Environmental Modelling Workshop 2013

An overview of modelling evaluations to support contaminant load management for the North Saskatchewan River

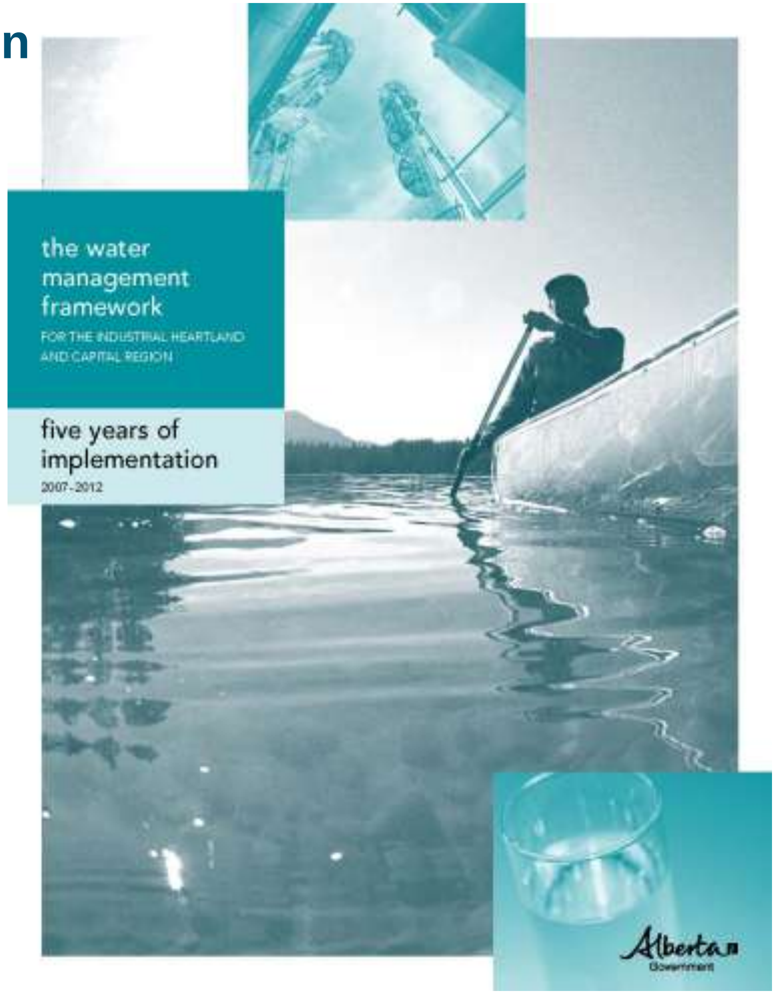
Darcy McDonald
Deepak Muricken
AESRD

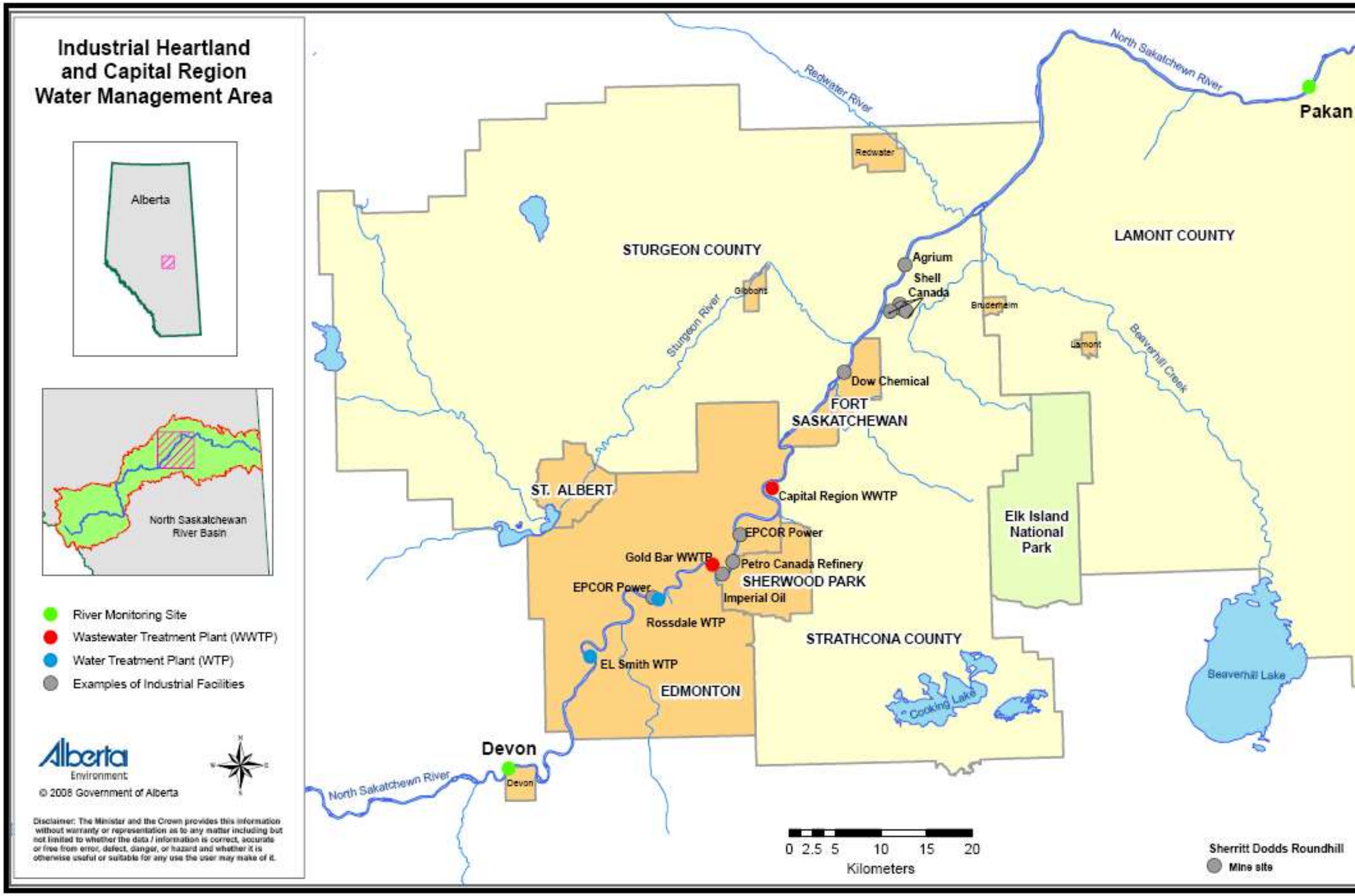
Background:

Water Management Framework
for the Industrial Heartland and Capital Region

- Framework describes:
  - Mandate
  - Vision
  - Strategic Objectives
  - Guiding Principles
  - Planning Horizon
  - Phases for implementation
  - Projects / Next Steps

http://environment.alberta.ca/01769.html





Alberta

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To support the NSR/IH Water Management Framework, various monitoring and evaluation initiatives have advanced in recent years to:

- Enhance and assemble information available for the NSR and pollutant sources to enable better evaluation of river conditions;
- Set appropriate water quality benchmarks that integrate the influence of variable flows;
- Evaluate river conditions relative to water quality objectives.
- Evaluate instream pollutant loads and options for their management.

NSR Model Development and Implementation…

Why use models?

"Nobody uses crystal balls anymore.!

NSR Modelling Scope:

- Represent pollutant transport and related biological response in the river to assess management scenarios (e.g., wastewater management for the reach d/s of Devon).

=> Develop a suite of modelling tools to evaluate local and basin-scale pollutant loads and transport.

Goal:

Support informed management decisions on development in the NSR Basin

Model Selection…

NSR Modelling Components:

1) **Loading Calculation Tools**
   (conservative; e.g., LOADS, LOADEST, FLUX)

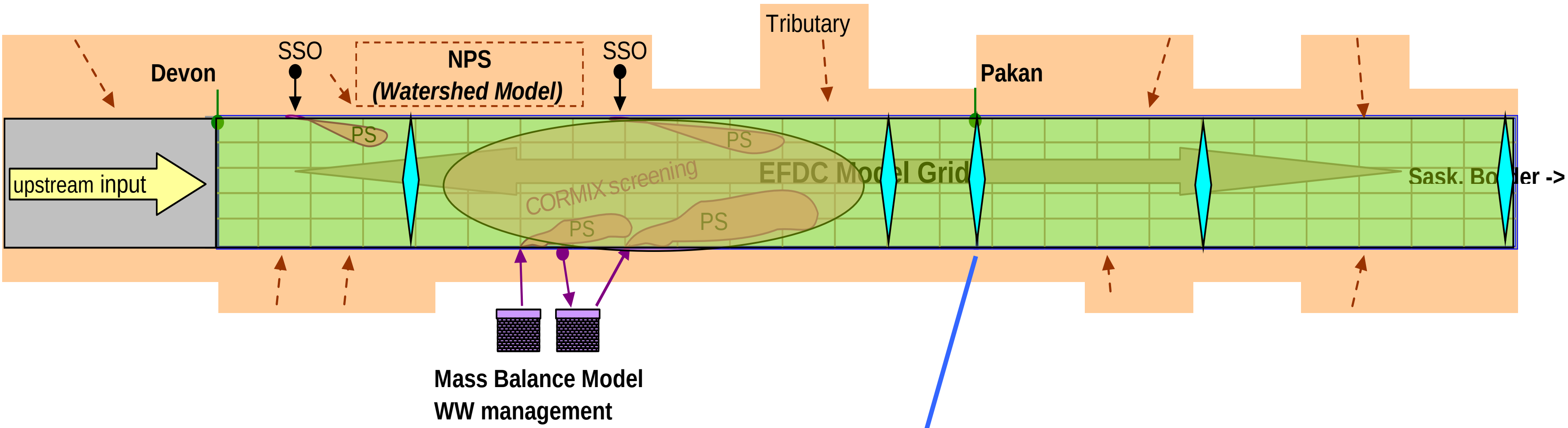
2) **Wastewater Treatment Efficiency Model**
   (end-of-pipe; mass balance model)

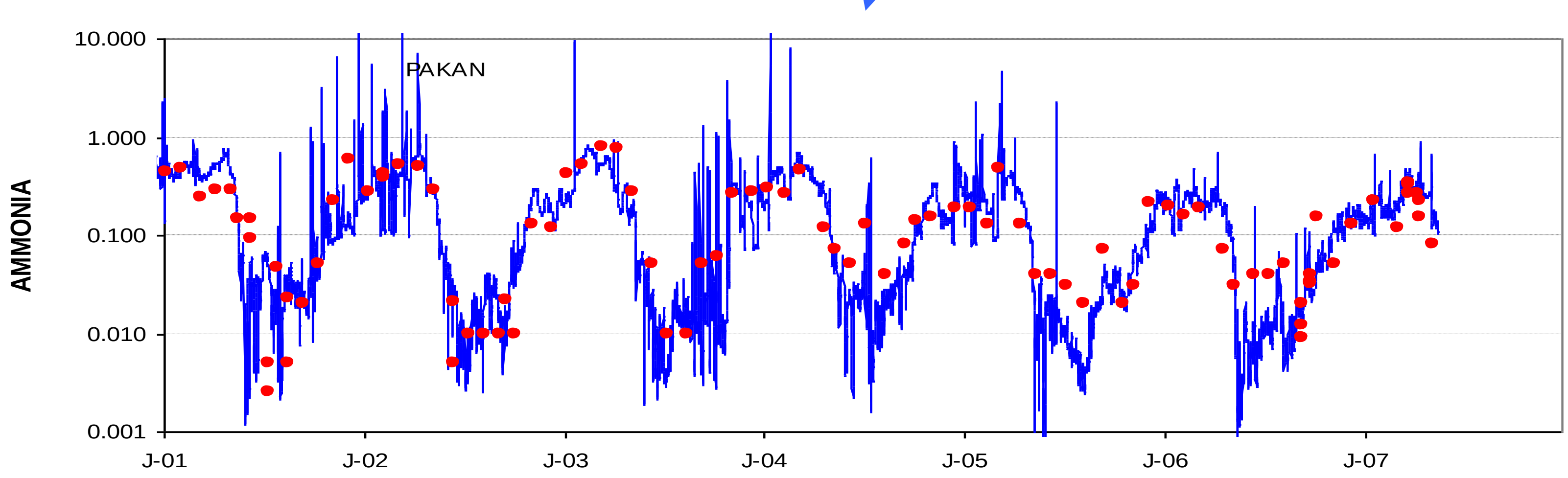
3) **Near-Field (mixing zone) Model**
   (CORMIX)

4) **Instream Hydrodynamic / Water Quality Model**
   (EFDC)

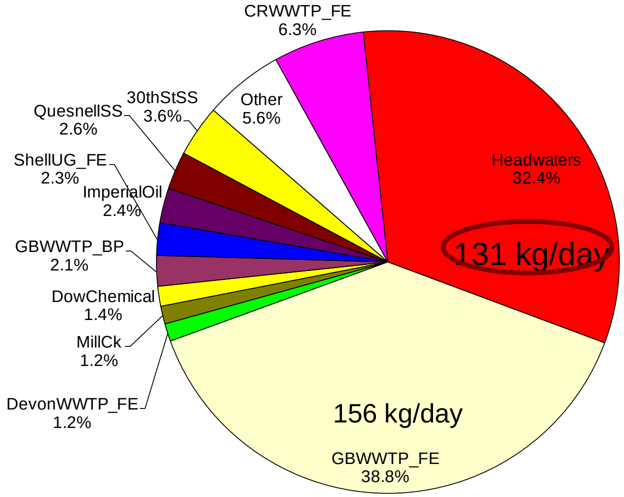
5) **Watershed (basin-scale) Model (hydrologic / water quality)**
   (LSPC)

Diagram of instream NSR showing model domains

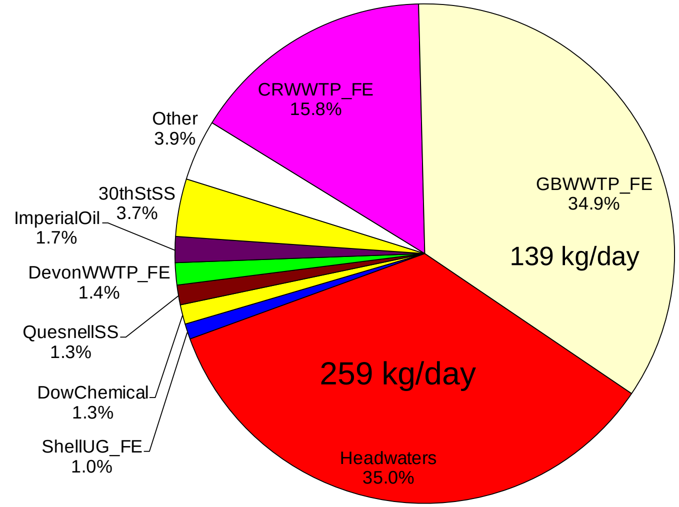




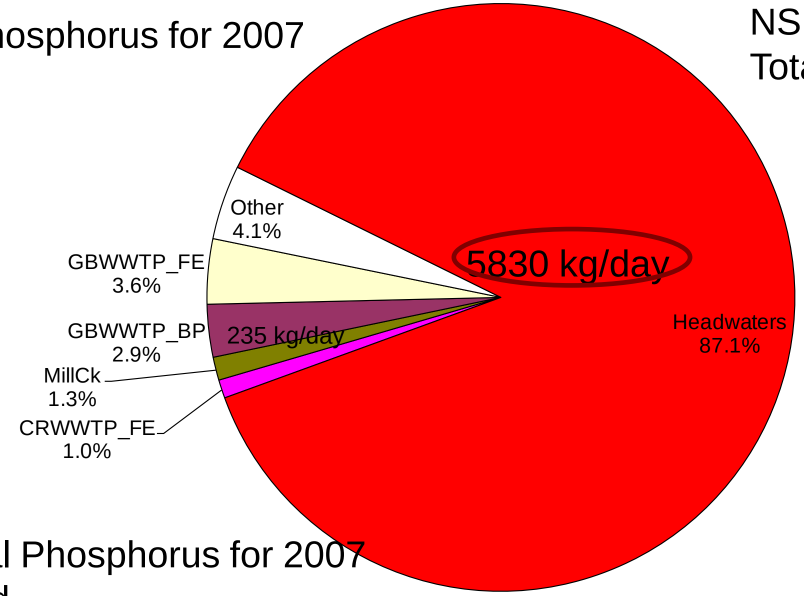
1). Contaminant Loading Calculations



NSR Fall Total Phosphorus for 2007
Total = 403 kg/d

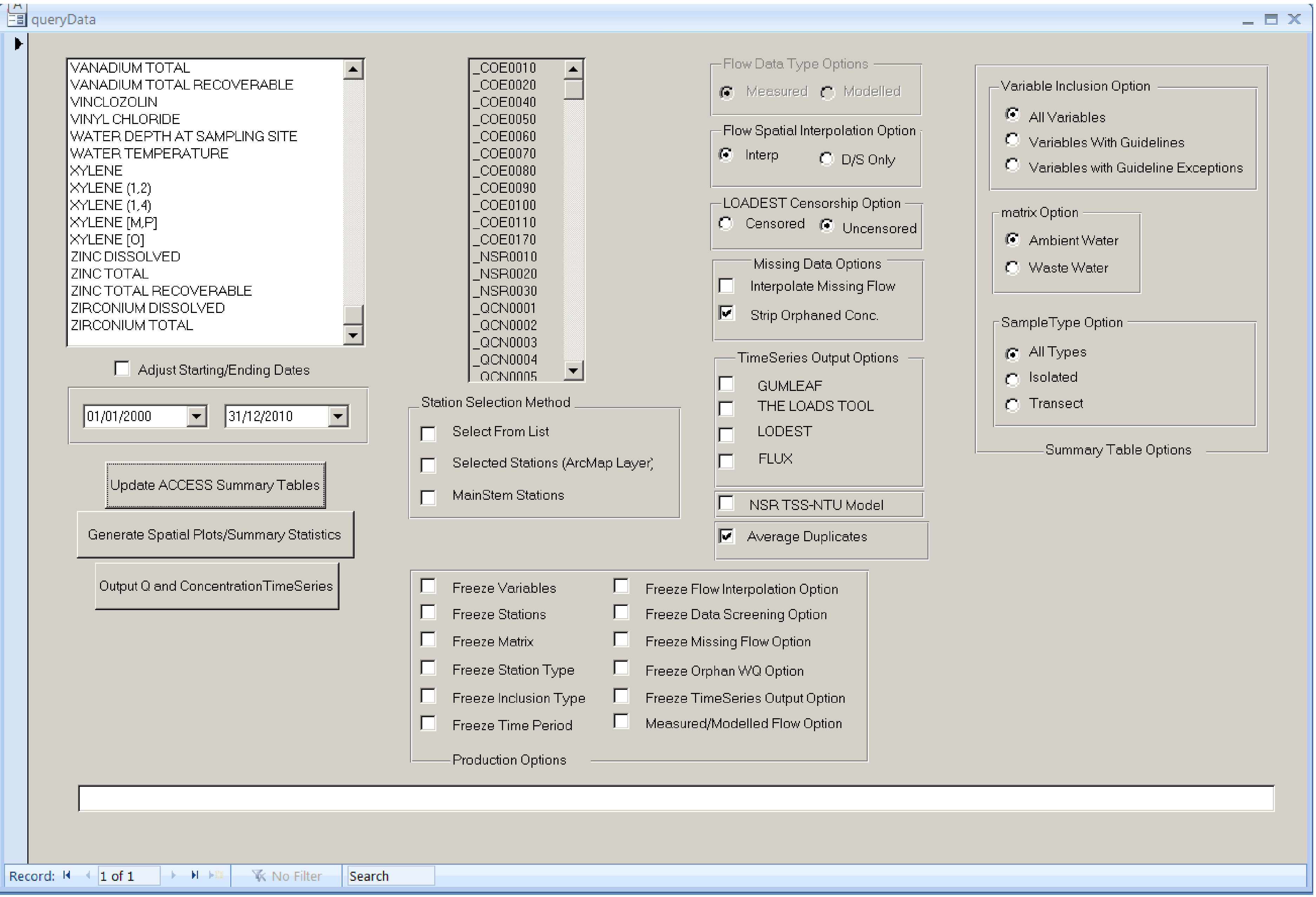


NSR Winter Total Phosphorus for 2007
Total = 398 kg/d



NSR Spring Total Phosphorus for 2007
Total = 6701 kg/d

NSR Load/Loading Calculations: Database User Interface



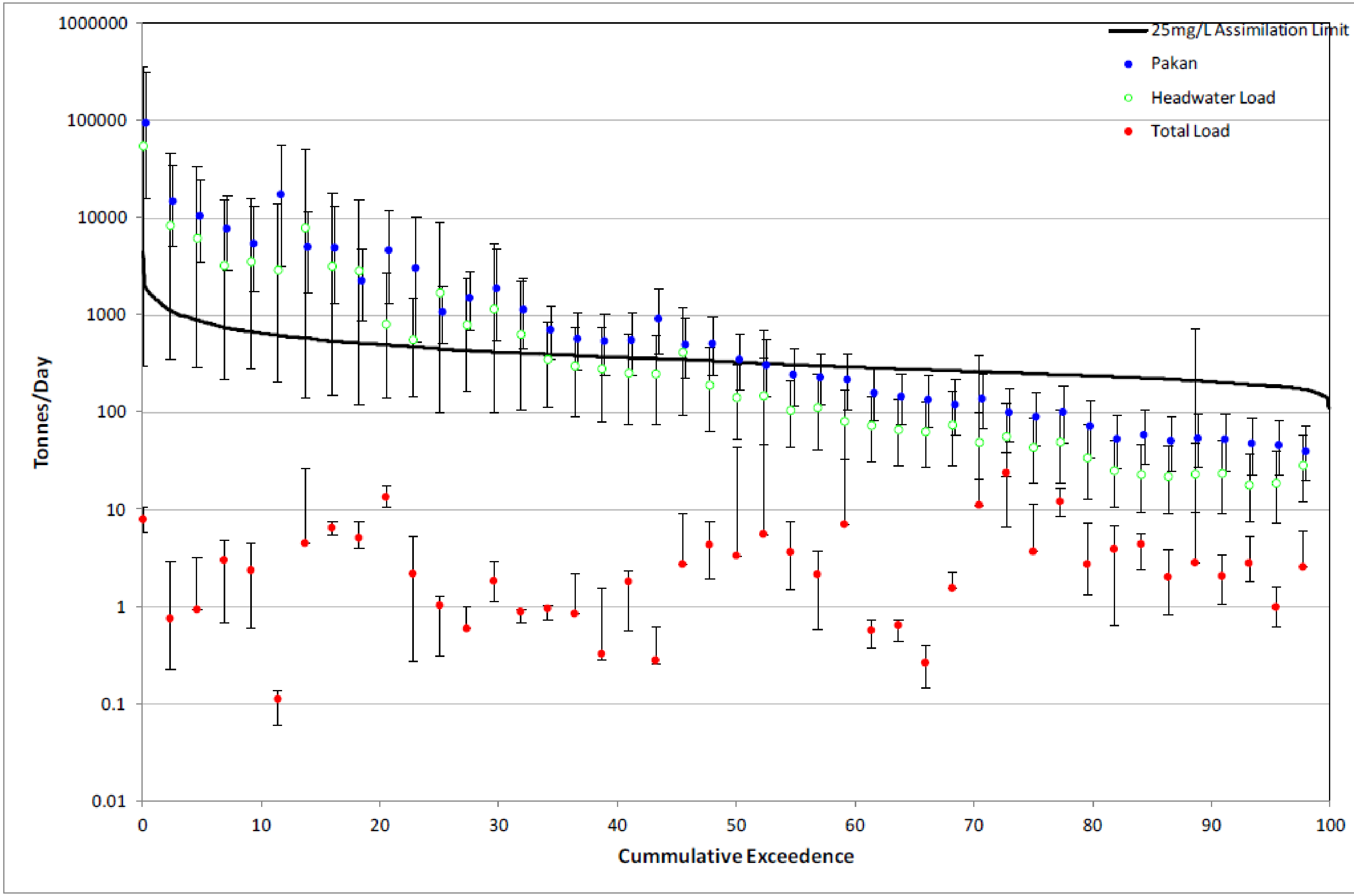
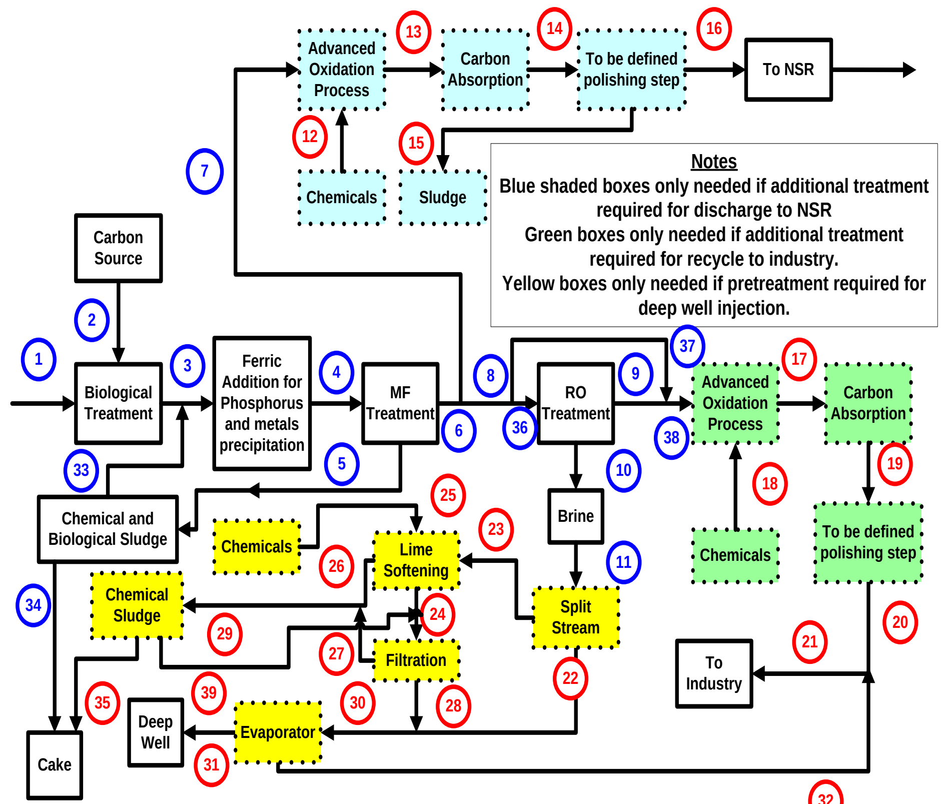


Figure 7 Example Load Duration Curve Based on Ambient Objective of 25 mg/L

2). Model for Evaluation of Industrial Water Supply and Wastewater Treatment.

- A Mass Balance Model (MBM) was developed to predict effluent loads discharged to the NSR for various wastewater management scenarios.
- The MBM applies optimal treatment processes to predict progressive reduction of contaminant load for the individual dischargers at a ten year time step.
- Output was incorporated in a TBL to evaluate socio-economic factors associated with various treatment scenarios.

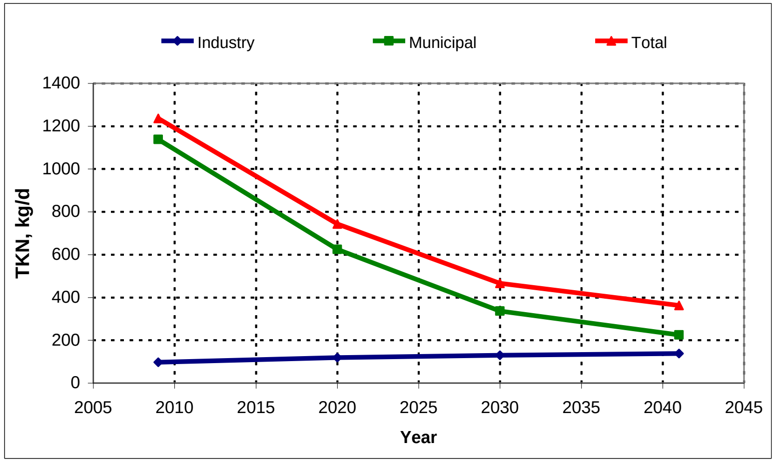


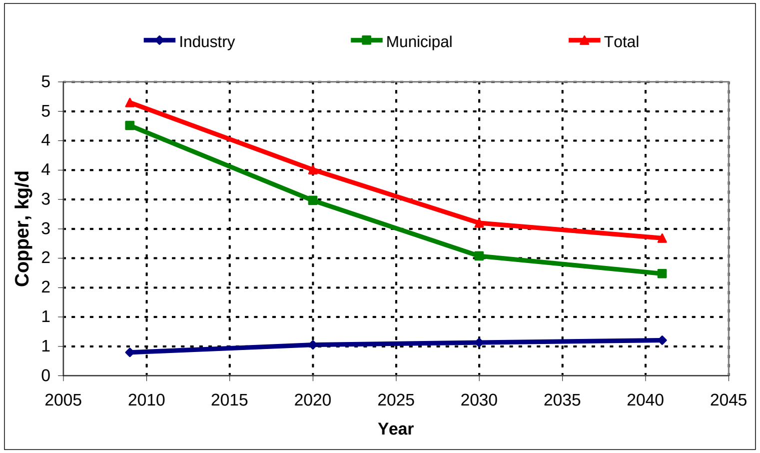
Industrial Wastewater Treatment Module

Mass Balance Model:

- Scenarios were selected based on TBL (triple bottom analysis) for assessment of load changes at temporal scale on the water quality of the North Saskatchewan River.

- The scenarios projected load reduction of nutrients and other constituents (e.g., metals, some organics) to the Year 2041.





3) CORMIX (Cornell Mixing Zone Expert System Model)

Why use a near-field model?

- A long list of Variables of Concern (VOCs) was included in the Mass Balance Model (>100).

-To enable inclusion of a practical number of VOCs in river modelling and WQO development, CORMIX was applied to screen and optimize the list.

-Screening was based on:

- *benchmark exceedences for WQ at mixing zone boundaries during 7Q10 flows, and:*
- *the occurrence of substantial differences between water quality values for Devon (u/s) and Pakan (d/s).*
- *effluent/ambient concentration ratios for various flow regimes*

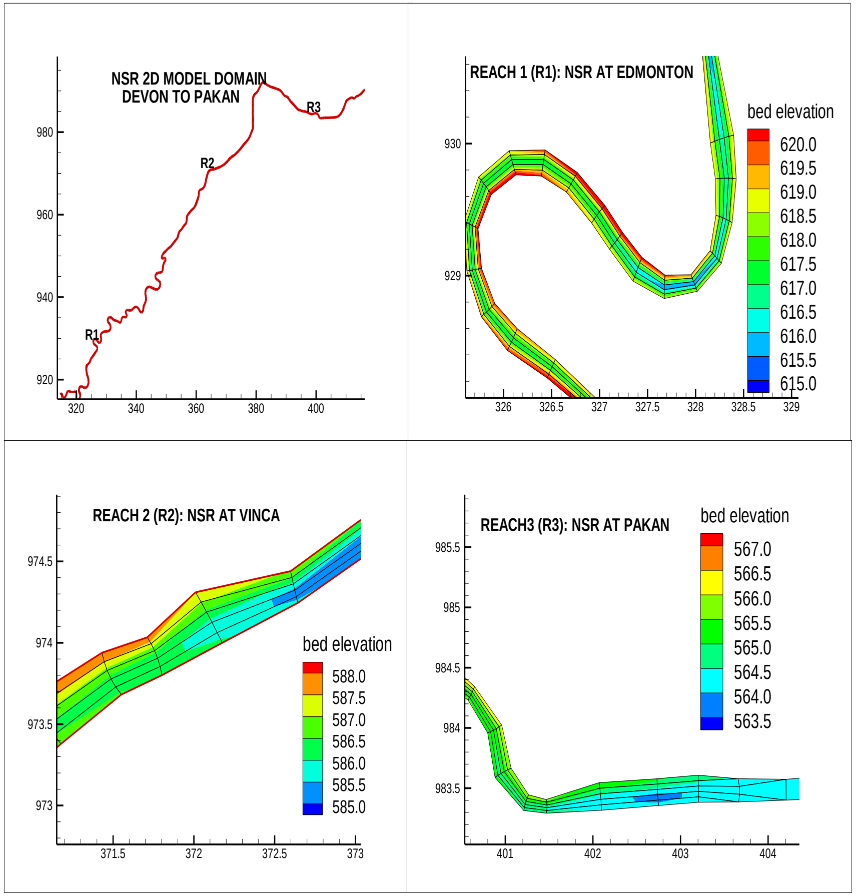
Near-field Screening Matrix: constituents flagged for further evaluation.

Benchmark Exceedence at Mixing Zone Boundary*

Variable	Scenario 1a	Scenario 1b	Scenario 2a	Scenario 2b	Scenario 3	Devon -> Pakan Δ median
Physical						
Total Suspended Solids	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.6
Nutrients and related						
Ammonia - N	10[ab],20[ab],30[a],40[a]	10[ab],20[ab],30[a],40[a]	10[ab],20[ab],30[a],40[a]	10[ab],20[ab],30[ab],40[a]	10[ab],20[ab],30[ab],40[a]	2.8
NO2+NO3 - N	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[a]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[a]	3.8
Phosphorus - Total	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[a],40[a]	10[ab],20[ab],30[a],40[a]	10[ab],20[ab],30[a],40[a]	3.1
Total Organic Carbon	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.2
Bacteria						
E. coli	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[a]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	2.0
Salts						
Sodium	20[b],30[b],40[b]	20[b],30[b],40[b]	10[b]			2.1
Chloride	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[a]	3.8
TDS	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.1
Metals						
Aluminum	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.5
Antimony	20[b]	20[b]				1.5
Beryllium	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b],20[b]	20[b]	10[b],20[b]	0.9
Cadmium	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.6
Copper	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.4
Fluoride	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	1.2
Lead	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.7
Manganese			10[b]		10[ab]	1.6
Mercury	10[ab],20[ab],30[a],40[ab]	10[ab],20[ab],30[a],40[ab]	10[ab],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[ab],20[ab],30[a],40[a]	1.2
Molybdenum	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b]			1.6
Nickel	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b]	10[b]	10[b],20[b]	2.9
Selenium	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[a],30[ab],40[a]	10[ab],20[a],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	1.7
Silver	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab]	20[ab]	10[ab],20[ab],30[ab],40[b]	1.9
Thallium	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b]	10[b]	10[b],20[b]	1.4
Tin	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b]		10[b]	2.4
Zinc	10[ab],20[ab],30[a],40[a]	10[ab],20[ab],30[a],40[a]	10[a],20[a]	10[a],20[a]	10[a],20[a]	1.6
Organics						
Chloroform	10[ab],20[ab],30[b],40[b]	10[ab],20[ab],30[b],40[b]	10[b],20[ab]	10[b],20[ab]	10[b],20[ab],30[b]	0.2
Phenol	10[ab],20[b],30[b],40[b]	10[ab],20[b],30[b],40[b]	10[b],20[b],30[b]	10[b],20[b],30[b]	10[b],20[b],30[b]	nd
Trihalomethanes	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b]	10[b]	10[b],20[b],30[b]	0.1

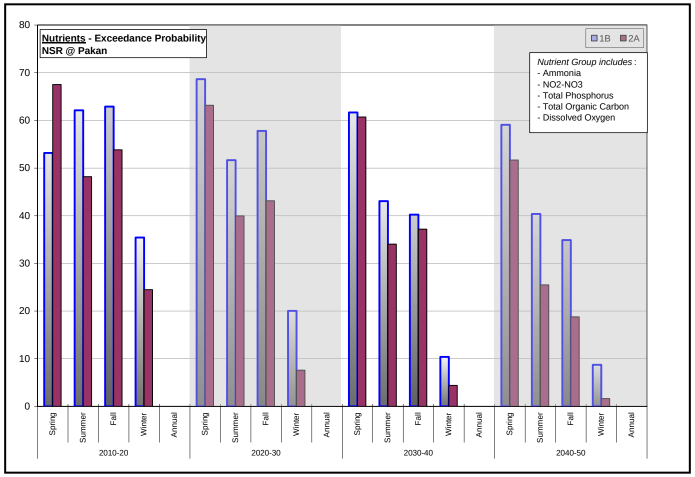
4). NSR River Water Quality and Hydrodynamic Model (EFDC)

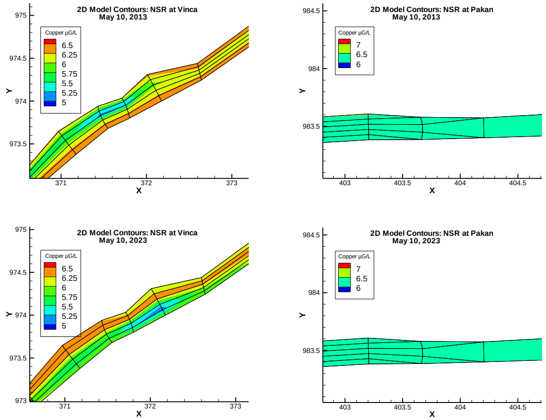
- Platform is “EFDC”, a hydrodynamic water quality model developed and supported by the USEPA/DSI.
- Represents lateral (cross channel) and longitudinal (along channel) processes and primary producer response (algae, macrophytes).
- The model includes tributary inflow, and all significant point discharges (WWTPs, CSOs, industrial facilities, and WTPs). There are ~ 40 discharges included.



Evaluation of Industrial Water Supply and Wastewater Treatment Scenarios (to 2041): Instream Modelling

- Model results were evaluated by:
  - Statistical comparison of model results, considering predicted departures from water quality benchmarks; and
  - Spatial plots of predicted concentration.
- The statistical comparison of model results is based on an exceedance score that includes scope, frequency and amplitude.
- Example spatial plots show the highest instream concentrations associated with effluent predicted at 7Q10 flows.



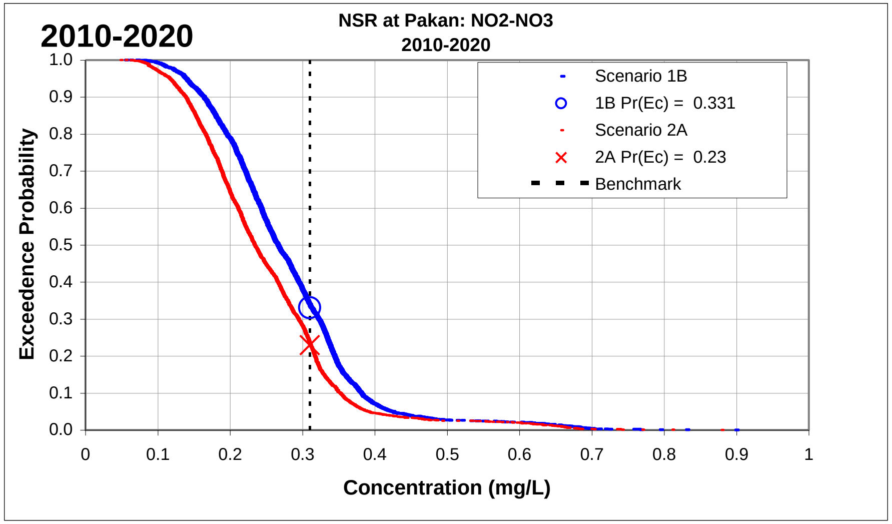


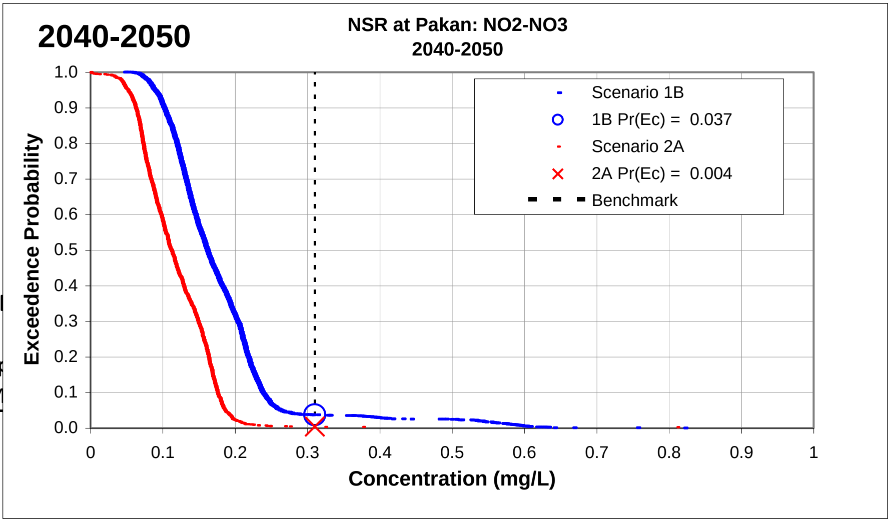
Exceedence Probability Calculation Sheet

Parameter: ***NO2-NO3 at Pakan*** mg/L

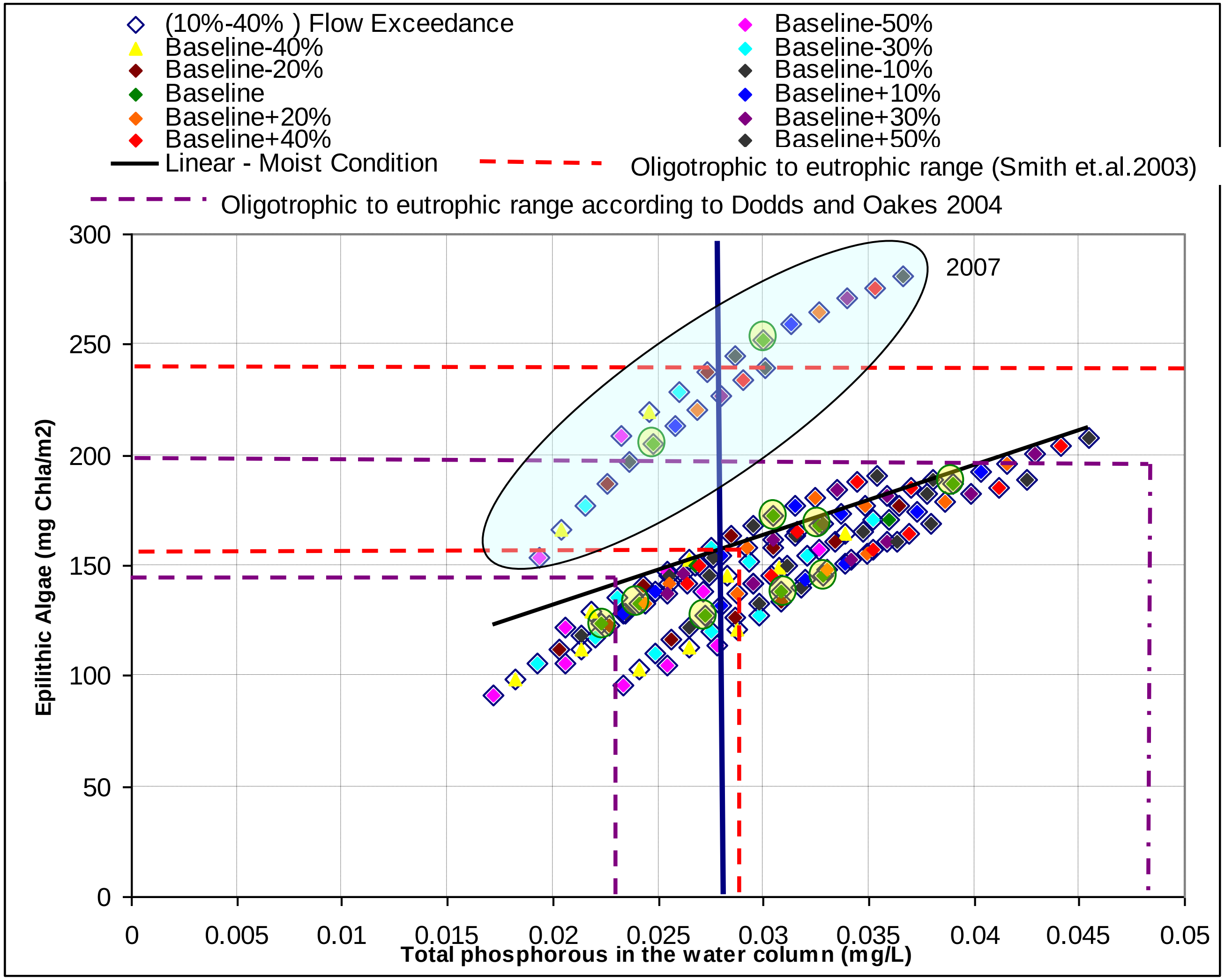
	Annual	Spring	Summer	Fall	Winter
Guideline Value =	0.31	0.098	0.098	0.098	0.31

Period	Season	Scenario 1B	Scenario 2A
2010-2020	Spring	**1B $Pr_{(Ec)}$ = 0.9**	**2A $Pr_{(Ec)}$ = 0.895**
	Summer	**1B $Pr_{(Ec)}$ = 0.878**	**2A $Pr_{(Ec)}$ = 0.823**
	Fall	**1B $Pr_{(Ec)}$ = 0.99600**	**2A $Pr_{(Ec)}$ = 0.98**
	Winter	**1B $Pr_{(Ec)}$ = 0.685**	**2A $Pr_{(Ec)}$ = 0.502**
	Annual	**1B $Pr_{(Ec)}$ = 0.331**	**2A $Pr_{(Ec)}$ = 0.23**
2020-2030	Spring	**1B $Pr_{(Ec)}$ = 0.893**	**2A $Pr_{(Ec)}$ = 0.878**
	Summer	**1B $Pr_{(Ec)}$ = 0.82600**	**2A $Pr_{(Ec)}$ = 0.693**
	Fall	**1B $Pr_{(Ec)}$ = 0.987**	**2A $Pr_{(Ec)}$ = 0.95**
	Winter	**1B $Pr_{(Ec)}$ = 0.143**	**2A $Pr_{(Ec)}$ = 0.026**
	Annual	**1B $Pr_{(Ec)}$ = 0.085**	**2A $Pr_{(Ec)}$ = 0.925**
2030-2040	Spring	**1B $Pr_{(Ec)}$ = 0.878**	**2A $Pr_{(Ec)}$ = 0.457**
	Summer	**1B $Pr_{(Ec)}$ = 0.73400**	**2A $Pr_{(Ec)}$ = 0.303**
	Fall	**1B $Pr_{(Ec)}$ = 0.95000**	**2A $Pr_{(Ec)}$ = 0.454**
	Winter	**1B $Pr_{(Ec)}$ = #N/A**	**2A $Pr_{(Ec)}$ = #N/A**
	Annual	**1B $Pr_{(Ec)}$ = 0.038**	**2A $Pr_{(Ec)}$ = 0.005**
2040-2050	Spring	**1B $Pr_{(Ec)}$ = 0.871**	**2A $Pr_{(Ec)}$ = 0.354**
	Summer	**1B $Pr_{(Ec)}$ = 0.672**	**2A $Pr_{(Ec)}$ = 0.063**
	Fall	**1B $Pr_{(Ec)}$ = 0.923**	**2A $Pr_{(Ec)}$ = 0.211**
	Winter	**1B $Pr_{(Ec)}$ = #N/A**	**2A $Pr_{(Ec)}$ = #N/A**
	Annual	**1B $Pr_{(Ec)}$ = 0.037**	**2A $Pr_{(Ec)}$ = 0.004**





Probability of Exceedence
= # failed tests/total number of tests



Modelled relationship between substrate algal abundance and TP (mean value of untransformed, response and explanatory variables, for incremental ten percentile flow exceedence), under moist conditions, for the North Saskatchewan River at Pakan (2005-2008).

5). NSR Watershed Model Development and application (LSPC):

- Work is ongoing to integrate with instream river model

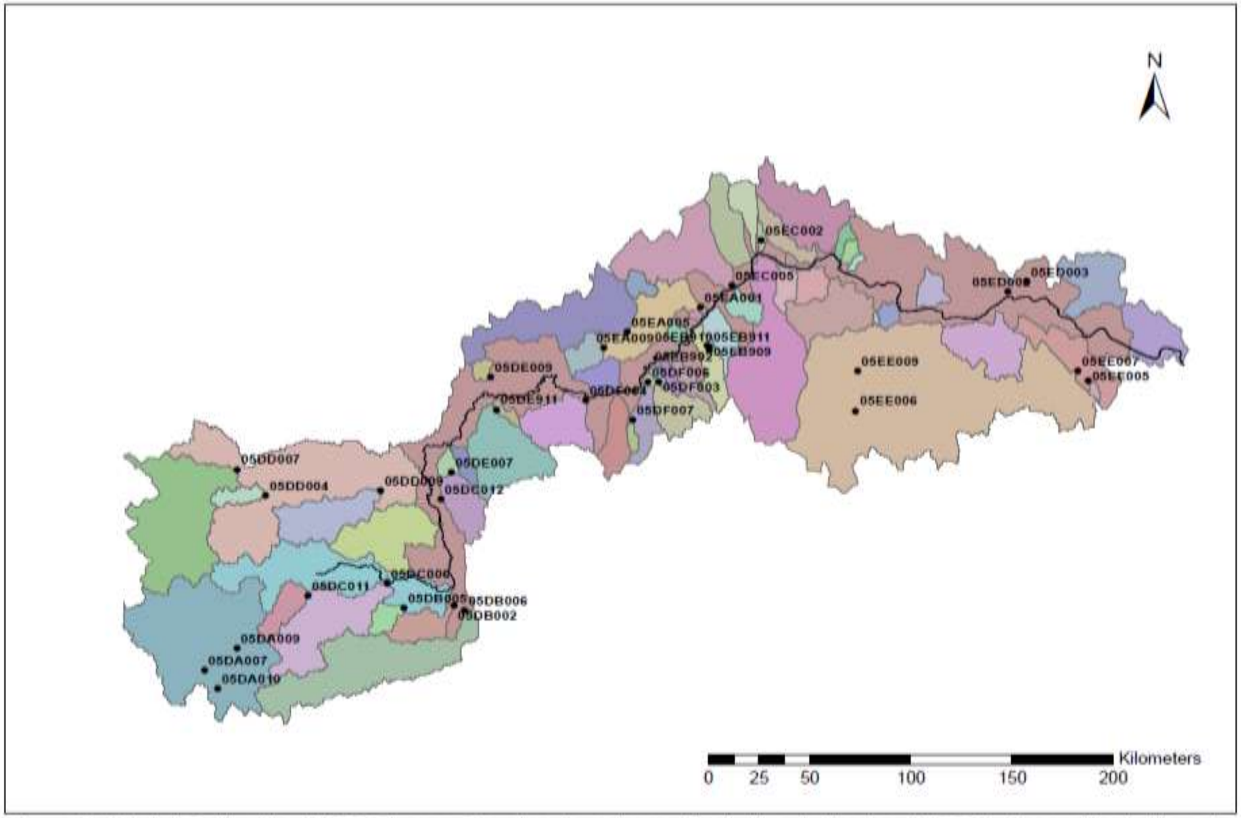


Figure 7. Model Calibration WSC Stream Gauging Locations. Black Line Indicates EFDC Instream Model Location

Seasonal TSS synoptic sampling on the NSR for 2008

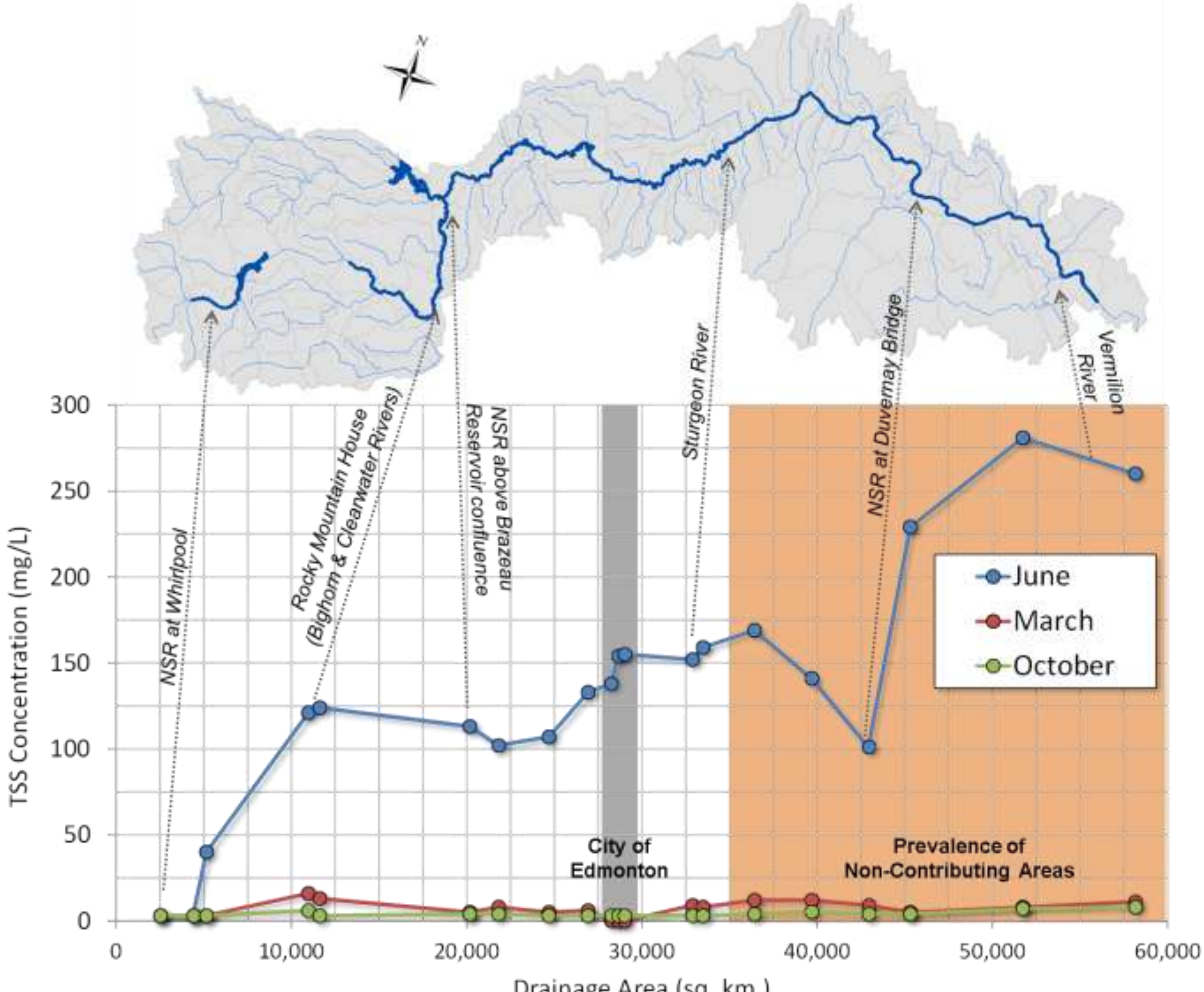
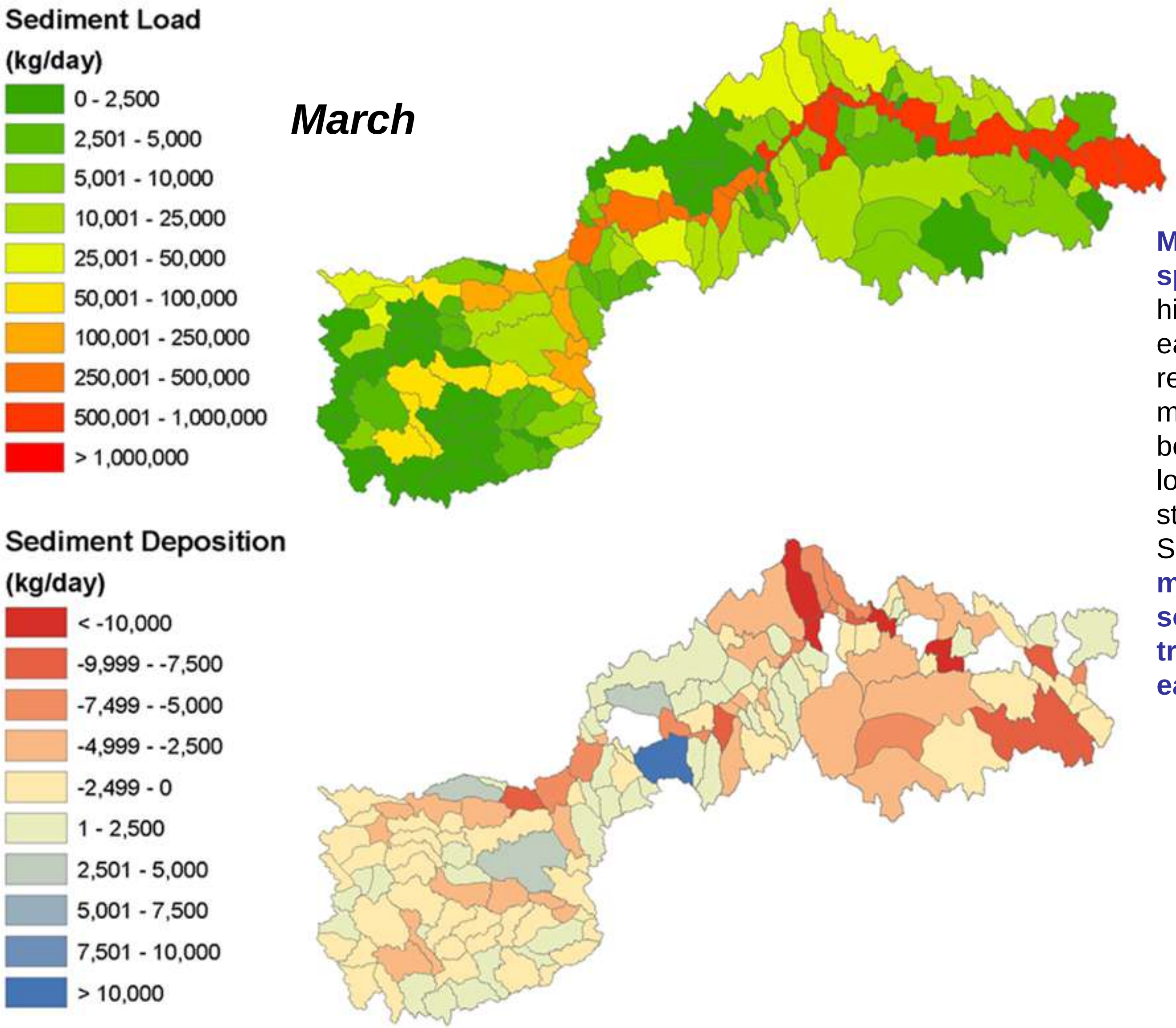


Table 3-4. Summary of seasonal flow patterns in NSR tributaries, sorted by average elevation

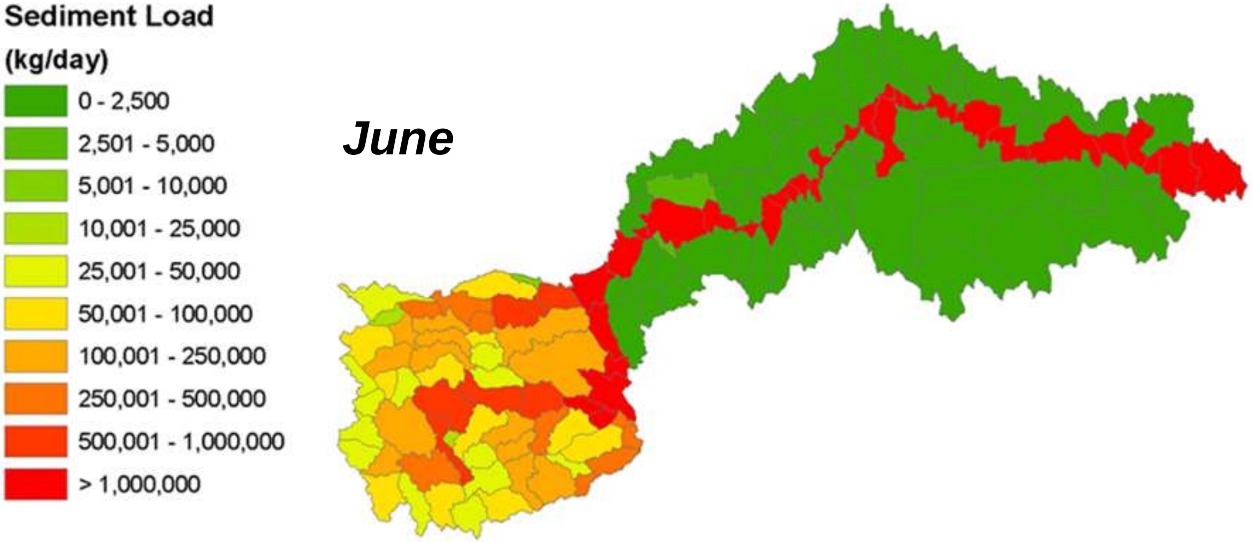
NSR Tributary		Average Elevation (m)	Percent NCA	Peak Flow Month	Percent of Observed Annual Flow	
Name	Gage ID				March-**April**-May	May-**June**-July
Ram River	05DC006	1,807	0.0%	June	20%	61%
Clearwater River	05DB006	1,731	0.0%	June	19%	51%
Baptiste River	05DC012	1,106	0.010%	June	30%	58%
Rose Creek	05DE007	974	0.004%	May	49%	62%
Modeste Creek	05DE911	893	0.0%	April	63%	50%
Tomahawk Creek	05DE009	799	0.0%	April	72%	41%
Strawberry Creek	05DF004	798	0.19%	April	71%	47%
Sturgeon River	05EA001	715	27%	April	82%	37%
Vermillion River	05EE009	673	77%	April	84%	41%
Vermillion River	05EE007	666	74%	April	96%	17%
Waskatenau Creek	05EC002	664	37%	April	92%	14%
Redwater River	05EC005	661	26%	April	90%	34%

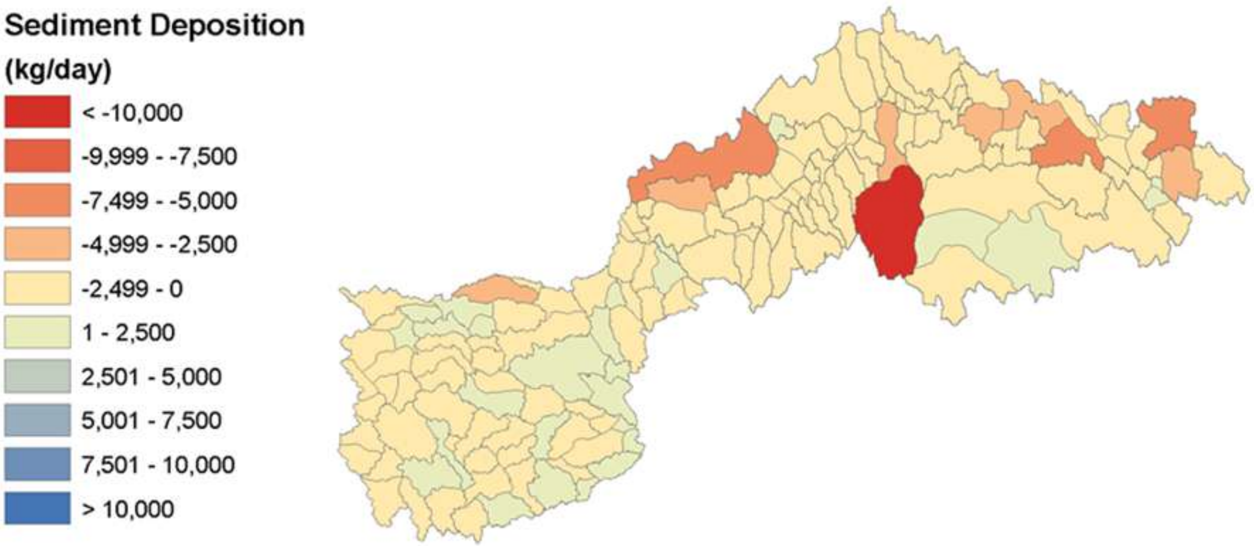
Modelled sediment loads (LSPC)



March => beginning of the spring snowmelt; note slightly higher sediment loading in the eastern portion of the watershed relative to the higher elevation mountain regions. Also the beginning of a pronounced loading increase in the lower stretches of the NSR mainstem. Sediment deposition map shows **mobilization of sediment from some lower elevation tributaries to the NSR where early snowmelt begins**.

Modelled sediment loads (LSPC)





June => peak sediment loads. The model shows that sediment yield reduces in the lower elevation watersheds where NCA is prevalent, but increases in the higher elevation watersheds where snowmelt occurs in the later part of the spring. However, there are some notable differences in the amount of sediment that is being transported through the tributaries.

Mainstem shows the highest transported sediment loads; it is the main conduit that connects the western mountain regions to the eastern prairie regions. **Net deposition is clustered around zero** (i.e. relatively small deposition and/or resuspension) during the month of June. This is because energy associated with the higher flows generally tends to keep sediment in suspension as it is transported downstream.

What are we capable of doing now?

- represent past and present conditions for river water quality
- can identify relative point and non-point source contributions (e.g., loads) to water quality and instream response
- can run "hypothetical" or predictive simulations of potential flow and pollutant loading scenarios

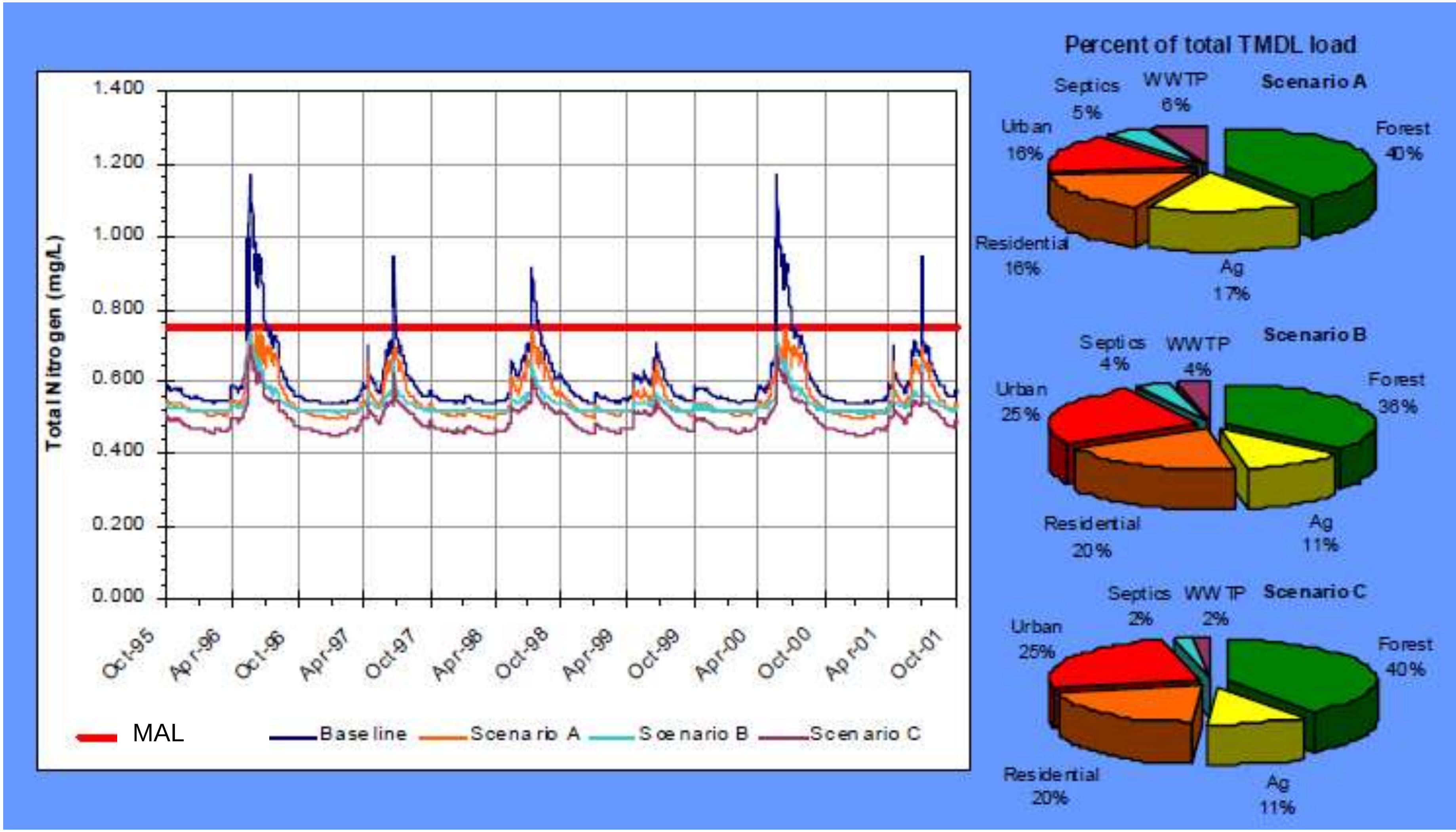
Ongoing Work and Next Steps:

- Continue to develop an integrated monitoring and reporting system (e.g., effluent: ambient) to better enable predictive evaluations in the NSR.
- Continue development of loading calculation tools, models, and related evaluations, for application in local and basin-scale assessment and future planning.
- Rationalize benchmarks (WQOs) with reference to effects.
- Watershed/regional planning initiatives will be able to use the model system, collaboratively.
- Test loading targets in the regulatory context (e.g., coordination of approvals).

Discussion

Allocation Scenarios

- Use modelling to represent different combinations of source reductions that meet water quality objectives



After TetraTech, 2009