Developing Environmental Components for a Water Balance

Project:

A Feasibility Study for a Proposed Mine in the Great Lakes Region

Challenge:

Need to develop a water balance to surround the traditional mine site-wide water balance to evaluate environmental impacts on a more regional scale.

Stochastic Climate Module needed to be defensible.

Regional scale model needed to include robust hydrologic components to simulate freezing/thawing of ice and attenuation of stream and lake flow.

srk consulting

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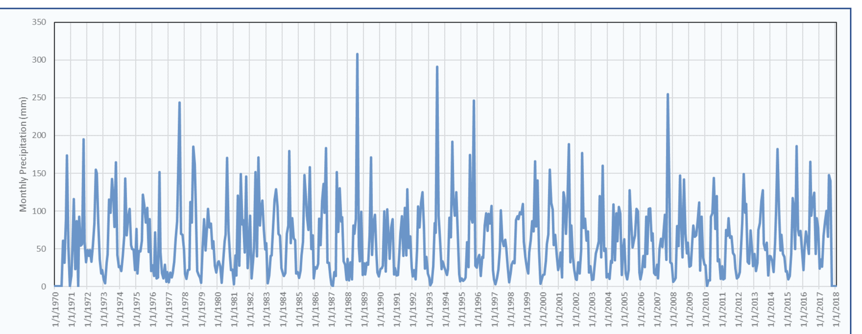
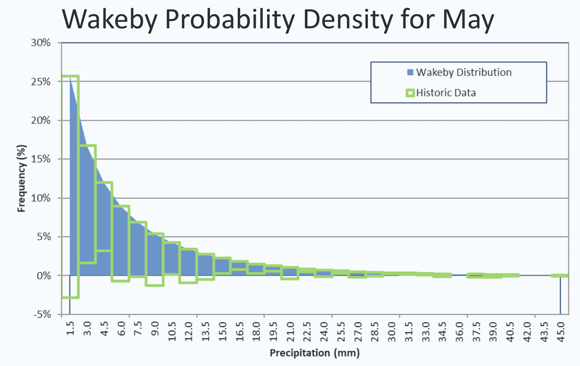
Stochastic Climate Generator

Using a large regional data set, regressed multiple stations to fill in the data gaps and build a continuous record of historical climate for the site



Examined ~50 different distributions and selected the Wakeby distribution as the best fit for precipitation for use with the WGEN climate generator

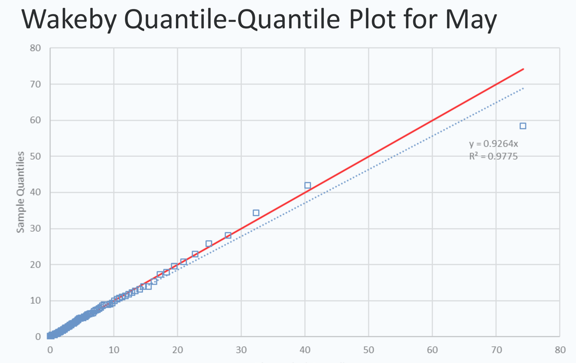
Wakeby Probability Density for May



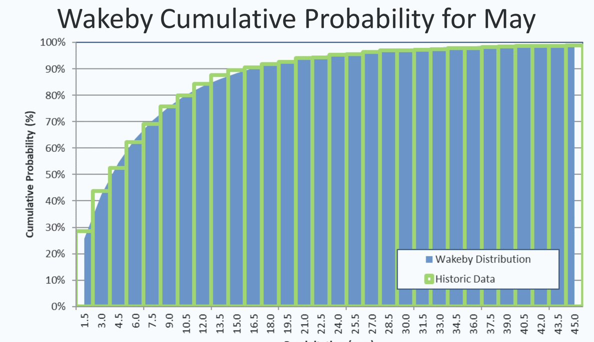
Wakeby Distribution

$$x(F) = \xi + \frac{\alpha}{\beta}\left(1-(1-F)^{\beta}\right) - \frac{\gamma}{\delta}\left(1-(1-F)^{-\delta}\right)$$

Wakeby Quantile-Quantile Plot for May

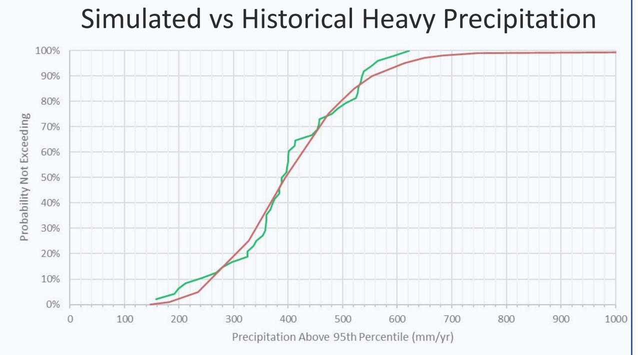


Wakeby Cumulative Probability for May

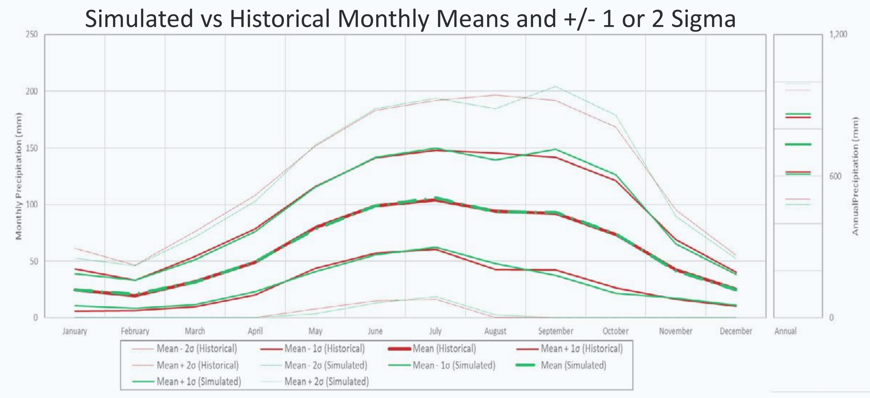


Model Simulations (1000 realizations) compared against statistics from historical record (annual and monthly mean and std. deviations, annual maximum event, heavy precipitation

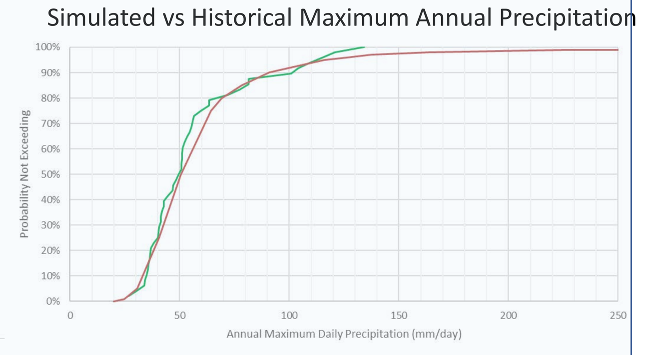
Simulated vs Historical Heavy Precipitation



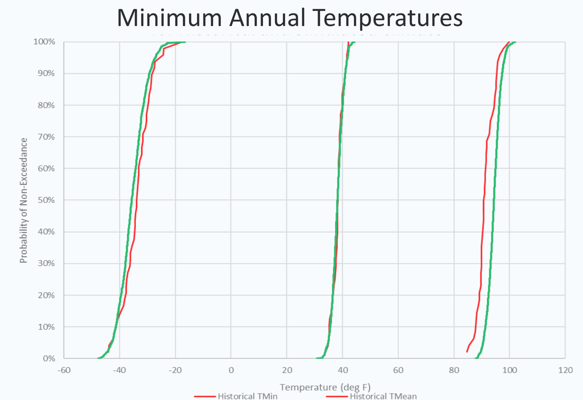
Simulated vs Historical Monthly Means and +/- 1 or 2 Sigma



Simulated vs Historical Maximum Annual Precipitation

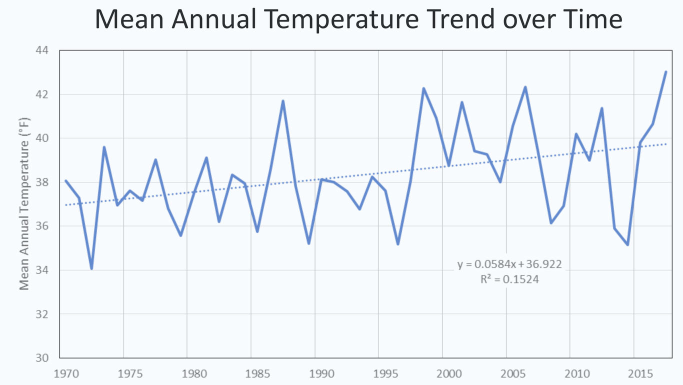


Simulated vs Historical Mean, Maximum and Minimum Annual Temperatures



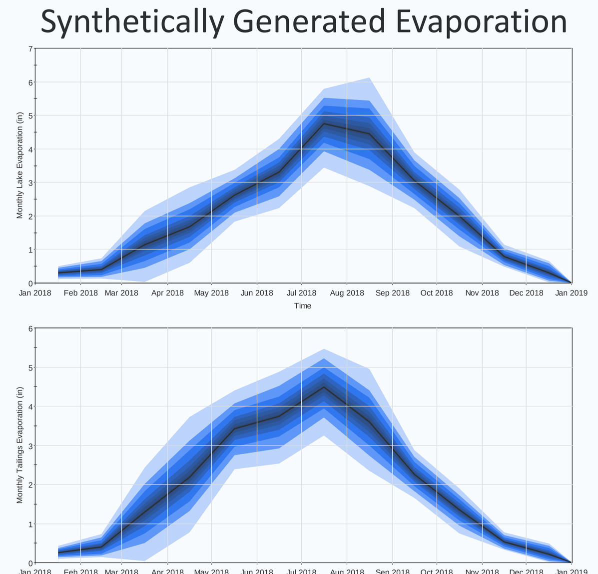
Daily Temperature Min, Mean, and Max fitted to a Beta distribution on a monthly basis. Simulated temperatures compared against statistics from the historical record

Mean Annual Temperature Trend over Time



Slight Warming Trend identified in the historical record and incorporated in the Stochastic Climate Model

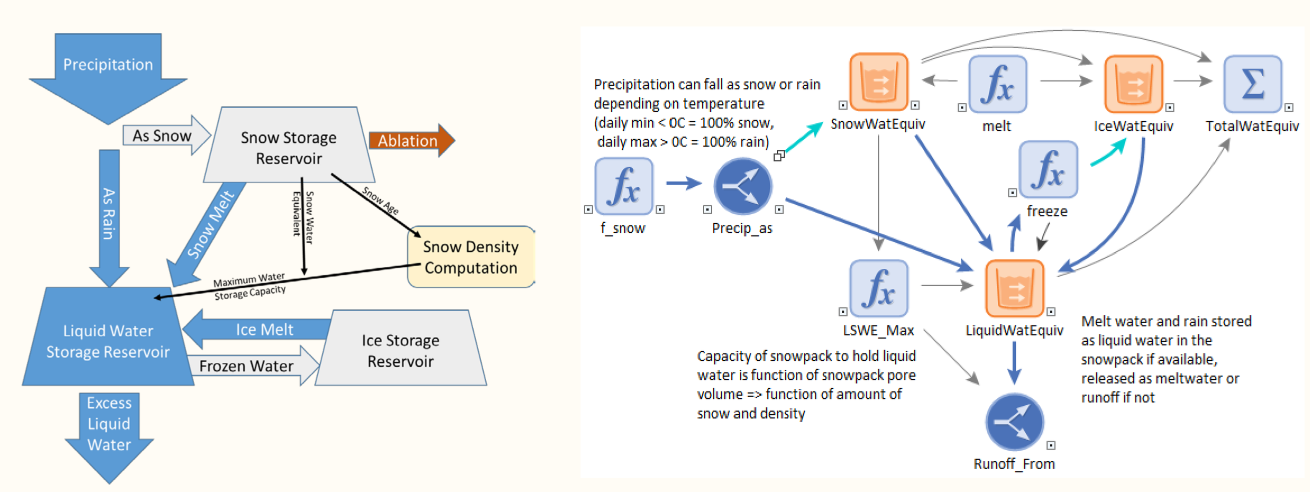
Synthetically Generated Evaporation



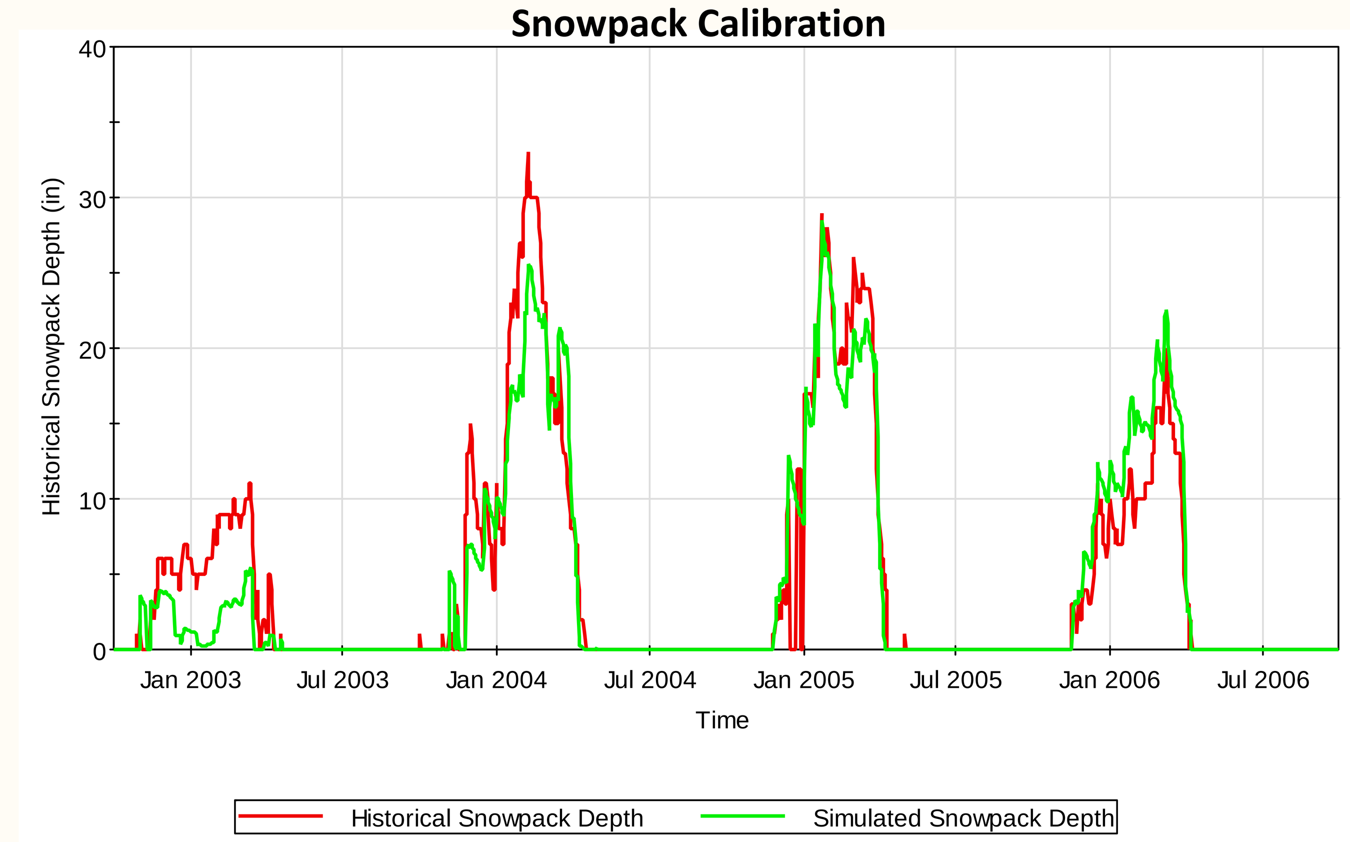
Historical daily evaporation developed from airport climate data (Temp, Rh, Solar Radiation, etc.) – Used Morton CRWE method for open water Evaporation and Penman-Monteith Method for land surface Evapotranspiration.

Snow Pack Accumulation and Melt

- Model is based on a paper by Kokkoen (2006)
- Basic mechanism for freezing and thawing is by temperature (degree-day method)
- Precipitation is proportioned between rain and snow based on the daily minimum and maximum temperature
- Snow density increases with the age of the snow pack
- The Snowpack can hold liquid or frozen water in the pore spaces
- As the pore spaces in the snowpack decrease (either through losses from melt or ablation, or through densification), the ability to hold moisture decreases and snowmelt may be released.
- Liquid water in the snowpack may freeze and is stored as ice
- Melt comes from snowpack first, ice last, ablation only from snow.
- Model calibrated to nearby station with daily snowfall, snow water equivalent, and snow depth data for several years



Snowpack Calibration



Open Water Ice Accumulation and Melt

Ashton Ice Growth Method (1989)

$$\frac{dh}{dt} = \left(\frac{1}{\rho\lambda}\right)\frac{T_m - T_a}{\left(\frac{h}{k} + \frac{1}{H_{ia}}\right)}$$

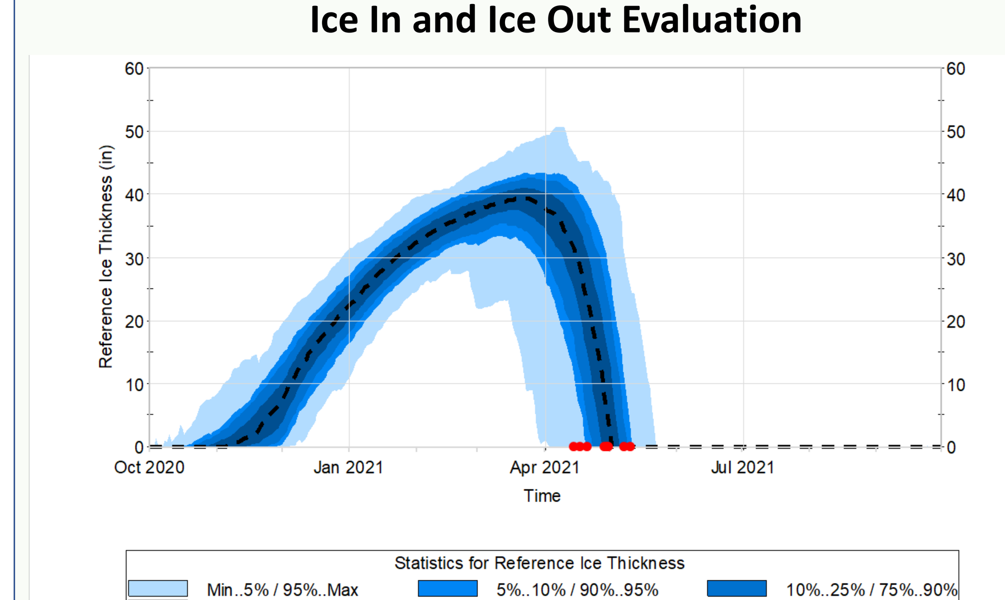
- Basic mechanism for ice growth by Temperature (degree-day method)
- Growth adjusted for ice thickness

Ashton Ice Decay Method (1983)

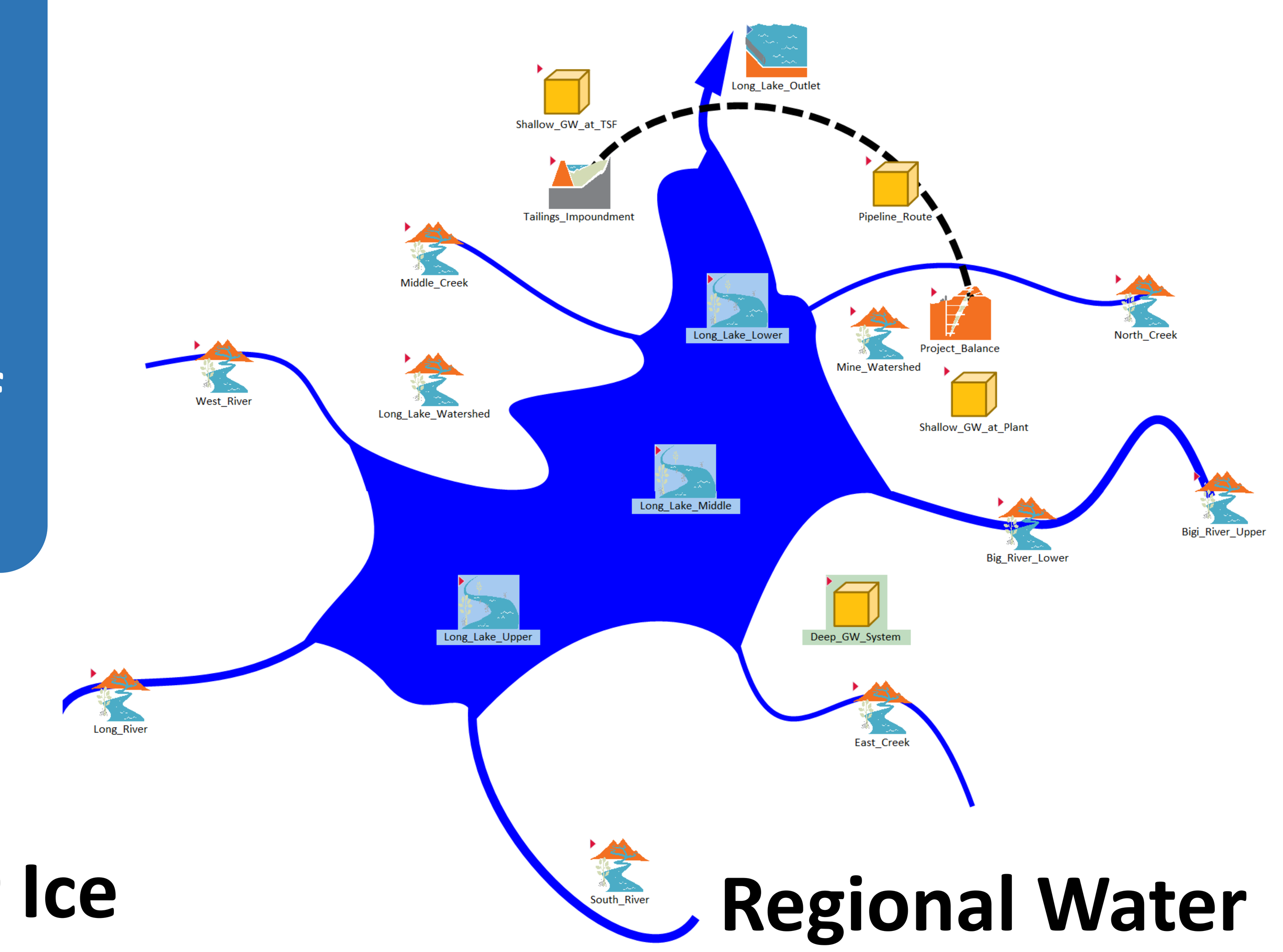
$$\frac{dh}{dt} = -\left(\frac{H_{ia}}{\rho\lambda}\right)(T_m - T_a)$$

- Basic mechanism for ice decay by temperature (degree-day method)

Ice In and Ice Out Evaluation



Prediction of Ice out dates based on Ice model



Regional Water Balance Schematic

Runoff and Streamflow

- Runoff calculated using the AWBM model
- Seasonal baseflow component from the shallow groundwater included based on numerical groundwater model
- Ice up and ice out of the streams and lakes effectively delaying winter baseflow
- Routing runoff and spring freshet through the drainages required seasonal delay and attenuation components in addition to those in the AWBM model

Streamflow Calibration