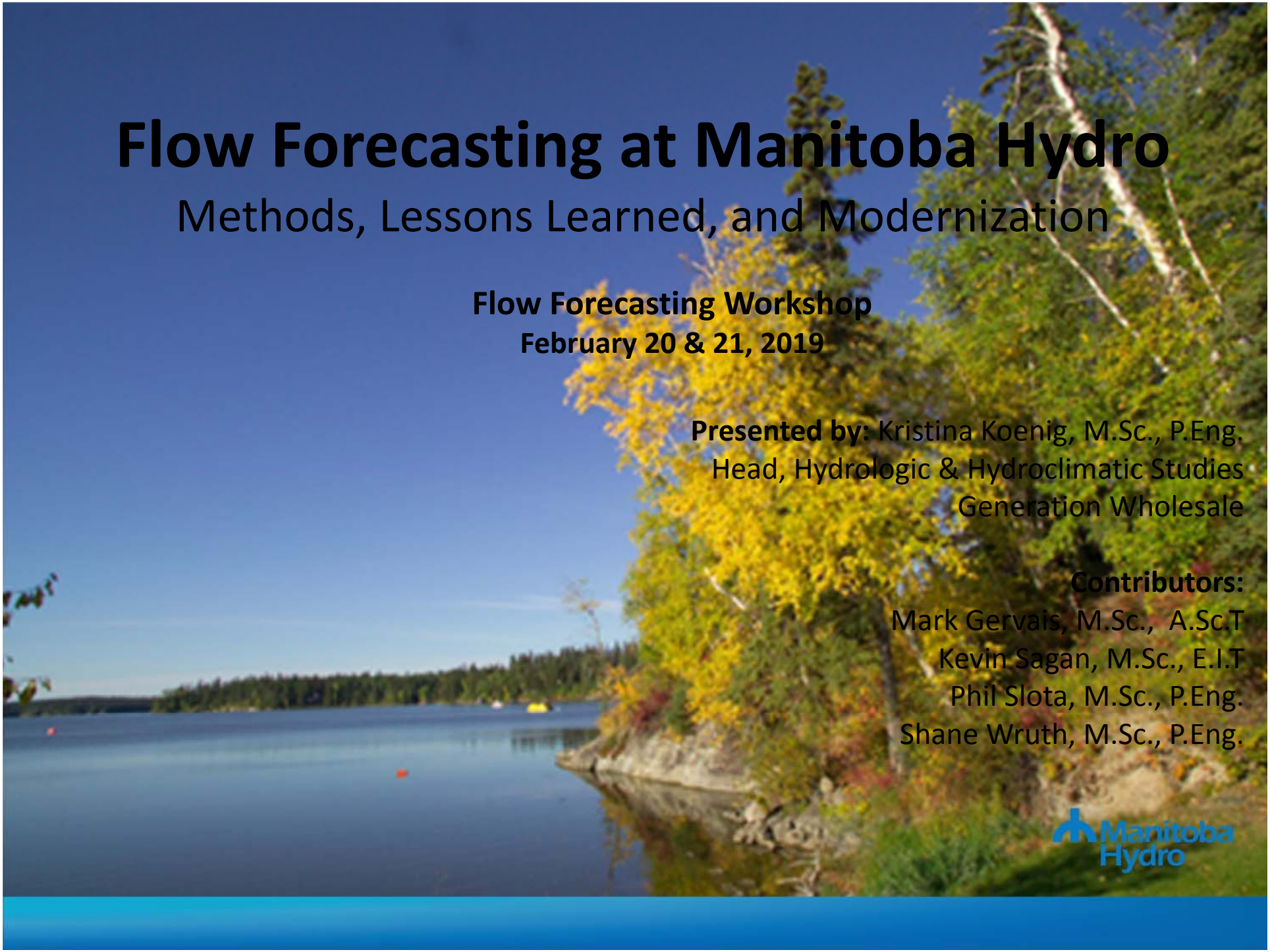


Flow Forecasting at Manitoba Hydro

Methods, Lessons Learned, and Modernization

Flow Forecasting Workshop
February 20 & 21, 2019

Presented by: Kristina Koenig, M.Sc., P.Eng.
Head, Hydrologic & Hydroclimatic Studies
Generation Wholesale

Contributors:
Mark Gervais, M.Sc., A.Sc.T
Kevin Sagan, M.Sc., E.I.T
Phil Slota, M.Sc., P.Eng.
Shane Wruth, M.Sc., P.Eng.

Manitoba Hydro



Manitoba Hydro

- Crown Corporation owned by Provincial Government
- One of the largest hydro utilities in Canada
- Serves over 0.5M electric and 0.25M gas customers
- Generation, Transmission & Distribution System
  - Import and Export Capabilities (Interchange)
- 5700 MW installed capacity
  - 15 Hydroelectric Generating Stations
  - 2 Thermal Stations
  - 4 Remote Diesel Stations
  - Purchase Wind (2 Independent Wind Farms)
- On average, 98% of electricity produced is from hydropower generation

Manitoba Hydro

Nelson-Churchill Watershed

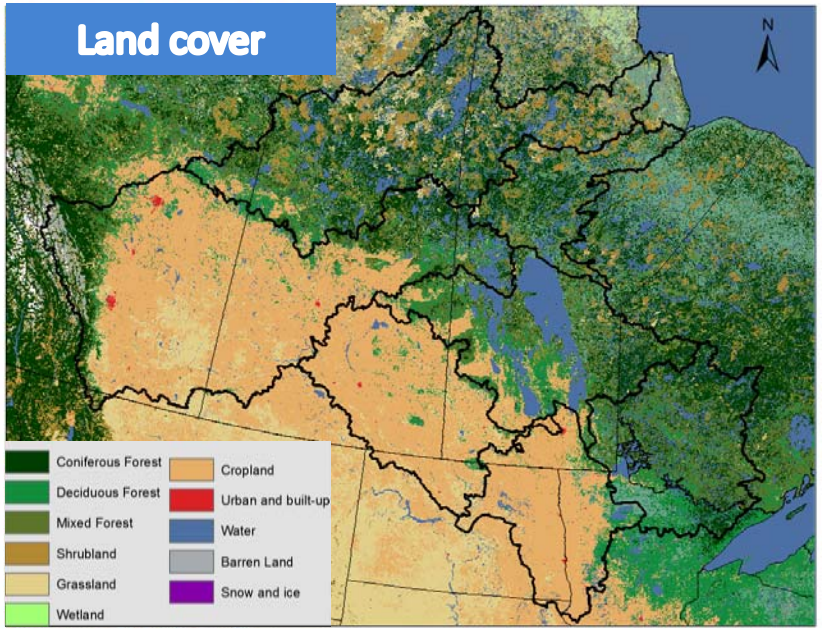


Major Sub-basins

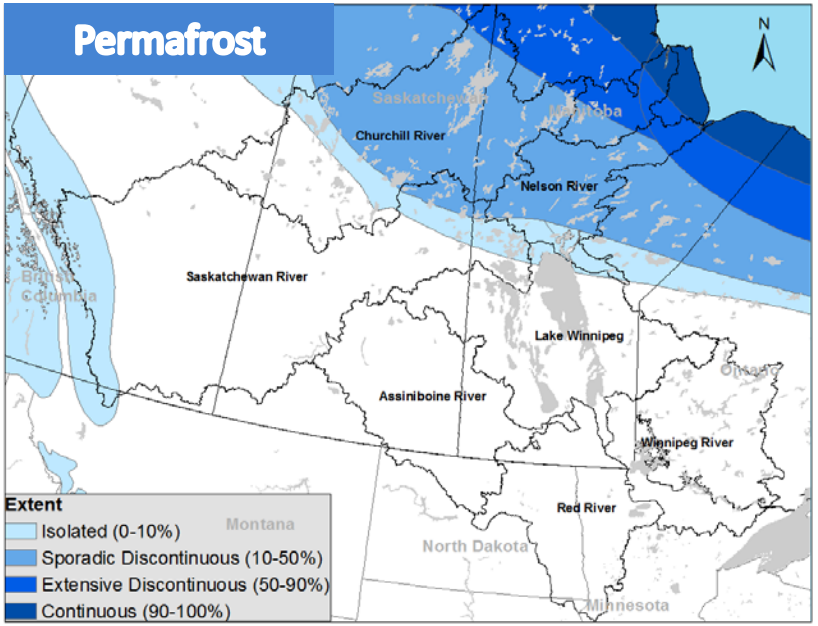
- Size: 1,437,589 Km^2
- 7 sub-basins- Churchill, Nelson, Saskatchewan, Lake Winnipeg, Winnipeg River, Assiniboine, Red River.

Nelson Churchill Watershed

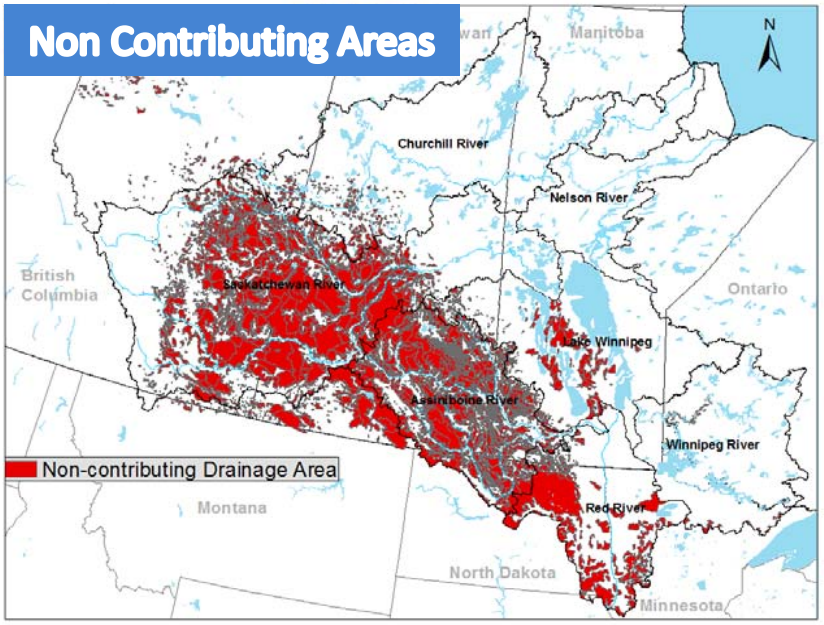
Land cover



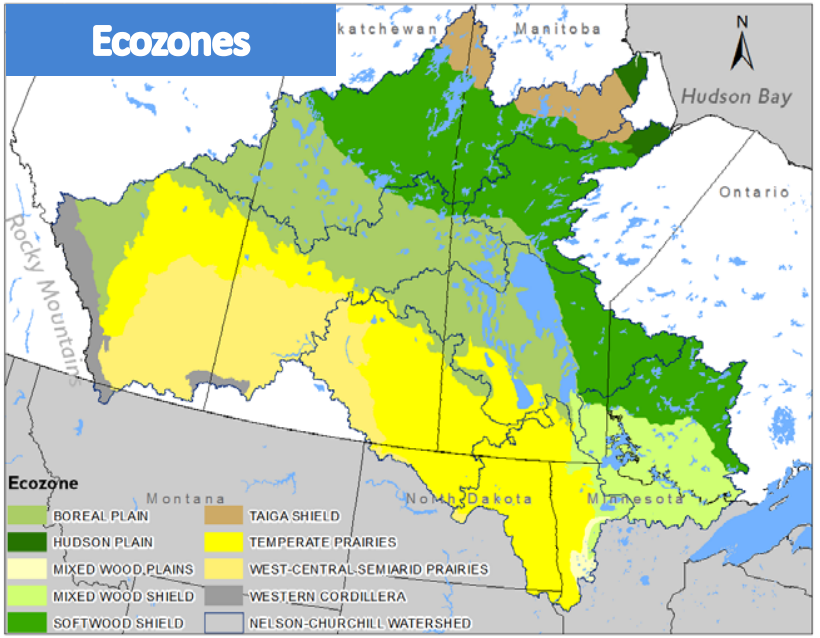
Permafrost



Non Contributing Areas

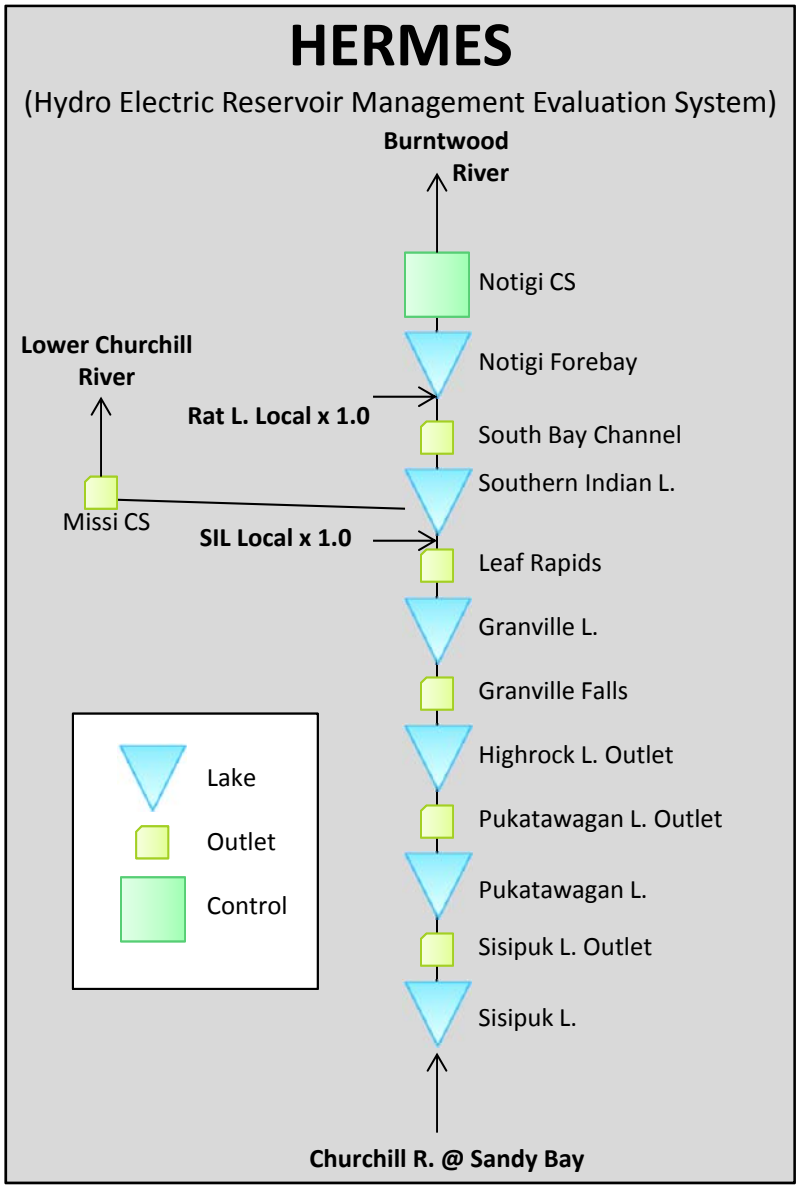


Ecozones

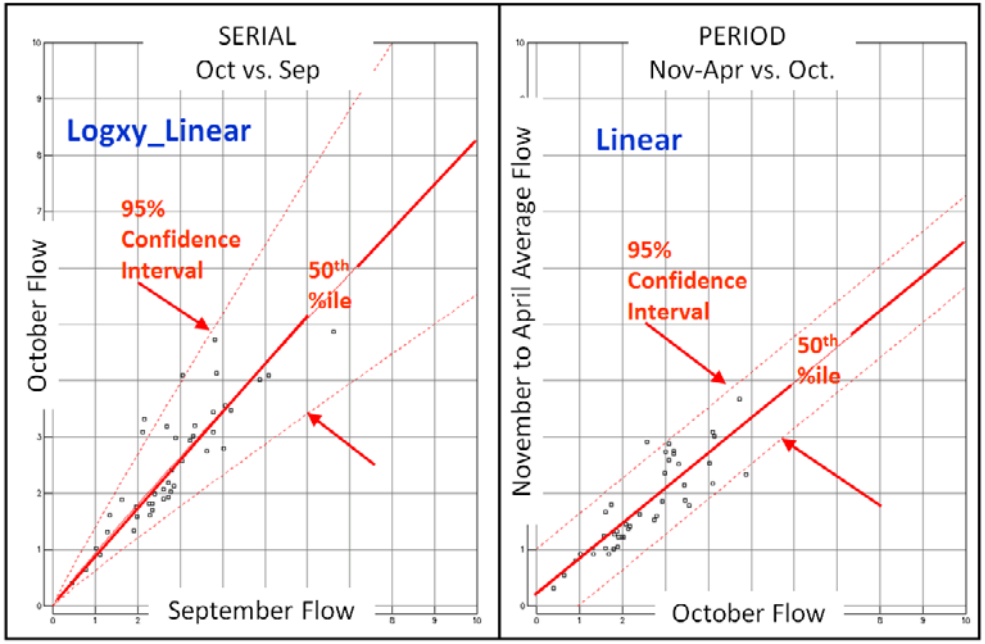



Current Forecasting Tools
Manitoba Hydro

Current Operational Inflow Forecasting



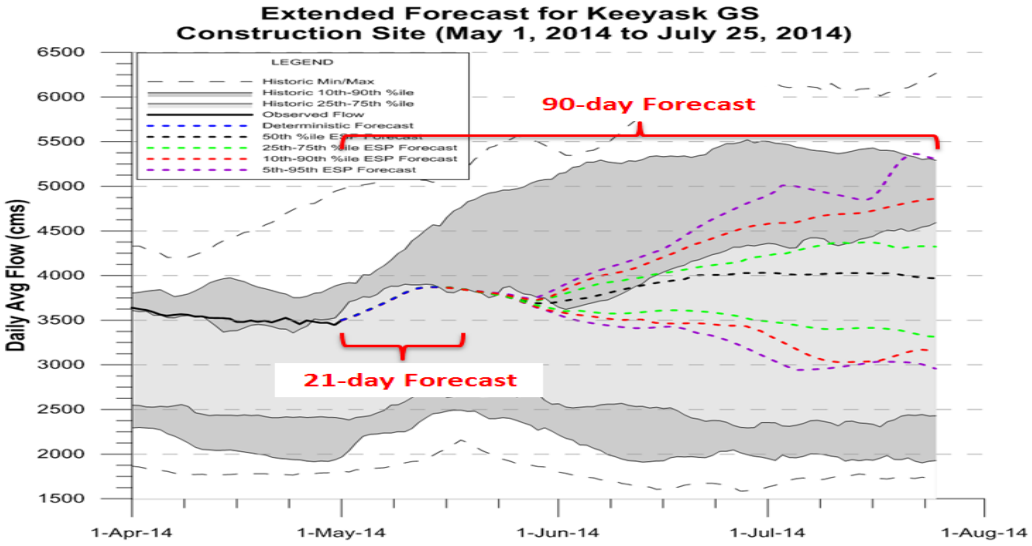
- **QSIM (Inflow Forecasting Tool)**
  - Autoregressive model structure
- **EMMA (Reservoir Optimization Tool)**
- **HERMES Decision Support System**



Current Physically-Based Inflow Forecasting

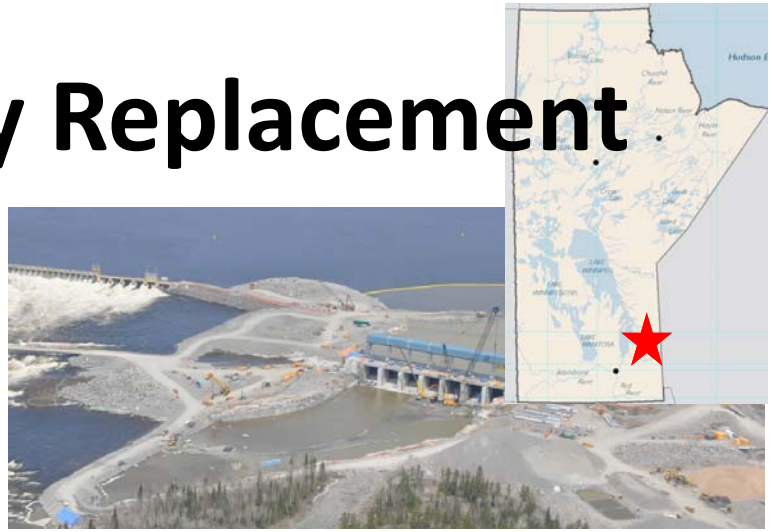
- Applications:
  - Pointe du Bois G.S.
    - Spillway Replacement (2011 – 2016)
    - Operations (2017 – present)
  - Keeyask Construction (2013 – present)
  - Winnipeg & Nelson River Tributaries
  - Lower Churchill River (2017 – present)



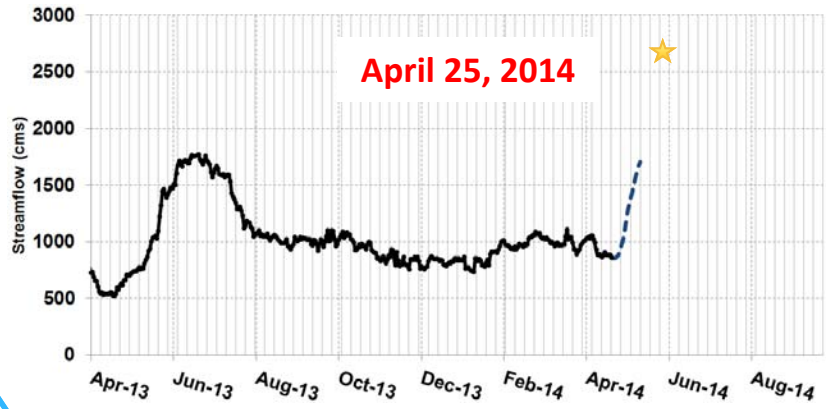


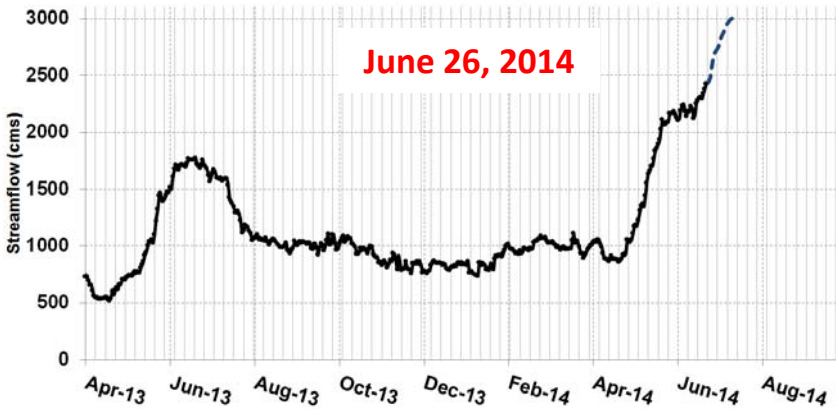
Pointe du Bois Spillway Replacement

- Construction- capacity was reduced; accurate information regarding flood risk & warning time
- 2014 flood event
  - Above average snowpack
  - Significant May/June rainfall
  - Record upstream inflows
- Flood risk to dam operations and construction:
  - Task force established
  - May-July: Daily forecasts issued.
  - Equipment and materials mobilized to expedite operation of new spillway if required.
  - Open communication with Lake of the Woods Control Board and MH Hydrologic Forecast Centre.
- New spillway was ready for operation in time to pass the flood peak.



Pointe du Bois Spillway under construction (2014)



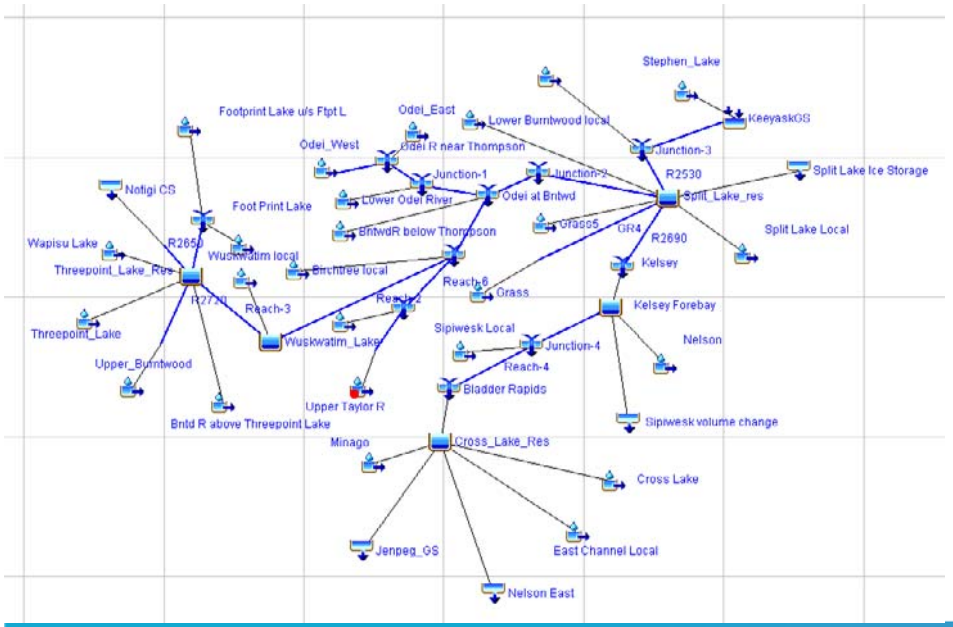



Hydrological Modelling
& Advancements
Manitoba Hydro

Hydrological Models

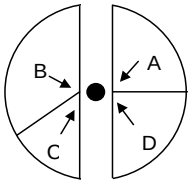
HEC-HMS

- Semi-distributed.
- Used successfully for inflow forecasting since 2011.
- Set up for key forecasting locations: Nelson and Lower Winnipeg Rivers.

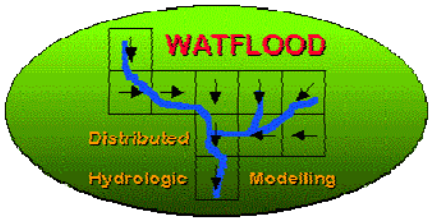


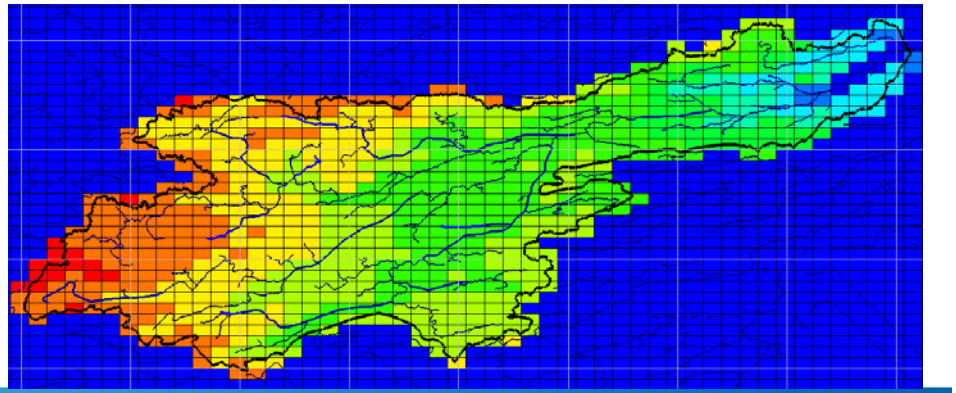
WATFLOOD

- Fully distributed.
- Set-up for all basins in Nelson-Churchill basin.
- Forecasting and climate change studies.



A - Land cover class 1
B - Land cover class 2
C - Land cover class 3
D - Land cover class 4





Hydrological Model Setup

HEC-HMS

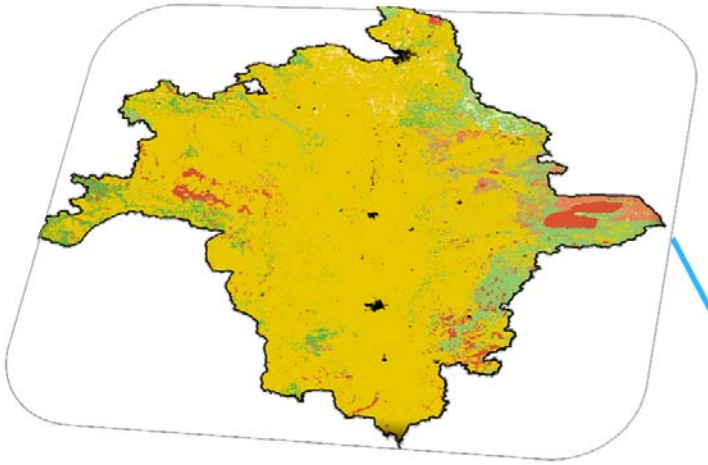
- Meteorological Forcing
  - Precipitation & Temperature: Interpolation of ECCC weather stations
- Calibration: OSTRICH

Watflood

- Digital Elevation Model (SRTM)
- Vegetative Cover (NALCMS)
- Surficial Material (GSC/USGS)
- Non-Contributing Area (AAFC)
- Meteorological Forcing
  - Precipitation: Canadian Precipitation Analysis (CaPA)
  - Temperature: Interpolation of ECCC weather stations
- Calibration: OSTRICH (Optimization Software Toolkit for Research Involving Computational Heuristics)

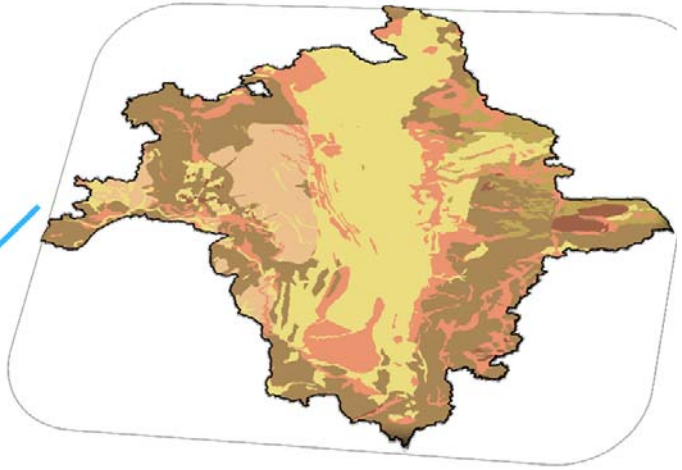
Red River- Land Class Enhancement Study

Vegetative Classes



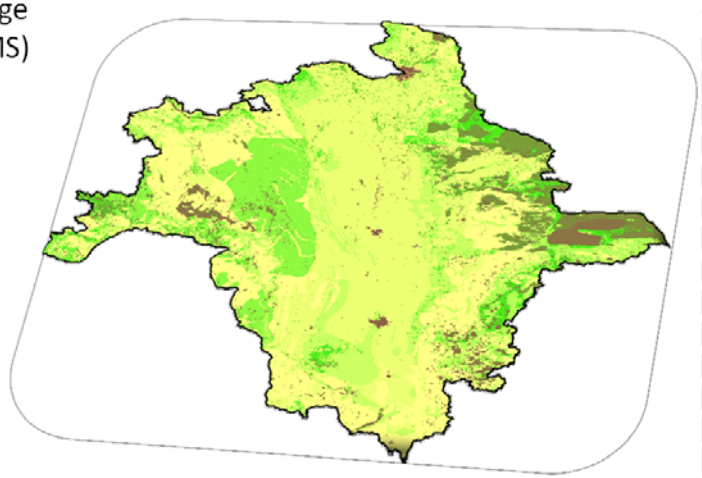
North American Land Change Monitoring System (NALCMS)

Soil Classes



Surficial Materials of Canada (GSC)/United States (USGS)

Merged Veg/Soil Classes



Veg/Soil Class

- Crop/ Till Blanket
- Crop/ Fine Soil
- Crop/ Coarse Soil
- Decidous Forest/ Till Blanket
- Crop/ Till Vaneer
- Grassland/ Till Blanket
- Grassland/ Coarse Soil
- Mixed Forest/ Till Blanket
- Grassland/ Fine Soil
- Grassland/ Till Vaneer
- Deciduous Forest/ Organic Soil
- Wetland/ Organic Soil
- Water
- Impervious

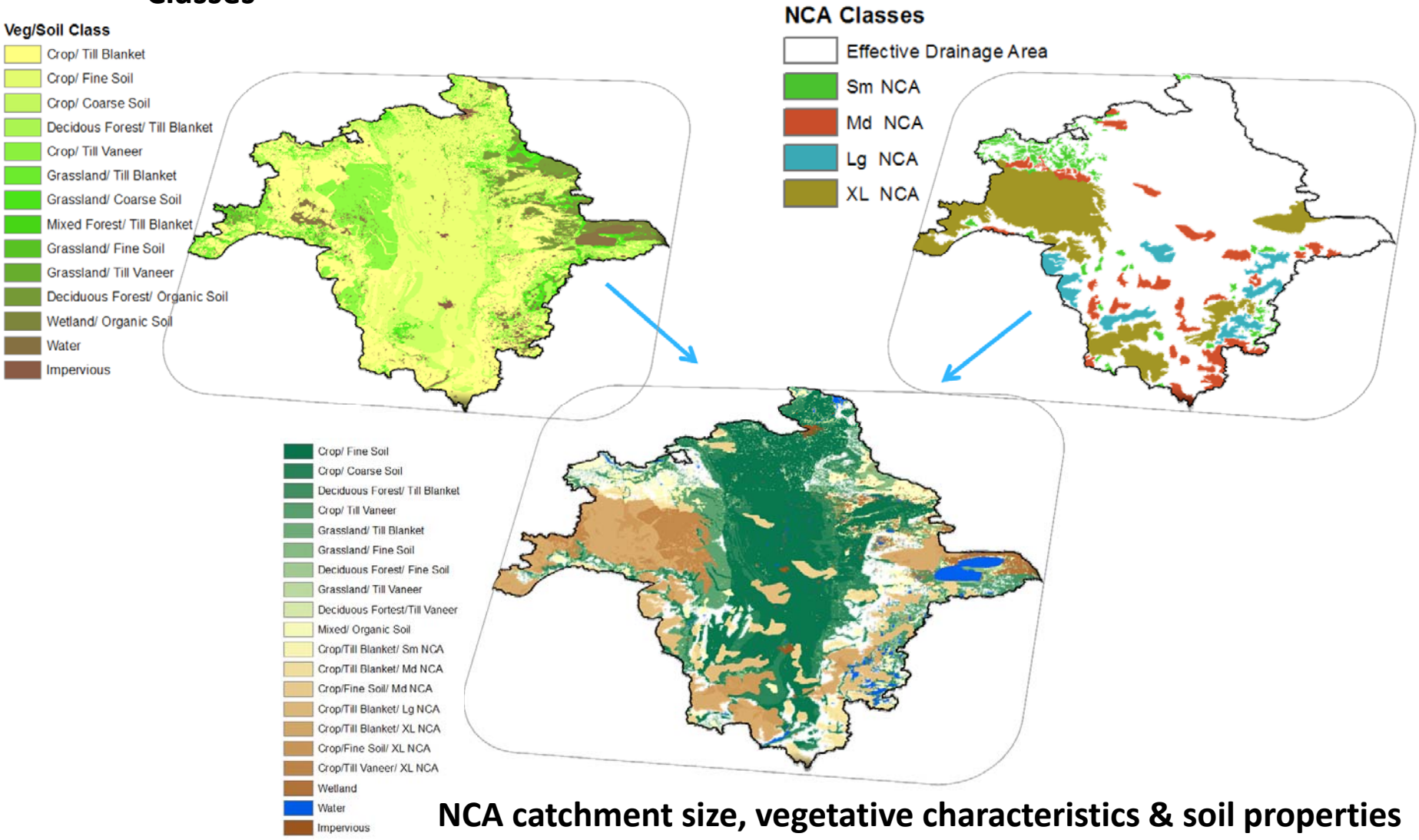
Manitoba Hydro

Watflood uses vegetative land cover classes to parametrize its hydrological parameters.

Red River- Land Class Enhancement Study

Merged Veg/Soil Classes

Non-Contributing Area



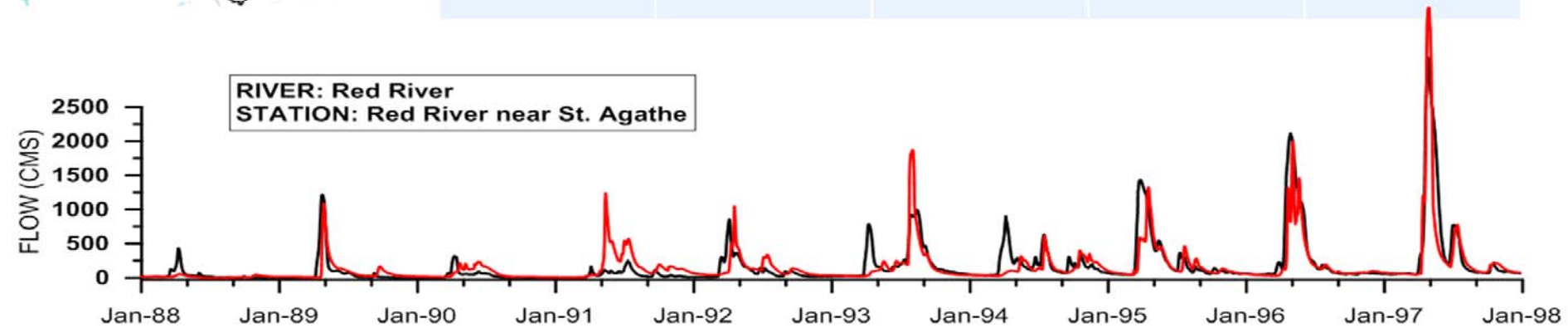
NCA catchment size, vegetative characteristics & soil properties

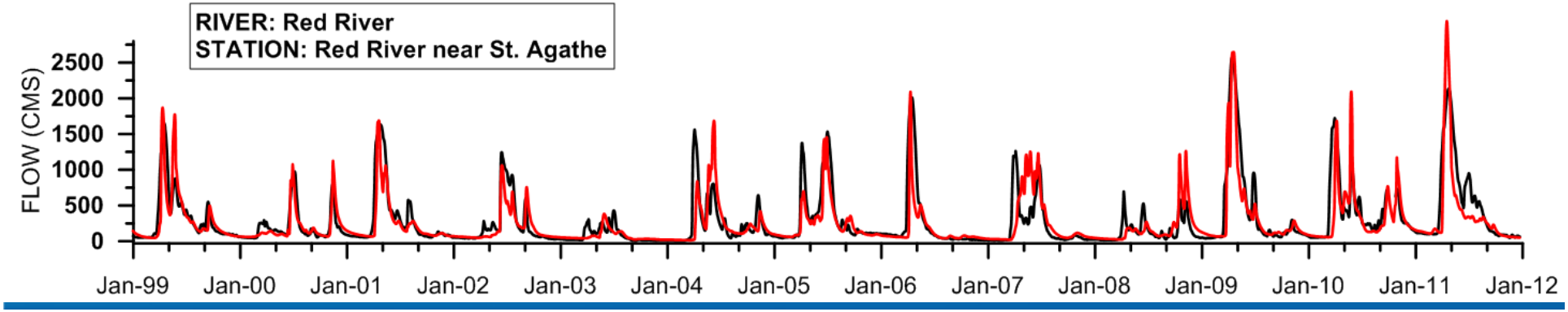
Red River Land Class Enhancement Study



Static NCA		KGE	NSE	PBIAS
Calibration	1988-1997	0.67	0.54	-16.4
Validation	1998-2011	0.63	0.53	-23.5

Dynamic NCA		KGE	NSE	PBIAS
Calibration	1988-1997	0.80	0.67	-2.7
Validation	1998-2011	0.77	0.64	-9.9







Operational Physically-Based Inflow Forecasting Framework (OPBIFF) -Modernization-

Modernized Forecasting Framework

- Delft-FEWS software from Deltares
- Interface software linking data, hydrological models, and operations
- MH-vendor joint configuration

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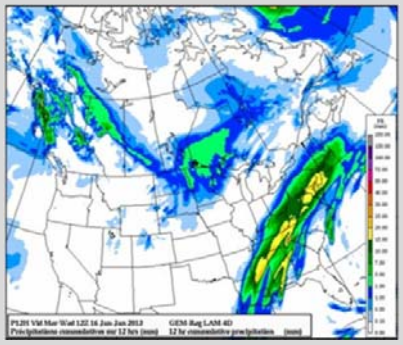
REQUEST FOR PROPOSAL 040901

IMPLEMENTATION OF THE DELFT-FEWS HYDROLOGICAL MODELLING AND RIVER FORECASTING FRAMEWORK SOFTWARE FOR HYDROPOWER OPERATIONS

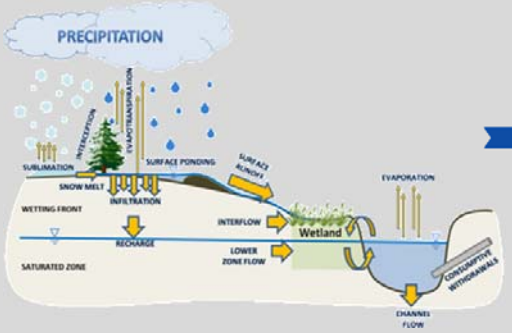
IMPORTANT
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MAY 30, 2018

Data Acquisition & Processing



Hydrological Model Runner

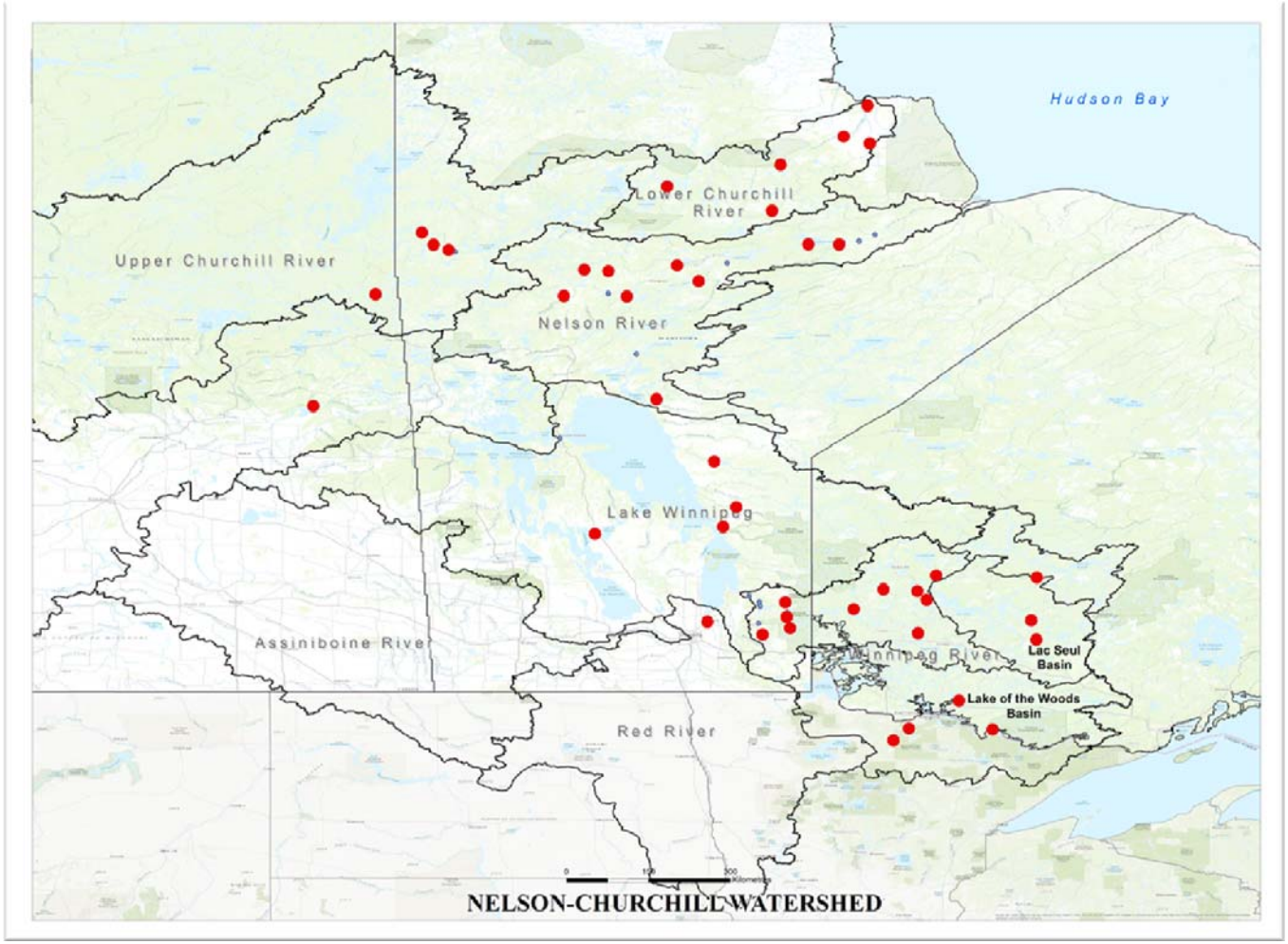


Stakeholder Integration

- Streamflow forecasts
- Reporting & alerts
- Operations integration

Manitoba Hydro

Inflow Forecasting Nodes



Manitoba Hydro

Forecast Input Data

Observed Climate

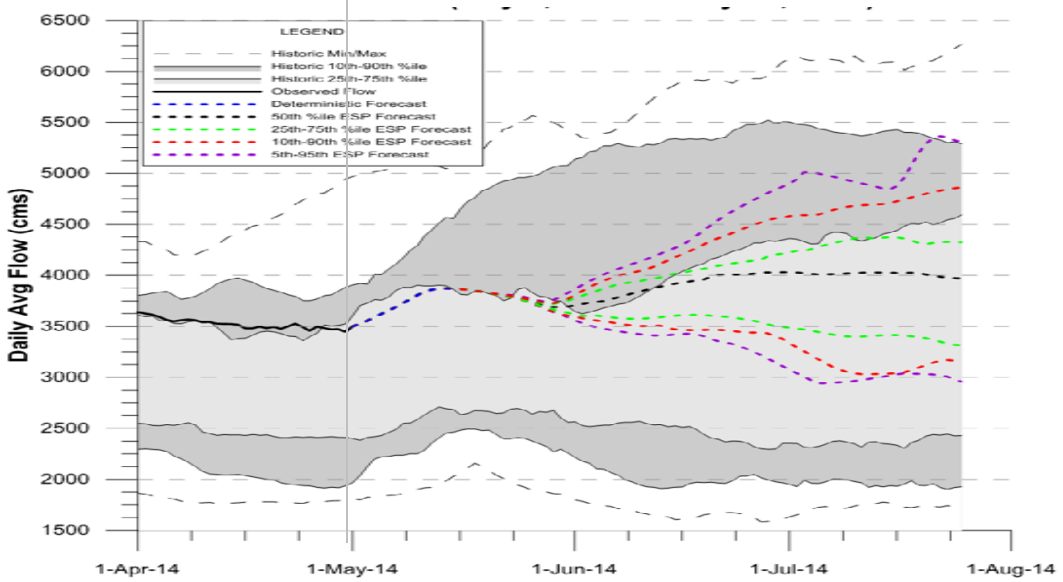
Hydrometrics and SWE Data

Forecasted Weather Data

Upstream Forecasts From Other Agencies

Historical

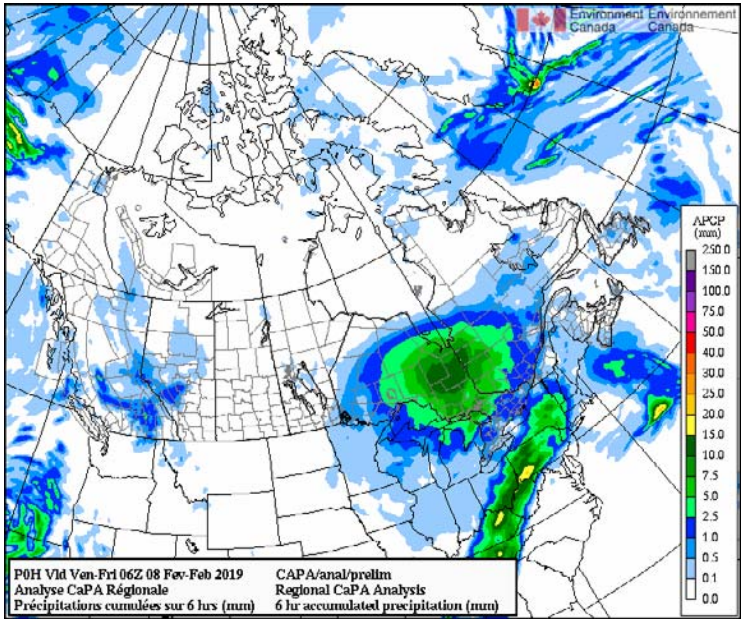
Forecast Period



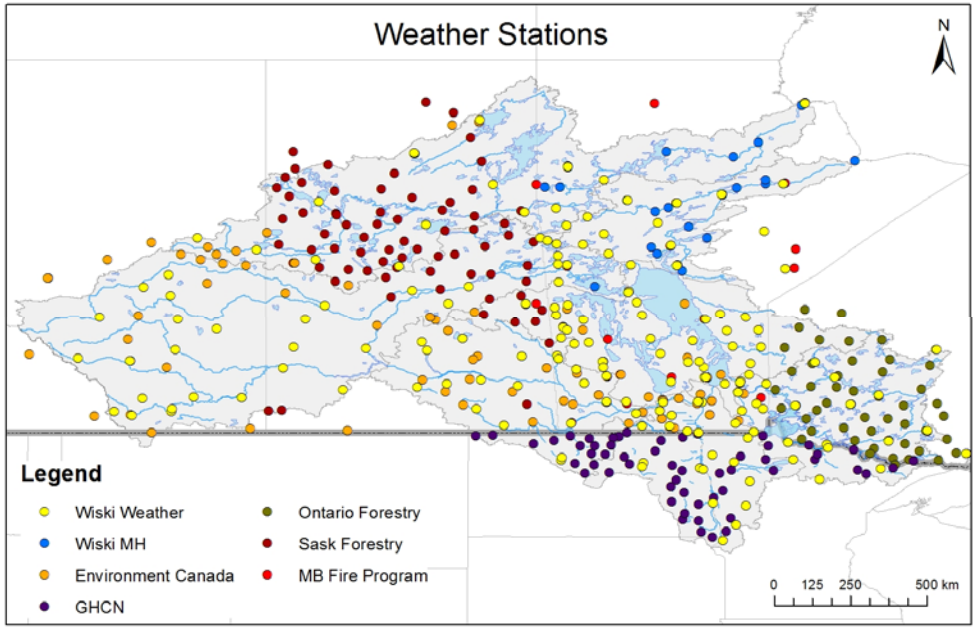
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Observed Climate Data (Historical)

CaPA (Historical Precipitation)



Station-Based Temperature & Precipitation HEC-HMS & Watflood



CaPA Interest

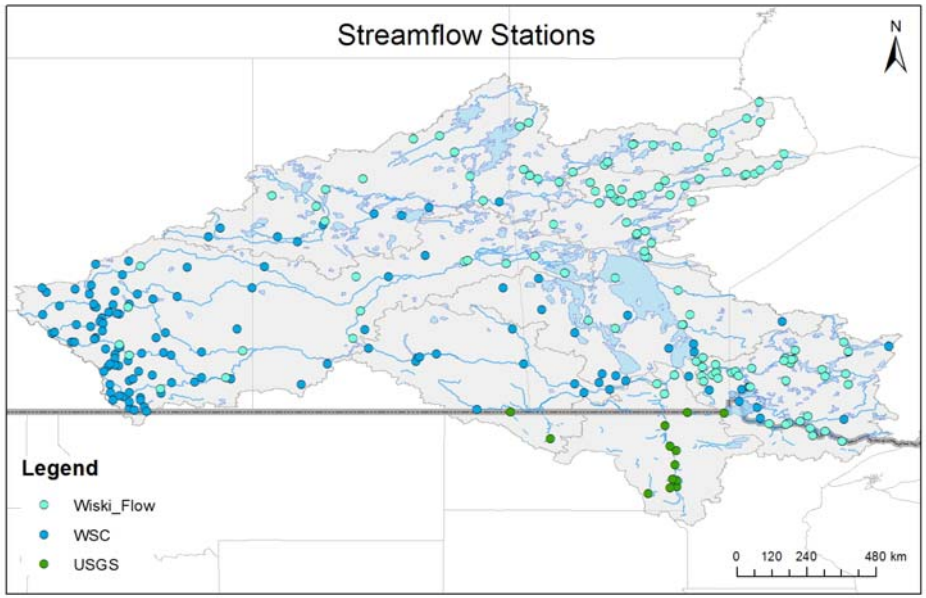
- CaPA (10km) hindcast to 1979
- Integrating satellite observations.
- Bias correction of solid precipitation.

Products/Data of Interest

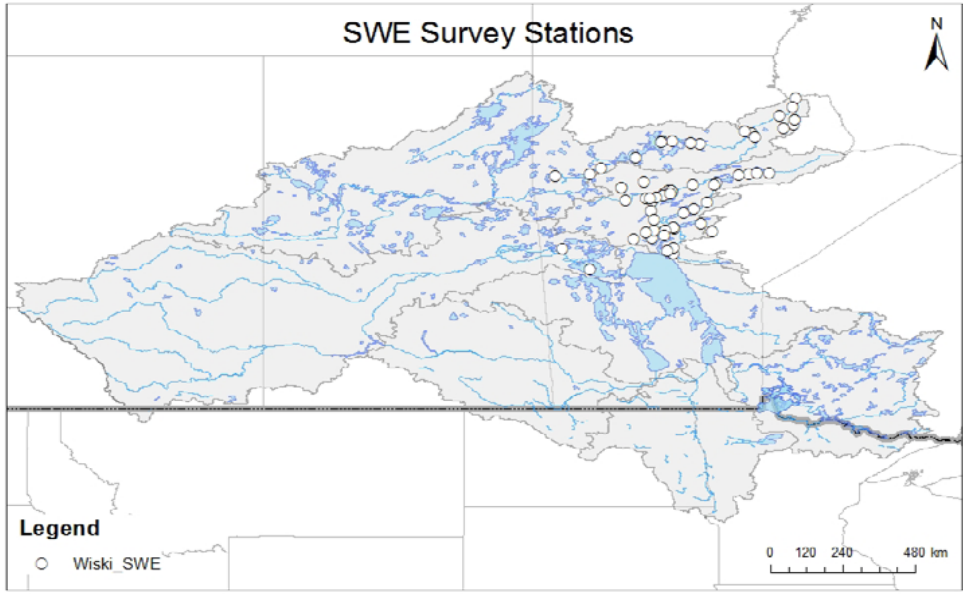
- QA/QC procedures for station & gridded data.

Other Input Data (Historical)

Hydrometric Station Data



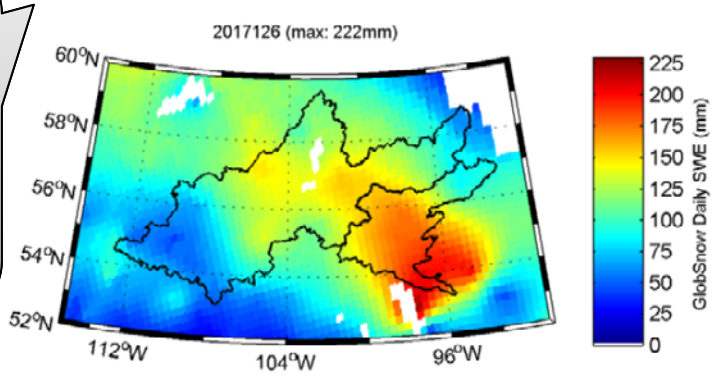
MH Snow Surveys (Snow Water Equivalent)



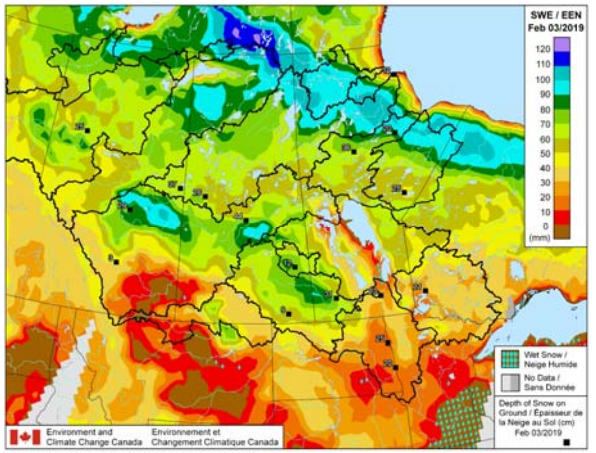
Products/Data of Interest

- Improved operational SWE measurement & analysis.
- How to incorporate SWE measurements into hydrological models.

GlobSnow (Snow Water Equivalent)



ECCC Snow Water Equivalent Products



Forecast Input Data

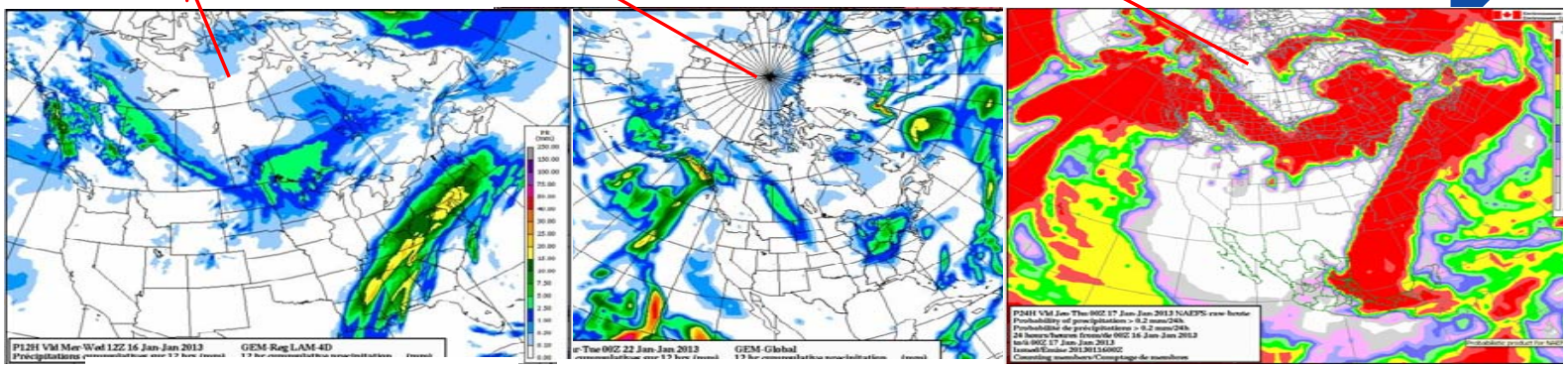
GEM Regional Deterministic Prediction System (RDPS)

GEM Global Deterministic Prediction System (GDPS)

North American Ensemble Forecast System (NAEFS)

Climate Normals (from historical records)

Historical | Day 1 & 2 | Day 3 - 6 | Day 7 - 16 | Day 17 - 21

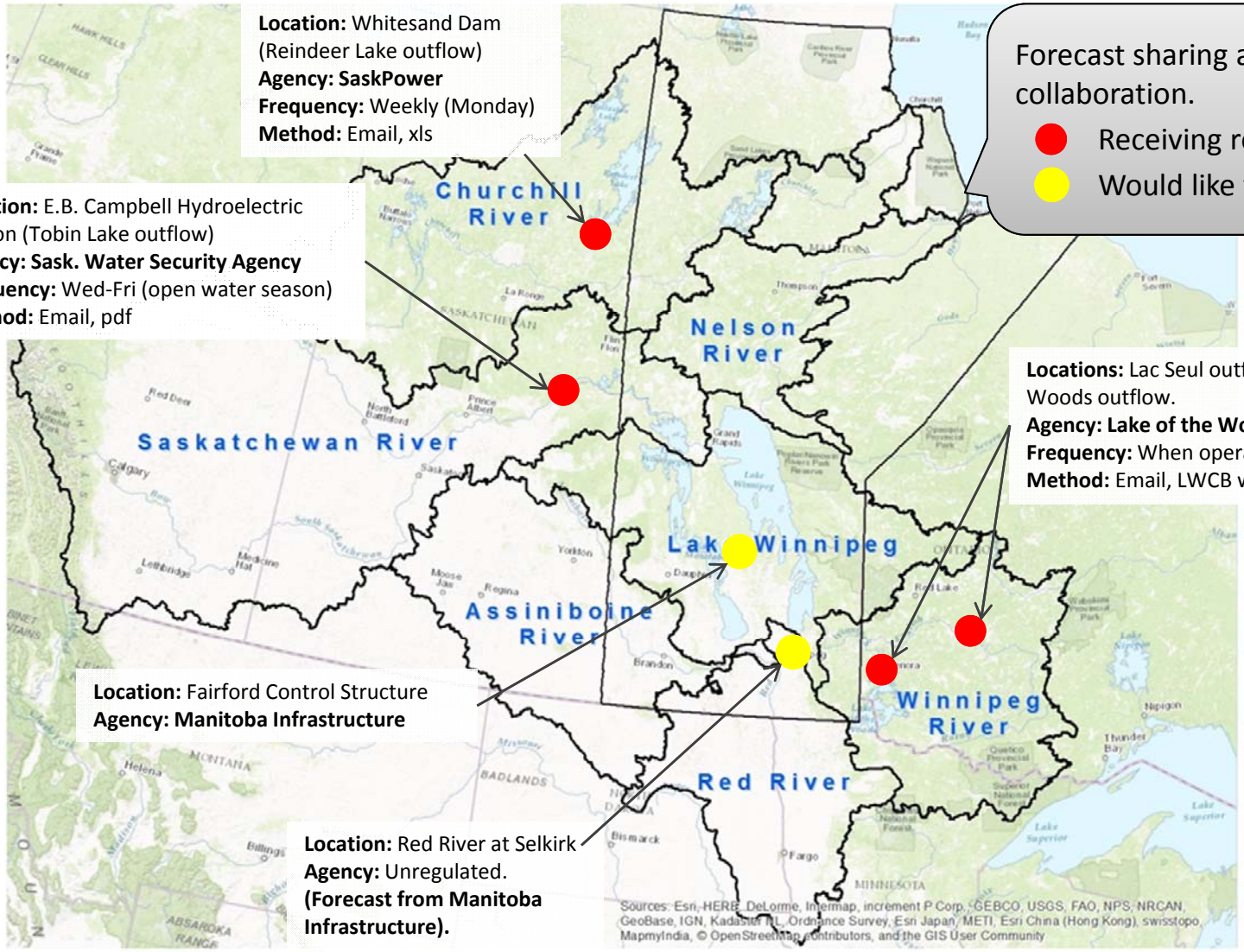


10km x 10km grid res. 25km x 25km grid res. 0.5 x 0.5 degree res.

Obtained from the Environment Canada Datamart

- Integrating into operational systems (reliability).
- Longer range forecasts (i.e. seasonal)
- Forecast bias corrections

Forecast Data – Upstream Agencies



Location: Whitesand Dam (Reindeer Lake outflow)
Agency: SaskPower
Frequency: Weekly (Monday)
Method: Email, xls

Location: E.B. Campbell Hydroelectric Station (Tobin Lake outflow)
Agency: Sask. Water Security Agency
Frequency: Wed-Fri (open water season)
Method: Email, pdf

Forecast sharing and data collaboration.

- Receiving regularly
- Would like to receive

Locations: Lac Seul outflow, Lake of the Woods outflow.
Agency: Lake of the Woods Control Board.
Frequency: When operations change.
Method: Email, LWCB website.

Location: Fairford Control Structure
Agency: Manitoba Infrastructure

Location: Red River at Selkirk
Agency: Unregulated.
(Forecast from Manitoba Infrastructure).

Summary

- Large diverse watershed
- Success in physically based inflow forecasting
- Operationally Physically Based Inflow Forecasting Modernization Project
  - 18 month phased project
  - System-wide application

Manitoba Hydro

Thank You

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Manitoba Hydro
kkoenig@hydro.mb.ca

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