Water-Quality Modeling in the United States and Canada for the Souris-Assiniboine-Red River Transboundary Watersheds

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Government of Saskatchewan


PROPOSED- SPARROW:MRB3-4 Canadian Extent
Saskatchewan
Winnipeg
North Dakota
BISMARCK
Fargo
Grand Forks
Missouri River
Assiniboine River Basin- FDA 05M
Qu'Appelle River Basin- FDA 05J
Souris River Basin- FDA 05N
Red River Basin- FDA 05O
Harmonized US8-CAN4 Units within the Souris and Red Basins
1:10M Hydro
LaittaM:IJC052711:EC FDA, USGS HUC8 1:10mHydro/Poly/10Mtopo

Project initiated by the International Joint Commission

International Joint Commission (IJC)

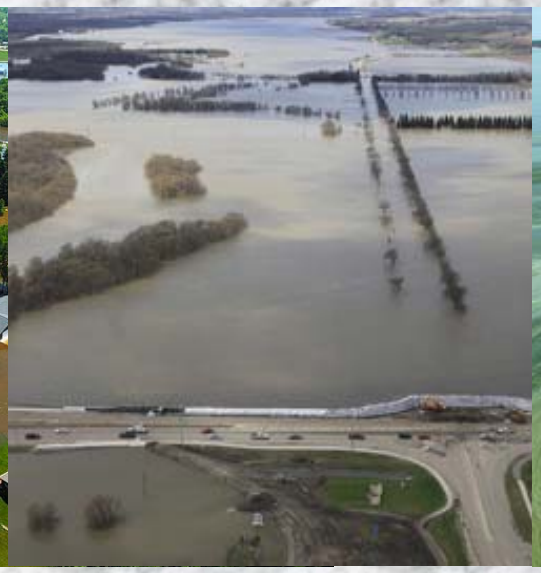
- Created by the United States and Canada under the 1909 Boundary Waters Treaty
- More than 20 boards made up of experts from both countries to help carry out it's responsibilities
- Works to resolve water-related disputes, acting impartially
- When asked by governments, investigates pollution problems for shared lake and river systems along the Canada-United States border

The Red-Assiniboine-Souris Basin – Context

The problem:

- Water quality (nutrients) a persistent problem in the Red-Assiniboine-Souris basin and Lake Winnipeg
- Unresolved questions as to nutrient loads across the borders and total loads to Lake Winnipeg, mitigation strategies, integrity of monitoring networks, etc.
- **IJC** – relatively new direction into WQ modeling (compared to hydraulic and hydrologic)

Souris R, Minot, ND, Sgt S Jackson, The National Guard



Assiniboine R, Brandon, MB, J Woods, CP

Paddle Canada (www.crca.ca)

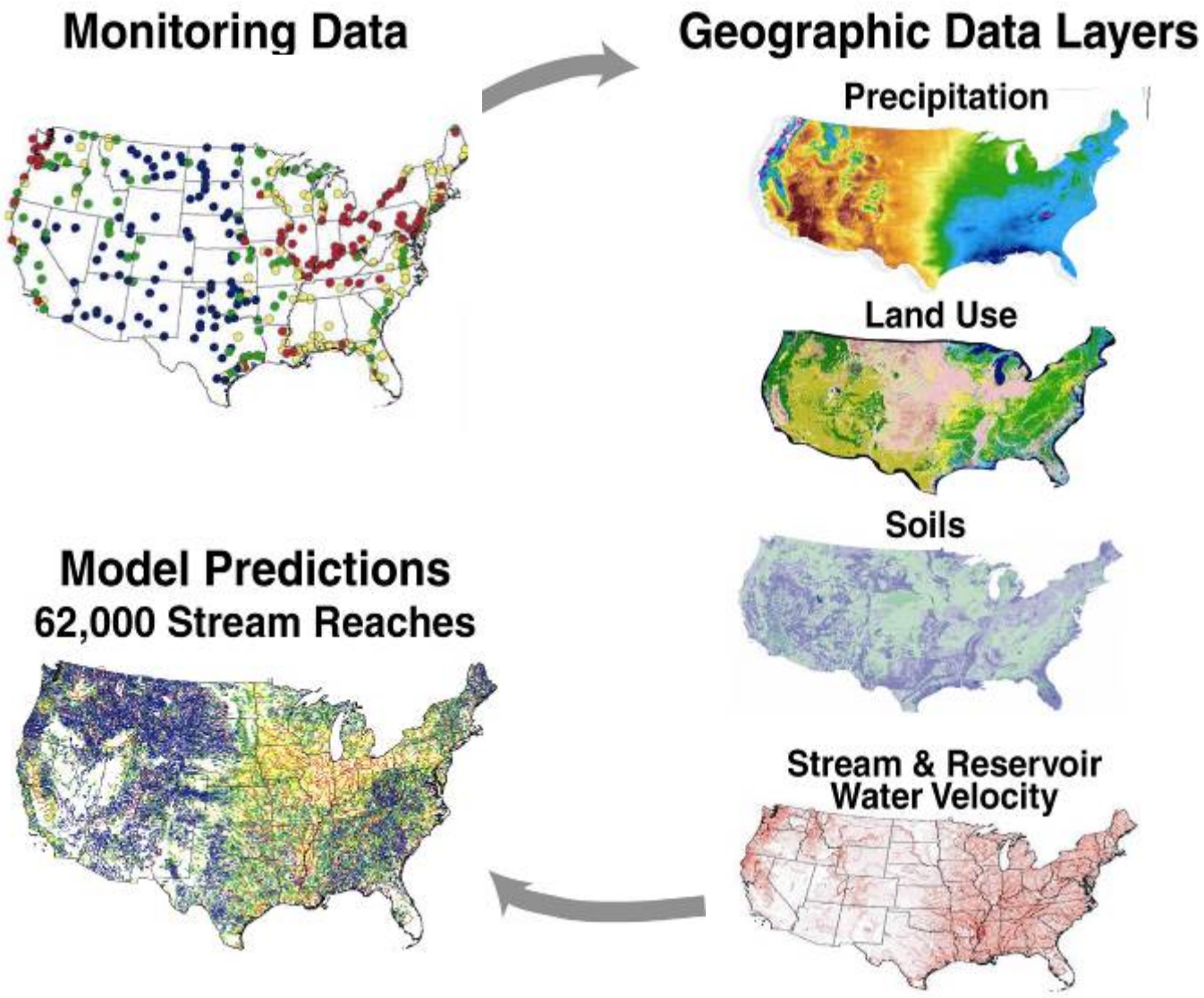
SPARROW Modeling of the Red-Assiniboine-Souris Basin – Summary

The project:

- International Watersheds Initiative (IWI) – binational integrated approach to investigating water quality issues
- Pilot system to demonstrate utility of the **USGS SPARROW** Water Quality Model in binational and Canadian contexts
  - Model selected from a suite of candidates
- Build on IWI hydrographic and geospatial harmonization project and associated expertise
- Assist Canadian agencies with SPARROW building capacity
- Project ongoing – overview of model and progress thus far

SPARROW Water-Quality Model

SPAtially Referenced Regression on Watershed Attributes

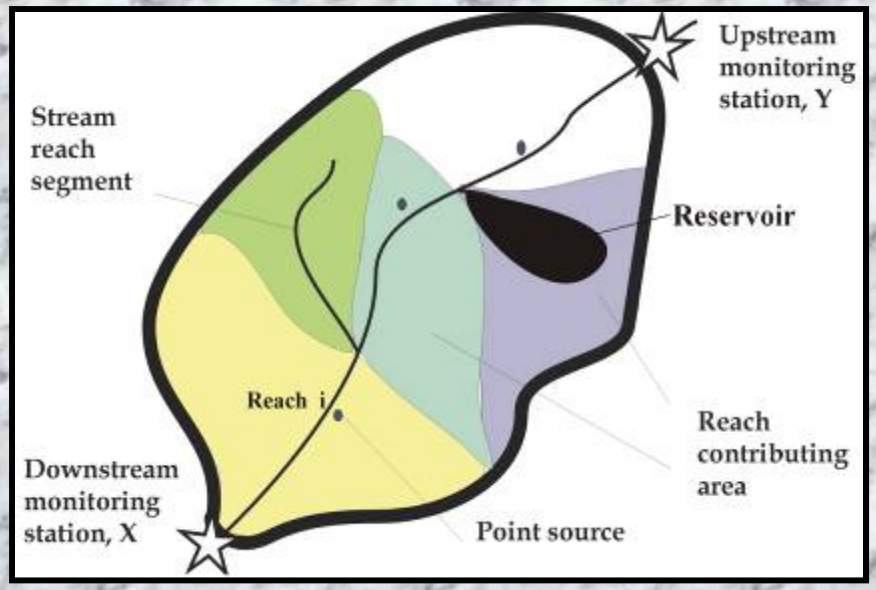


SPARROW's Reach-Scale Mass Balance

Reach network relates watershed data to monitored loads

$$LOAD_i = \left\{ \sum_{j \in J(i)} \left[\sum_{n=1}^{N} S_{n,j} \beta_n \exp(-\alpha' Z_j) \right] \prod_m \exp(-\delta_m^s T_{i,j,m}) \prod_l 1/(1+\lambda^r q_{i,j,l}^{-1}) \right\} \exp(\varepsilon_i)$$

- Monitored Stream Load
- Sources
- Land-to-water transport
- Aquatic transport
- Error



- Spatial reference frame is stream network, coupled to DEM
- Fundamental spatial element is stream reach and associated incremental drainage area
- SPARROW estimates the optimal set of rate coefficients that balance material mass (source inputs, stream loads, and storage/loss)

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Team:

Project lead and principal investigator

- Wayne Jenkinson – National Research Council – Ottawa

Others:

- Glenn Benoy – Environment Canada and Agriculture & Agri-Food Canada (AAFC) – Fredericton, New Brunswick
- Craig Johnston – United States Geological Survey (USGS) – New Hampshire
- Erika Klyszejko – Environment Canada
- Ted Yuzyk – IJC - Ottawa
- Martin Serrer – National Research Council - Ottawa
- Elaine Page – Manitoba Water Stewardship
- O. S. (Arasu) Thirunavukkarasu –Saskatchewan Environment

Notable support (data & advice) from:

- David Saad – USGS - Wisconsin
- Rich Moore – USGS – New Hampshire
- David Wolock – USGS - Kansas
- Steve Preston – USGS - Delaware
- Jason Vanrobaeys – AAFC
- Mike Laitta – IJC – Washington D.C.
- Conrad Wyrzykowski – AAFC
- Pam Minifie – Saskatchewan Environment
- Mark Henry – Statistics Canada
- Mike Wieczorek – USGS – Maryland
- Tim Bondelid – NHDPlus / USEPA consultant

Constructing Red-Assiniboine-Souris-SPARROW model

Stream network "framework" of the model

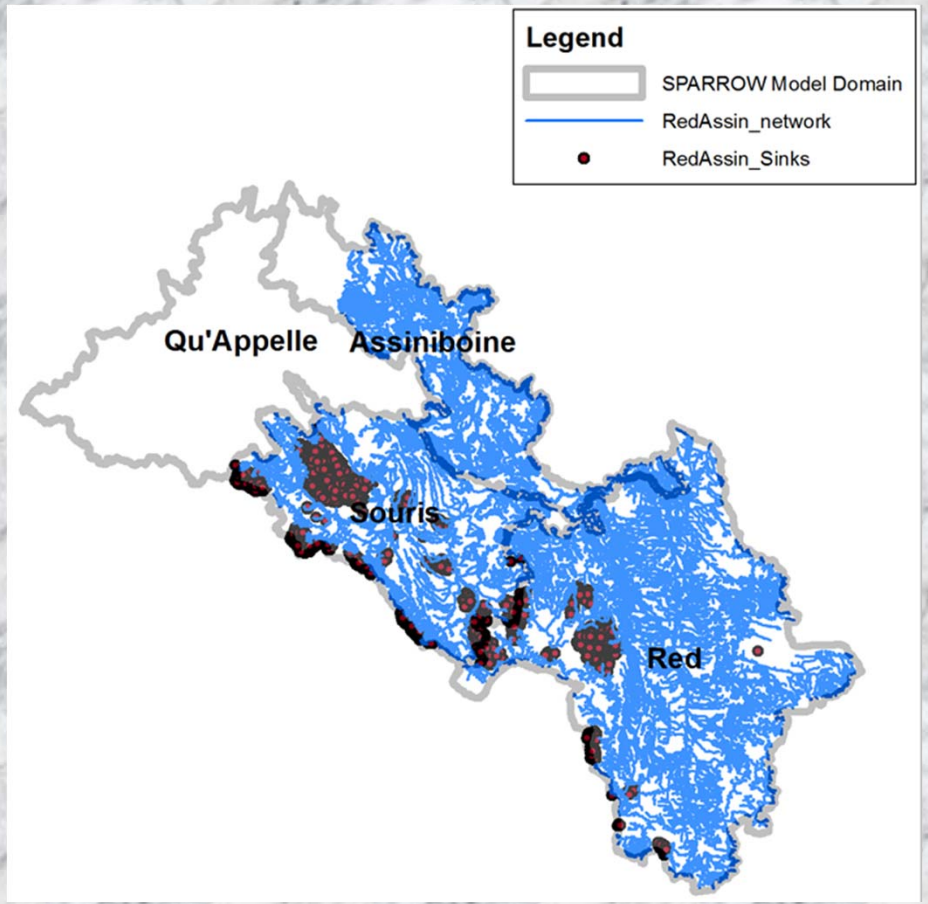
Extremely challenging region for network generation

Combination of data sources:
- Canadian NHN
- IJC harmonized NHN/NHD
- NHDPlus NHD data

Over 74,000 unique stream segments. SPARROW will predict nutrient estimates for all of these

"Sinks" or prairie potholes / closed lakes also considered – identify areas that do not "contribute"

Network navigation attributes built.
- Necessary for SPARROW transport of nutrients



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Generating Catchments

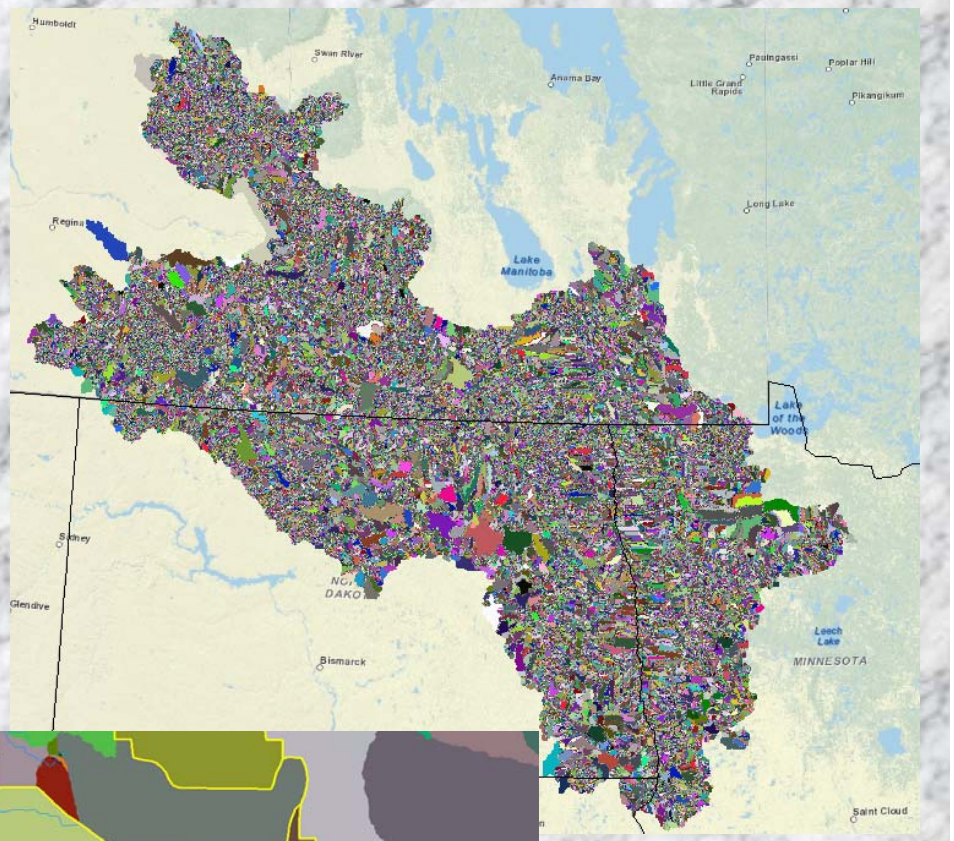
Created using a modified US **NHDPlus** computer script

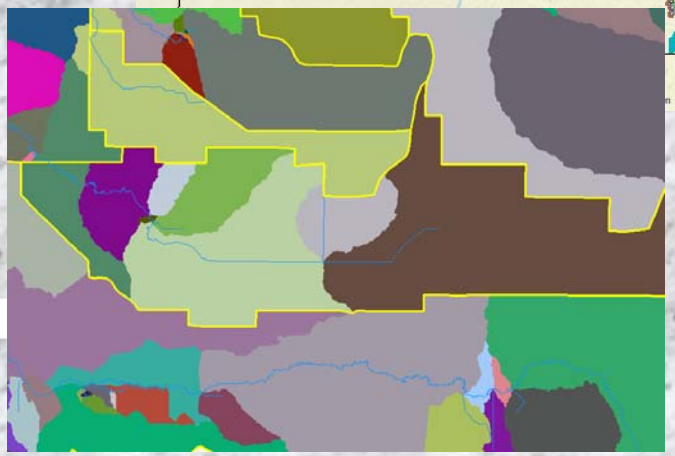
Script uses a harmonized DEM from US and Canadian sources to create a HydroDEM (hydo-conditioned DEM)

HydroDEM consists of enforcing mapped hydrologic features:

- Existing basin divides (walling)
- Drainage enforcement of model stream network (stream-burning)
- Waterbodies (bathymetric gradients)
- Non-contributing areas (sinks)

Catchments are created for each stream segment and sink feature (over 86,000 catchments - mean size 2.7 km^2)





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Estimating Streamflow and Velocity

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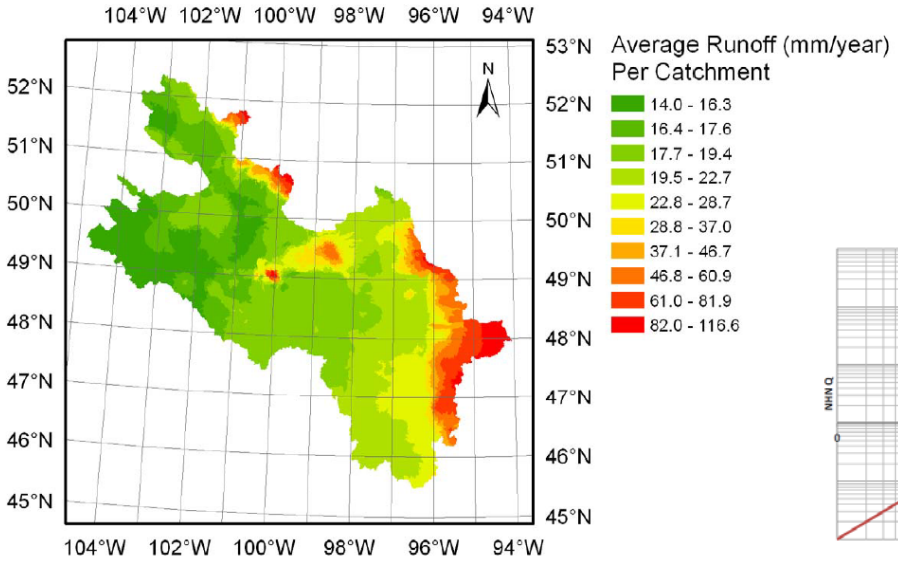
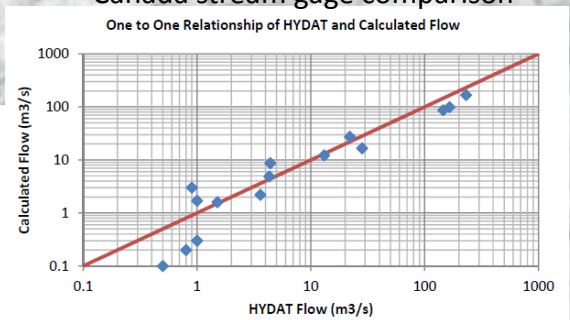
Estimates of streamflow and velocity computed for all stream segments (over 74,000)

- Uses same runoff map data and method as the US **NHDPlus** Version 2 dataset
- Stream velocity estimated using published Jobson equation



Canada stream gage comparison



US stream gage comparison

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SPARROW Modeling Station Flux Estimation – Water Quality Data - Canada

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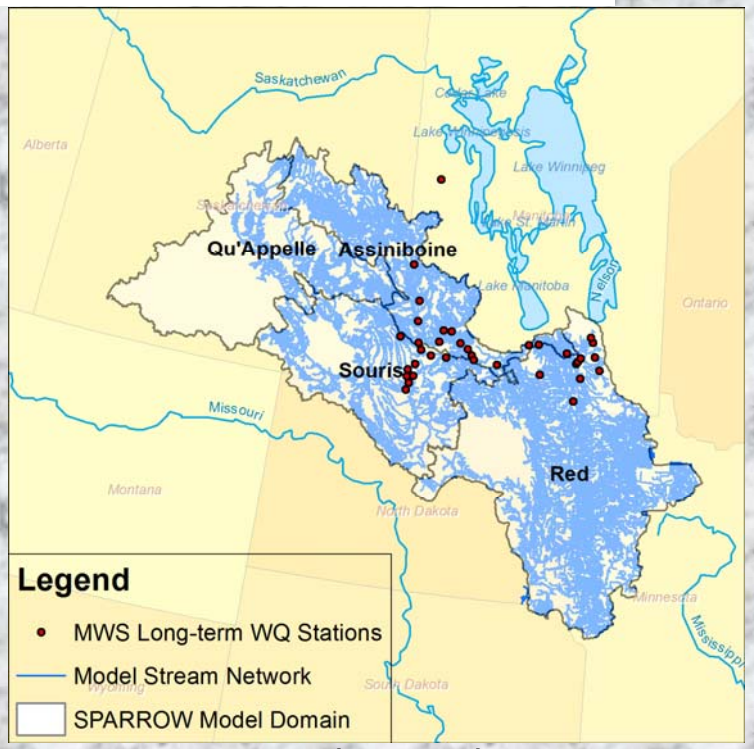
- Integrates long-term discharge and water quality data
- Water quality stations that meet requirements
  - Current with "base year"
  - Adequate period of record
  - Reasonable frequency
- Loads estimated with co-located flow measurements
  - Complicated by seasonal stations
  - Not all WQ stations have co-located flow
  - Flow estimate corrections by drainage-area ratio or similar
- USGS-developed Fluxmaster SAS program used to estimate loads
- Goal to finalize calibration load sites by June 5th, 2012

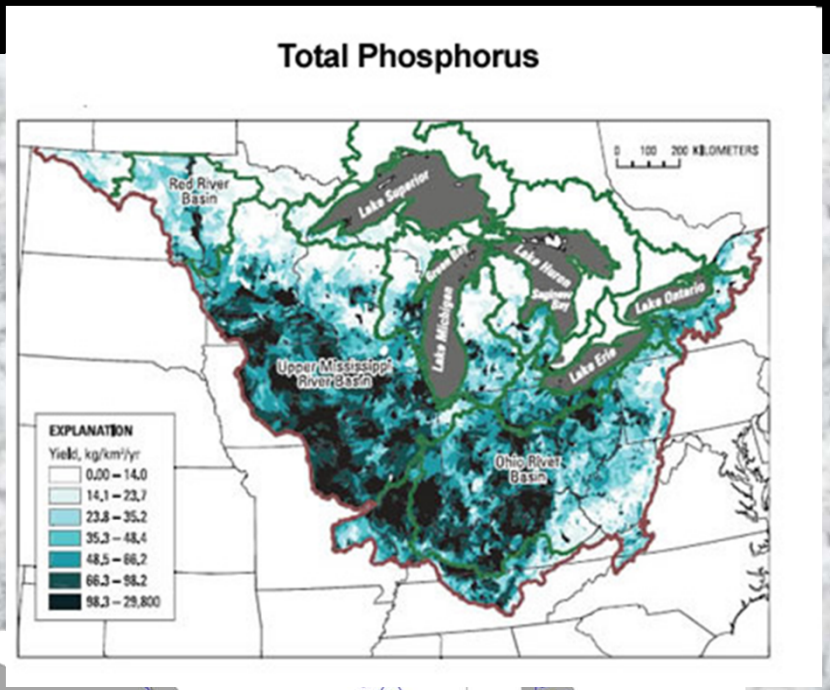


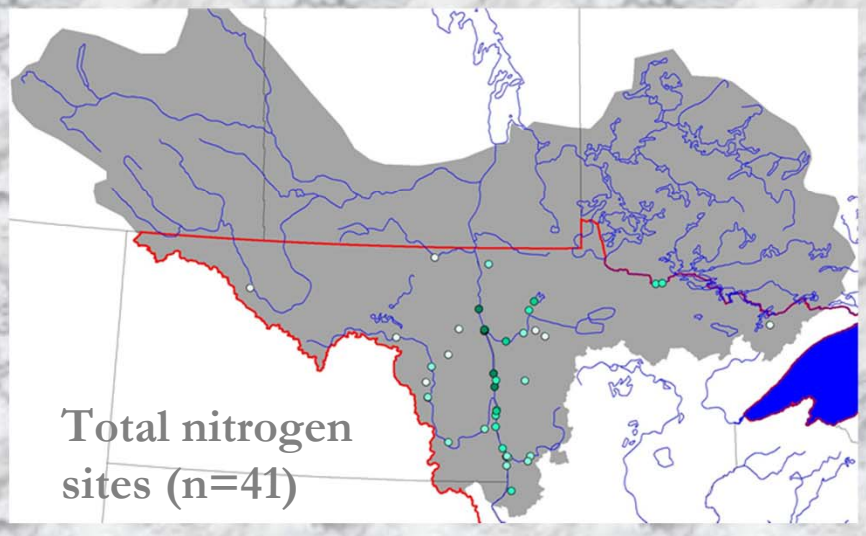
Canadian side
25 candidate sites so far

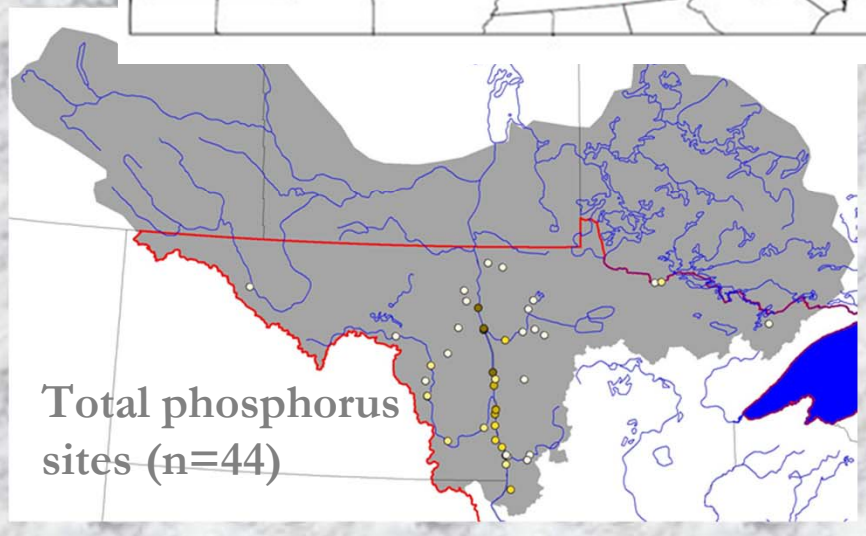
Most in Manitoba (Manitoba Water Stewardship, City of Winnipeg)
Saskatchewan (SEEMS database)
Prairie Provinces Water Board and border stations

SPARROW Water Quality Data – Distribution in the US

- 60-90 candidate sites compiled for the USGS MRB 3 SPARROW model being shared for the binational model
- More sites may become available from a refined MRB 3 SPARROW model now under development
- MRB 3 model has same “base year” as the binational Red-Souris-Assiniboine model







SPARROW Model Input Variables

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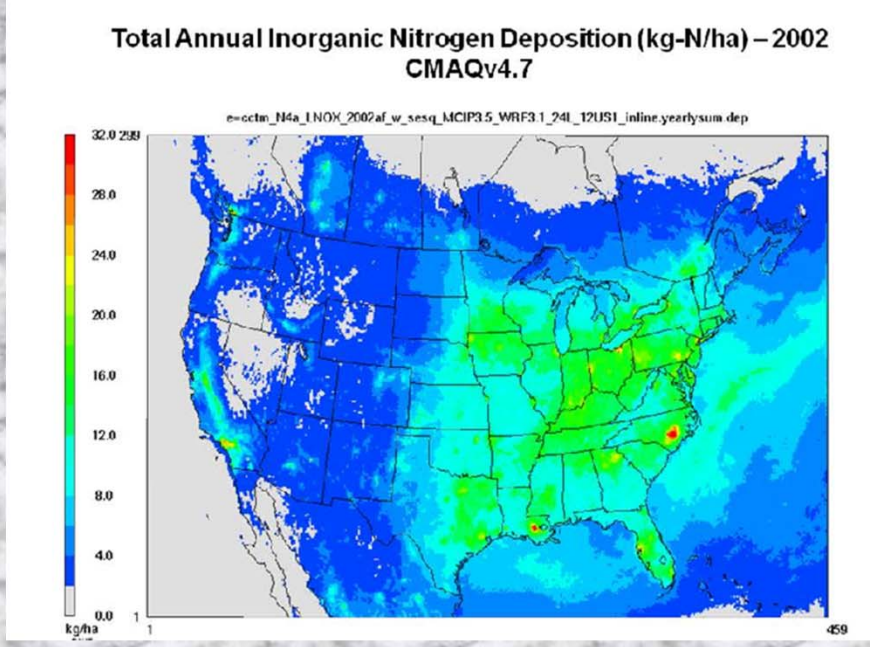
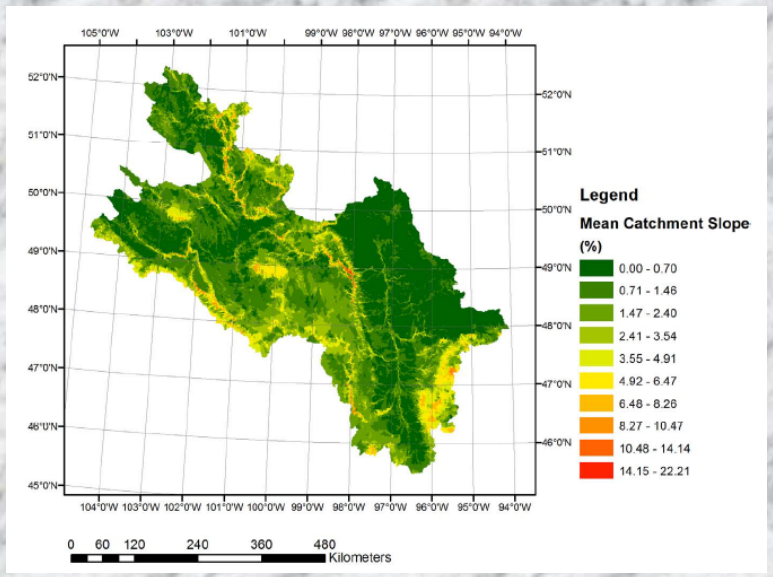
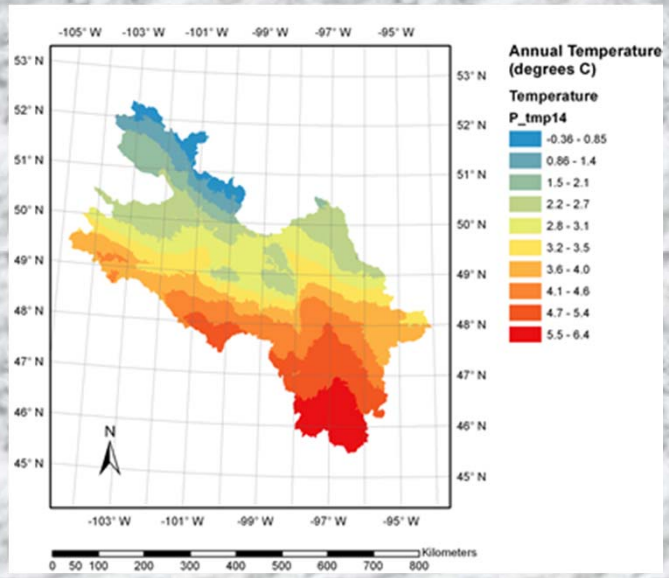
Geospatial data acquired and processed per catchment:

- Slope
- Mean overland flow path distance to stream
- Atmospheric N deposition(CMAQ)
- PRISM (Climate) / CaPA (Climate)
- Land use
- Reciprocal hydraulic load







SPARROW Model Input Variables

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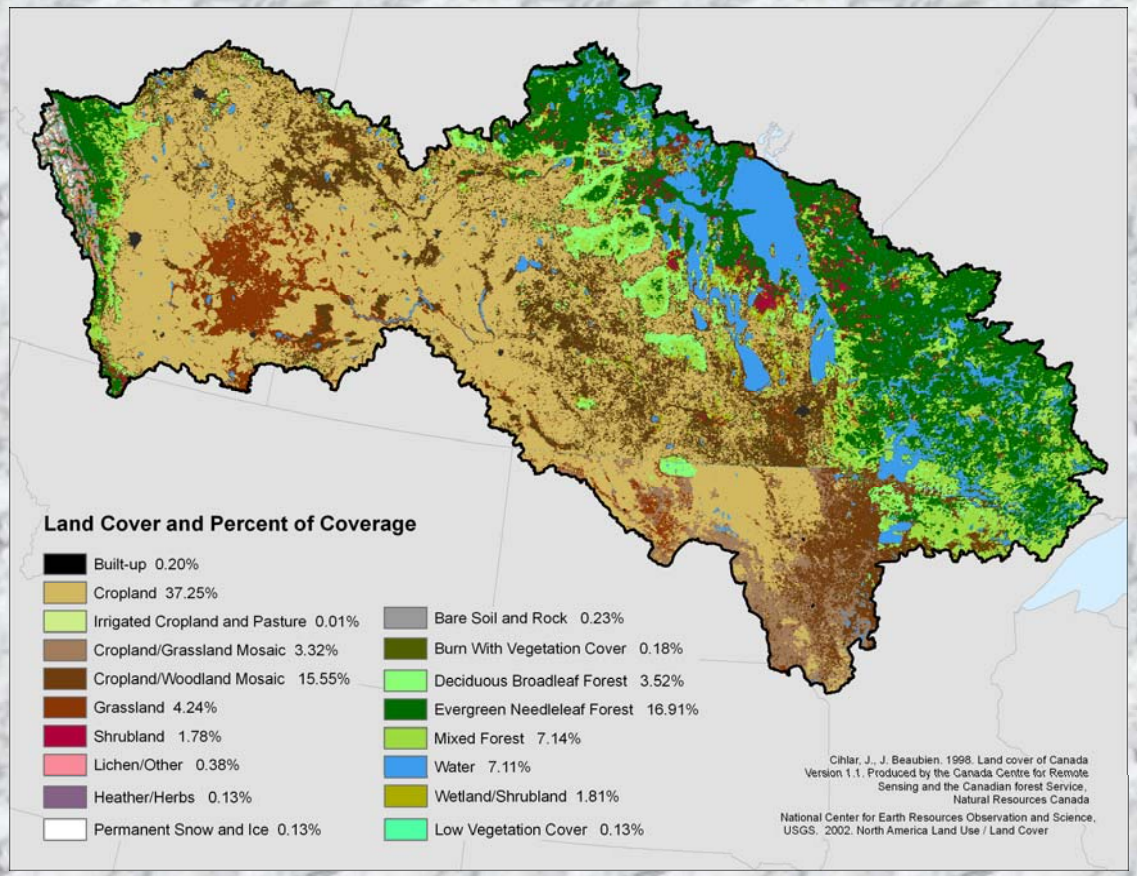
More data required and being collected:

- Agricultural land use (cropping systems, livestock density)
- Fertilizer and manure application estimates (Census)
- Soil conductivity and soil test P (National soil databases)
- Point source data
  - Wastewater treatment plants
  - Industries



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Example Data Harmonization Task

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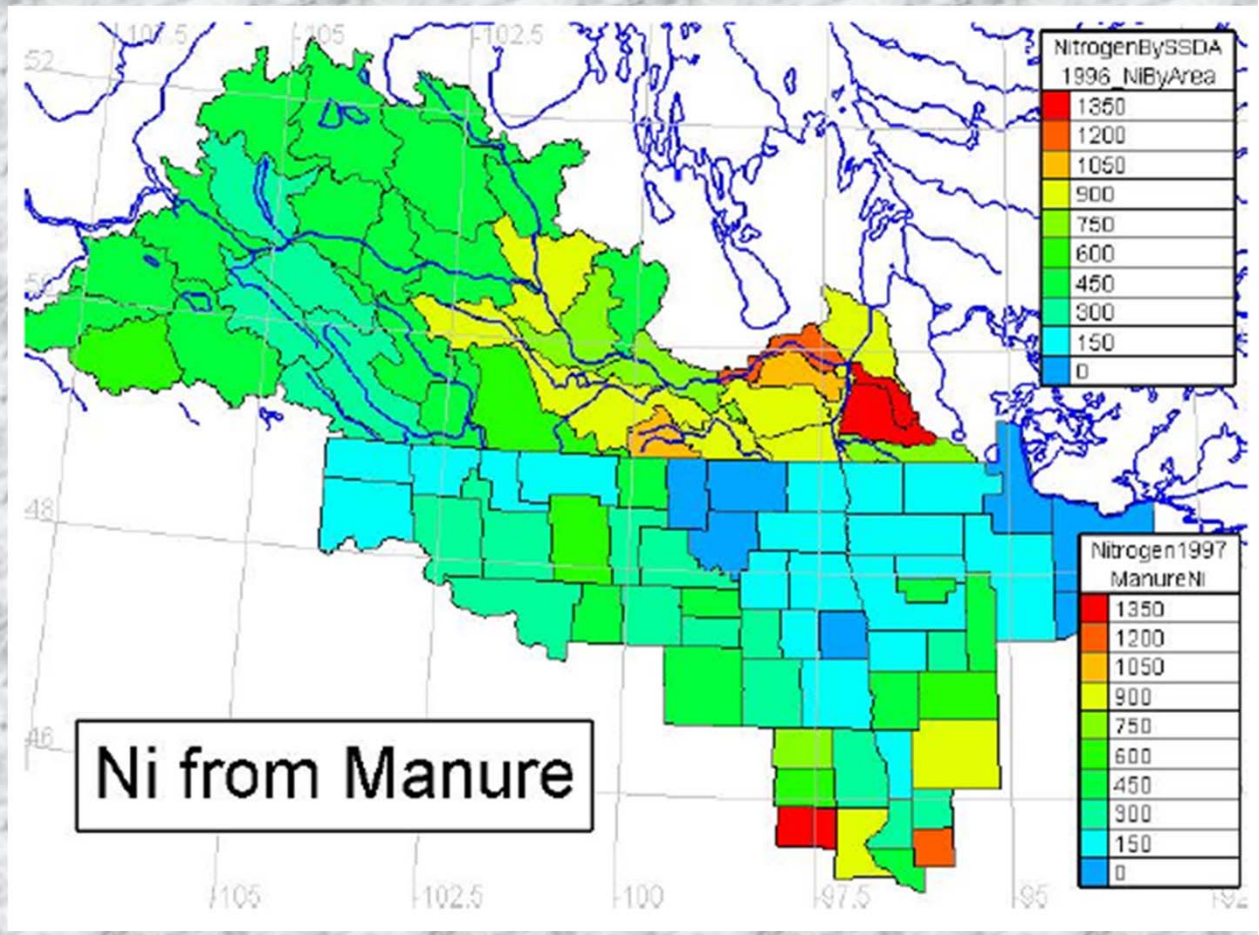
Nitrogen estimates from manure

- Canadian side appears higher than US
- Livestock count data acquired on both sides of the border
- Uniform equation will be applied to animal count data



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Next Steps and Opportunities

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- Working Model / Calibrated Model – Finalized by Sept. 2012
  - Apportion SPARROW nutrient source estimates by watershed and by jurisdiction
  - Identify weaknesses in monitoring networks through uncertainty analysis
- Scenario simulations
  - Connect previously isolated areas (e.g. Devil's Lake)
  - Adjust fertilizer / manure loading levels
  - Adjust climate inputs according to RCM forecasts
  - Scenarios defined by provincial and state agencies to achieve water quality objectives (e.g. Lake Winnipeg) and address flooding issues (e.g. water diversions, wetland restoration)
- Possible future watershed applications (Great Lakes basin)
  - The harmonization challenges are being overcome
  - Next binational applications will go more quickly
  - This application likely one of the most challenging

Questions?

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