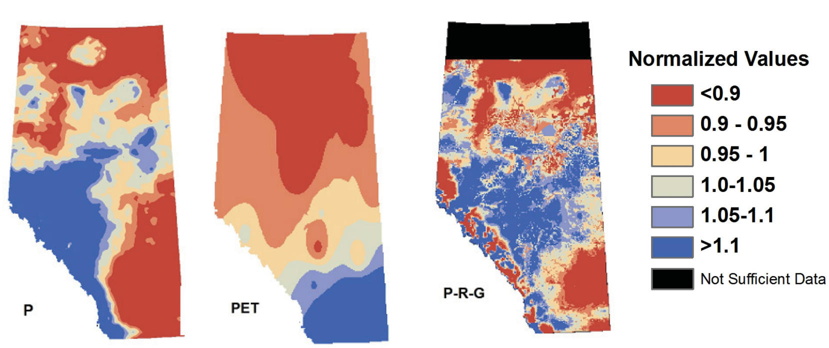
Moisture supply in a soil-plant surface is usually constrained. Thus actual ET is less than potential ET

- More Solar Energy → More Evaporation & Evapotranspiration
- Higher Altitude (Cooler Temperatures) → Less Evaporation & Evapotranspiration
- More Humidity → Less Evaporation & Evapotranspiration
- More Wind Velocity → More Evaporation & Evapotranspiration
- More Supply of Moisture to the Soil-Plant Surface → More Evapotranspiration

Estimation of E and ET by Morton's Model

As a surface undergoes drying from initially moist conditions, the potential evapotranspiration (PET) increases while actual evapotranspiration (AET) decreases. Morton's Complementary Relationship Areal Evapotranspiration (CRAE) Model uses this relationship between PET and AET to estimate the evaporation from a water surface or the evapotranspiration from terrestrial surfaces. The complementary relationship of PET and AET is also evident from the spatial distribution of Precipitation (P), PET and estimated AET derived from a water balance of [AET=P-R-G] over Alberta. As south-east Alberta is comparably dry the PET is relatively higher while the AET is relatively lower. In contrast, as west-central Alberta is comparably wetter, the PET is relatively lower while the AET is relatively higher.

ESRD used Morton's CRAE Model to estimate monthly PE, SLE, PET and AET at 20 stations across Alberta from 1912 to 2009



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Data Requirement for Morton's Model

Morton's CRAE model neither uses nor requires data input about the soil –vegetation system

ESRD's monthly estimation of evaporation and evapotranspiration for Alberta (1912-2009) by Morton's model are based on the following data:

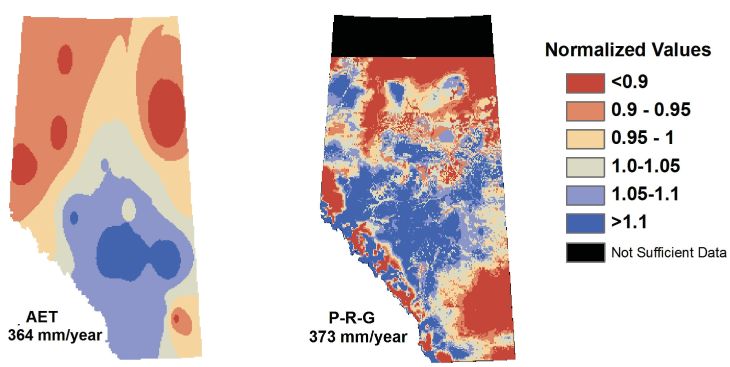
- Station Fixed Data:
  - Latitude (degree)
  - Elevation (meter)
  - 30 years (1970-2000) annual average precipitation (mm)
- Monthly Time Series:
  - Monthly mean air temperature (°C) and dew point temperature (°C)
  - Solar radiation measured, or estimated by: $R_s = K_t * R_a * \sqrt{(T_{\max} - T_{\min})}$ $MJm^{-2}day^{-1}$

R_a → Extra-Terrestrial Radiation ($MJm^{-2}day^{-1}$)
K_t → Adjustment Coefficient (0.16)
T_{max} → Daily Maximum Temperature (°C)
T_{min} → Daily Minimum Temperature (°C)

How Accurate are Estimates of ET by Morton's Model?

When compared to FAO Penman-Monteith (Standard-Grass) model, Morton's model provides lower PET in fall-winter and slightly higher PET in summer

Considering all of Alberta, the mean annual actual evapotranspiration estimated by Morton's model (364 mm) and its spatial distribution are quite compatible with that estimated from the simple water balance model (373 mm) for Alberta.



Limitations of Morton's Model

The shortest recommended interval for estimation of E or ET by Morton's model is 5 days

- Requires very accurate humidity data.
- Daily estimates of evapotranspiration require adjustments from weekly/monthly estimates.
- Can not be used near sharp environmental discontinuities (e.g. abrupt land cover changes).
- The model inputs require data from a weather station whose surroundings are representative of the area of interest.
- Cannot be used for predicting impact of natural or man-made changes to land cover or vegetation.

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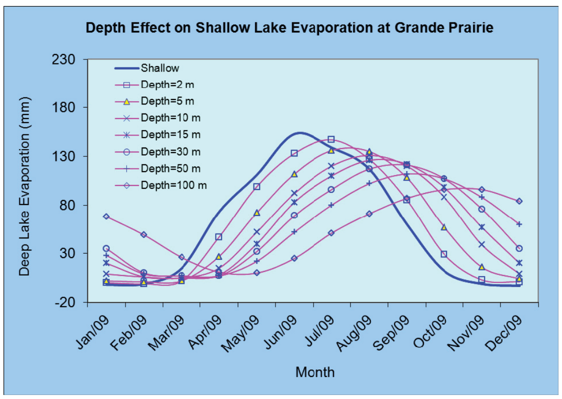
Depth Effects on Morton's Shallow Lake Evaporation (SLE)

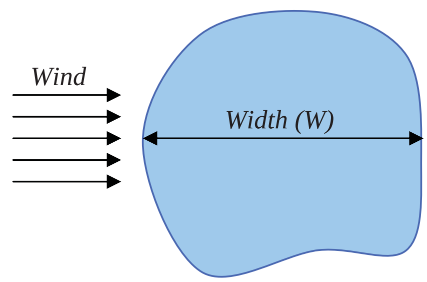
The plot on the right shows how monthly distribution of SLE can be altered with lake depth, considering a hypothetical lake at Grande Prairie having total dissolved solids (TDS) concentration of 100 ppm



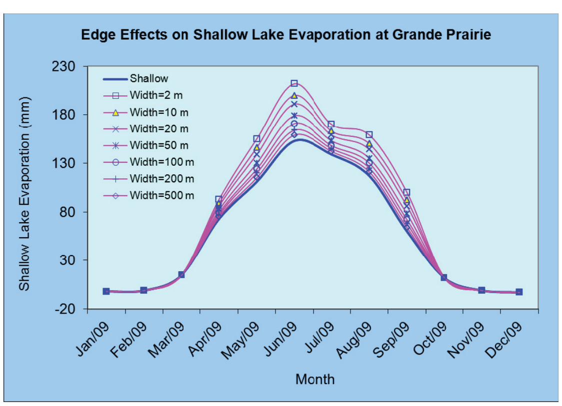
Morton's SLE does not consider the seasonal changes in subsurface heat storage within water bodies. Even though annual gross evaporation totals remain the same, monthly distribution of evaporation is significantly altered with increasing lake water depth because of subsurface heat storage effects. To apply Morton's SLE for deep lakes, an approximating method of heat storage routing has to be applied to compute Deep Lake Evaporation (DLE). SLE to DLE conversion is complex and iterative. A detailed procedure can be found in Morton's Paper*.

Morton's SLE for Ponds/Dugouts: Edge Effects

SLE is comparatively higher at the upwind edge of a lake (transition zone of land and water body) as the hot dry air from land surface approaches a water body. For a large lake this effect can be ignored as the increased SLE at upwind edge diminishes quickly in the downwind direction and become constant. However, for small ponds or dugouts this higher rate of SLE becomes increasingly significant.



The plot on the right shows how SLE can be altered with lake width along the windward direction, considering a hypothetical lake at Grande Prairie



For a small pond or dugout having width of *W* meters in the direction of prevailing wind, shallow/deep lake evaporation of E_L mm and potential evaporation (PE) of E_P mm, the adjusted lake evaporation would be*:

$$E_{Pond} = E_L + (E_P - E_L)\frac{\ln(1 + W/13)}{W/13} \text{ mm}$$

*Morton, F.I., 1983. "Operational Estimates of Lake Evaporation". *Journal of Hydrology*, 66, 77-100.

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