Water resources management modelling for IWRM within Canada's large river basins

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Introduction

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Canada's large river basins have specific hydrological characteristics:

- River flow driven by 'Water Towers'
- Cold region hydrology – winter buildup of snowpack and spring melt

Canada generally has sufficient water; however, water resources are under threat:

- Climate change
- Increasing demand
- Pollution
- Fragmented management

Water management models

- Water resources planning and optimization – resolving problems involving conflicting objectives
  - Assurance of supply
  - Current and projected water requirements
  - User priorities and acceptable risks of non-supply
  - System operating rules
  - Scheduling of interventions
- Improving management of water for equitable water sharing during times of insufficient water supply – requires an integrated approach
- Modelling provides a testing environment for assessing the system under selected future scenarios

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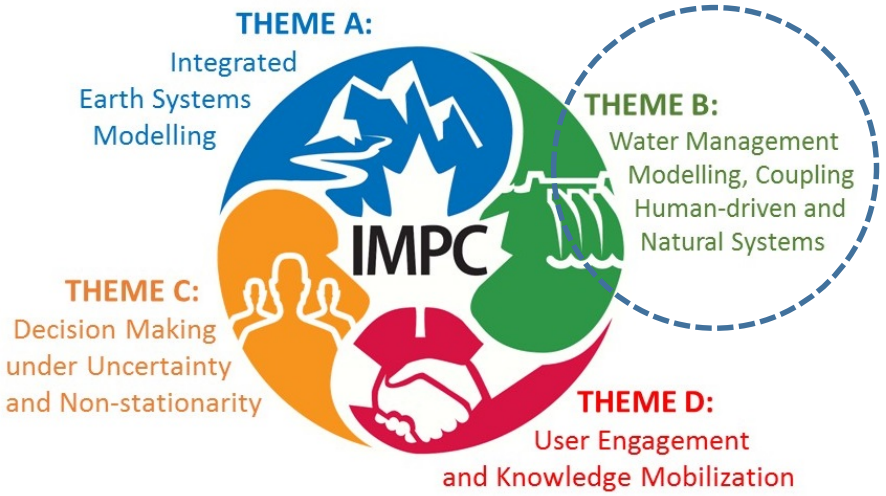
Aims of research

- IWRM is needed to manage Canada's large river basins
- IMPC- aims to deliver decision-making tools and solutions for achieving IWRM within Canada's major river basins
- Theme B: Investigating water management models for integration into a modeling framework: MESH
- Initial application to the Saskatchewan River Basin (SaskRB)
- Operating policy of the SaskRB guided by the WRMM application
- Multi-model assessment approach taken



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Initial assessment of models

#	1	2	3	4	5	6	7	8
Program Name	WEAP	MIKE HYDRO Basin	Colorado DSS	WRMM	RiverWare	HEC-ResSim	FreeWAT	SWAM
Price	$250 - $1000 US Dollars / 2yrs	$380 CAD + applicable charges (shipping, etc)	FREE	Not available for public use	$2360 - $4160 US Dollars / yr	FREE	FREE	Not available for public use
Allocation Algorithm	Prioritized (lp-solve)	Prioritized, Fract. of flow (1. p.68)	Prioritized, MDSA algorithm (1.p.10)	Prioritized, Out-of-Kilter algorithm (p.1-2)	Flexible Rule-based allocation, CPLEX (p. 5)	Only Release Allocation, (2.p.11-82)	Surface/Ground- water rights (3.p.13,3.p.18)	Colorado DSS MDSA algorithm (p. 3-1)
Time step	1 – 365 days	Seconds (1.p.3)	Daily & monthly (1.p.5)	1-365 days (p.1-7)	Hourly to yearly (p. 3)	TBD	TBD	Monthly (p. 1-1)
Demand Sites	Agriculture, Urban, Industry, etc.	Agriculture, Urban, Industry, etc (1. p.101)	Agriculture, Urban, Industry, etc	Agriculture, Urban, Industry, etc (p.1-5)	General water users (p. 1460)	N/A	Irrigation	Agriculture, Urban, Industry (p.2-5, p.2-10)
GUI	YES	YES	YES	YES	YES	YES	YES based on QGIS	YES basen on MS Excel
API	YES	YES (3)	N/A	N/A	RCL (p. 1)	YES (only internal)	N/A	N/A
Scenario Analysis	YES	YES (2. p.7)	YES (2.p.7)	N/A	YES (p. 1)	YES (2.p.13-i)	N/A (1.p.13)	N/A
Rainfall-Runoff Modeling	Simp. FAO, MABIA, PGM, SMM	NAM, UHM[1] (1. p.49)	N/A	N/A	N/A	N/A	N/A	N/A
Irrigation Demand	Based on FAO56	FAO 56 (1. p.109)	ASCE Pen-Mont (2.p.3)	Jensen-Haise eq. (p. c-2)	N/A	N/A	[probably] FAO 56 (1.p.56)	Blaney Criddle eq. (p. 2-10)
Water Quality Modeling	DO, BOD, Temp. Link to Qual2k	BOD, DO, NH4, NO3, P, user defined, (1. p165)	N/A	N/A	DO, TDS, TDG, Temperature (p. 1)	N/A	N/A	N/A
Groundwater Modeling	Link to MODFLOW Link to MODPATH	Linear reservoir (1&2 aquifer) (1.p.50)	Link to MODFLOW (3.p.33)	N/A	N/A (p. 117)	N/A	MODFLOW* (1.p.iii)	N/A
Reservoir Operation	YES	YES (1. p.132)	YES (1.p.254)	YES (p.1-5)	YES (p. 1)	YES	N/A	YES (p. 2-3)
Financial Analysis	Simple Cost - Benefit	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Internal Scripting Interface	VBS, PHP, Ruby, Python, Perl, JS	N/A	Self-developed commands (3.p.227)	N/A	RiverWare Policy Language (p. 1)	Jython (2.p.14-49)	N/A	N/A
Hydropower Modeling	YES	YES (1. p.147)	N/A	YES (p.1-5)	YES	YES (2.p.11-44)	N/A	N/A
Calibration Algorithm	PEST Algorithm	SCE, PSE (2. p. 24)	TBD	N/A	N/A	YES but Unknown (2.p.14-39)	UCODE_2014 (6.p.21)	N/A
Input Data Format	Manual Time series, Excel/Delaminated text	.dfs0 and shapefiles (1.p.34, p.173)	ASCII (e.g.2.p.72)	ASCII (p.1-9)	TBD	HEC-DSS time series files (2.p.13-8)	ASCII, istSOS, .sqlite, MODFLOW inpt. (5.p.7)	N/A
Output Data Format	Graphical Maps, Time series (ASCII, Excel)	.dfs0 and shapefiles (1.p.38, p.175)	ASCII, graphics	ASCII (p.4-10)	ASCII, Excel, HTML, Graphics (p. 1)	ASCII, graphics (2.p.F-6, F-1)	Graphics, ASCII (3.p.120, 3.p.125)	N/A
GIS interface	YES	YES	YES	N/A	YES w/ Georef. (p. 15)	YES (1.p.6)	YES base on QGIS	N/A
Linked to other models before?	SWAT (1, 2, 3)	TBD	TBD	N/A	MODFLOW (1, 2)	HEC-HMS (1, 2) WEHY-HCM (1)	N/A	N/A
Automation	YES	YES	TBD	YES	YES (p. 1)	YES (2.p.14-49)	N/A	N/A
Languages Support by API	VB/S, C, Python, MATLAB , etc (COM)	Any .NET compatible prog. lang. (3.p.1)	N/A	N/A	N/A	Jython (only internal) (2.p.14-49)	N/A	N/A
Website	http://www.weap21.org	https://www.mikepoweredbydhi.com	http://cdss.state.co.us	http://www.unitechsolutionsinc.com	http://www.riverware.org	http://www.hec.usace.army.mil/	http://www.freewat.eu	https://cdmsmith.com
Reference(s)	WEAP Online Help	1. Hydro Basin Manual 2. Auto calibration Manual 3. Intrf. Prog. Guide	1. StateMod Manual 2. StateCU Manual 3. StateDGI Manual	WRMM Manual (Not available on internet)	RiverWare User Guide	1. HEC-Ressim Quick Start 2. HEC-ResSim Manual	FreeWAT Manuals (6 volumes)	SWAM Manual

Final choice of models

	WRMM	WEAP	MODSIM	WRIMS
Freeware	Not available for public use	$250–$1 000 for 2 year single license	Free	Free
Open source	No	No	No	Yes
Time step	1–365 days	1–365 days	15 minutes– 1 month	1 day or 1 month
GIS interface	No	Yes	Yes	No
Additional functionality	No	Rainfall-runoff, water quality, financial analysis	Link to external models	Linked to external DLLs- water quality, flow routing
Previously linked to other models	No	SWAT	SWAT, MESH, QUAL2K, GA, PSO, ANN	IWFM, CalLite, PRISM, APSIDE, DSM2-SJR
Automation	Yes	Yes	Yes	Yes

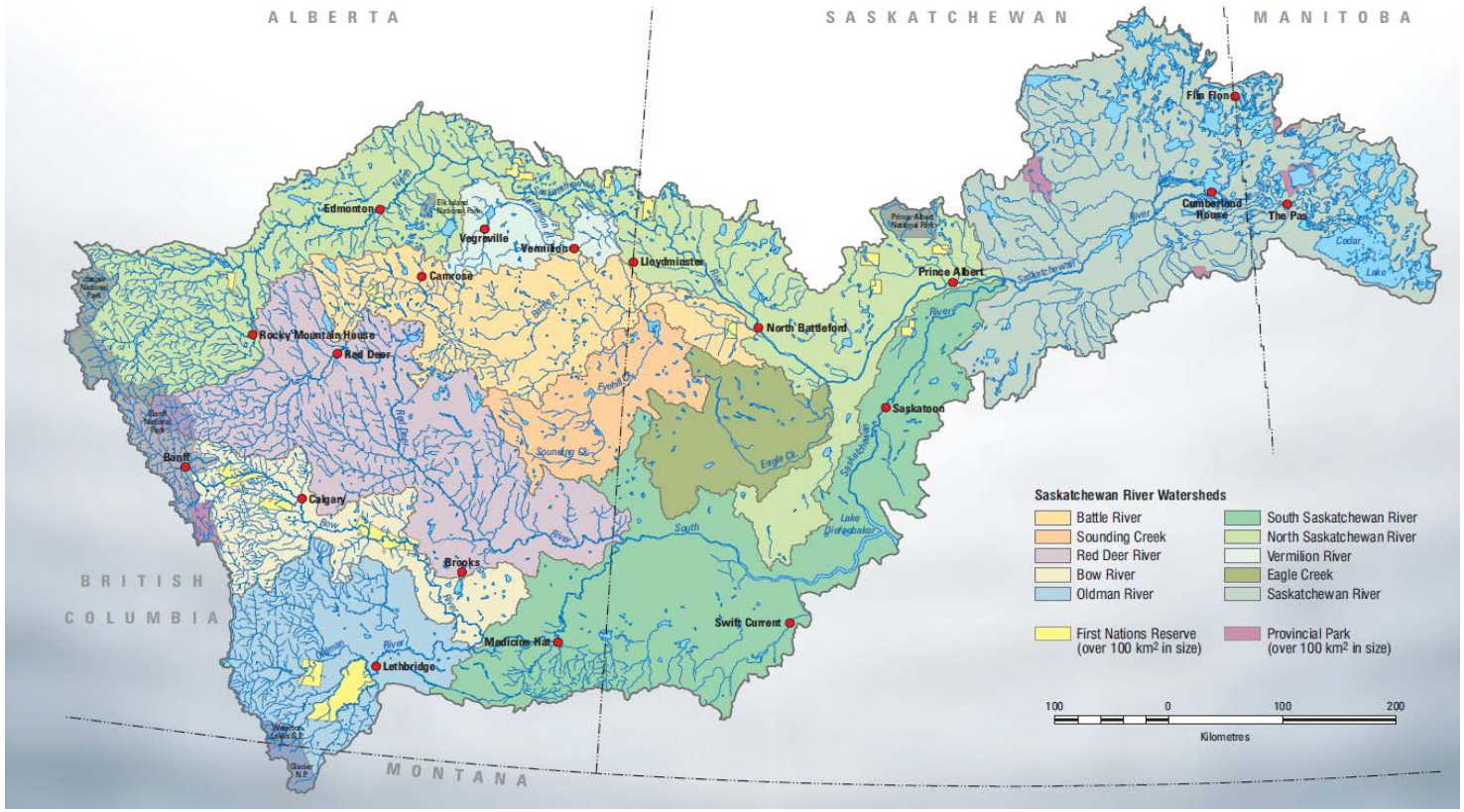
IMPC Water Management Modelling

- Kasra Keshavarz - WEAP: Integrated Water Resources Management of the Saskatchewan River Basin using WEAP

- Syed Mustakim Ali Shah- MODSIM: Application of a Network Flow Model for Integrated Water Resources Management in Saskatchewan River Basin

- WRIMS

Brief description of the SaskRB



Source: http://www.saskriverbasin.ca/pages/state_of_the_basin_report.html

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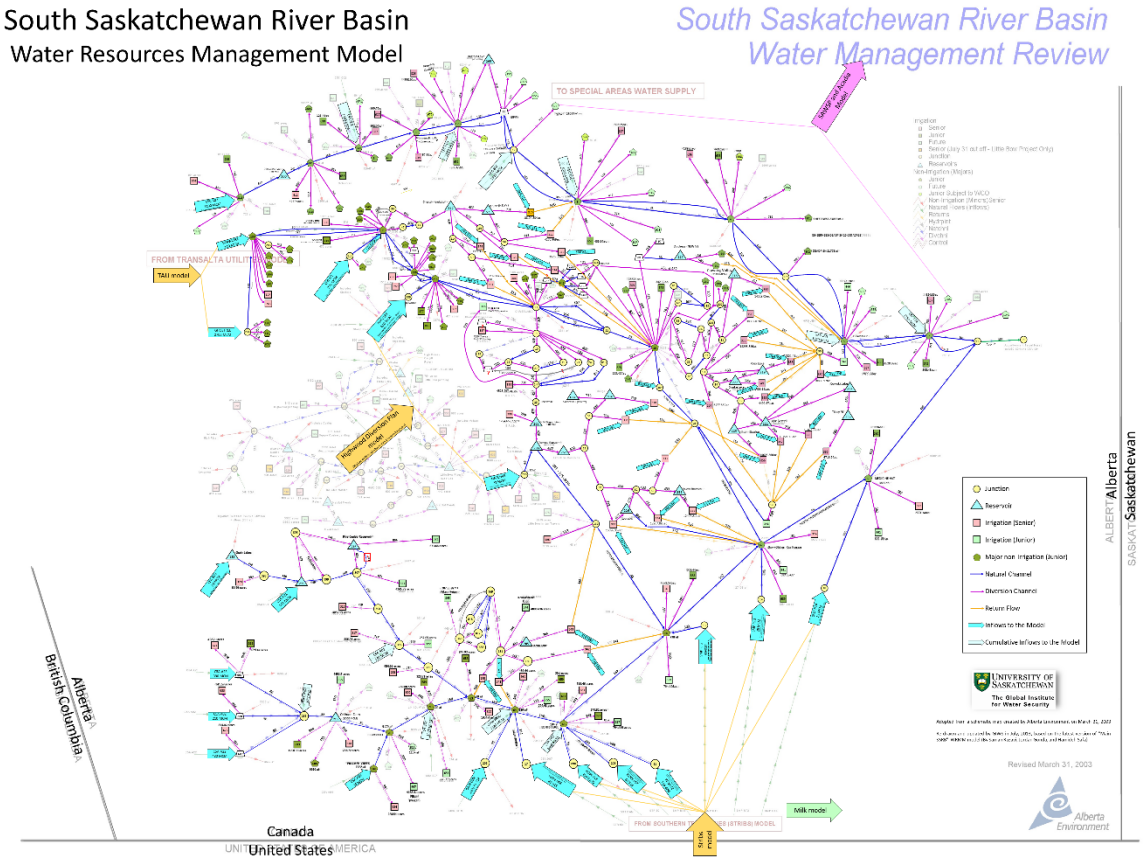
WRMM management of SaskRB

- Complex operating policy
- Large range of priorities of users
- Multiple relaxation zones in:
  - Reservoirs
  - Natural channels
  - Diversion channels
  - Apportionment channel
- Control structures
- Hydropower



Water Resources Integrated Modelling System (WRIMS)

- Generalised water management model for evaluating operational alternatives of large, complex river basins
- Developed by the Californian Department of Water Resources
- Used in the development of CALSIM – management model applied to California
- Uses Water Resources Simulation Language (WRESL) - for flexible operational criteria specification
- Licensed under the Eclipse Public License and includes an open-source CBC solver
- Good support and documentation
- Highly flexible

WRIMS

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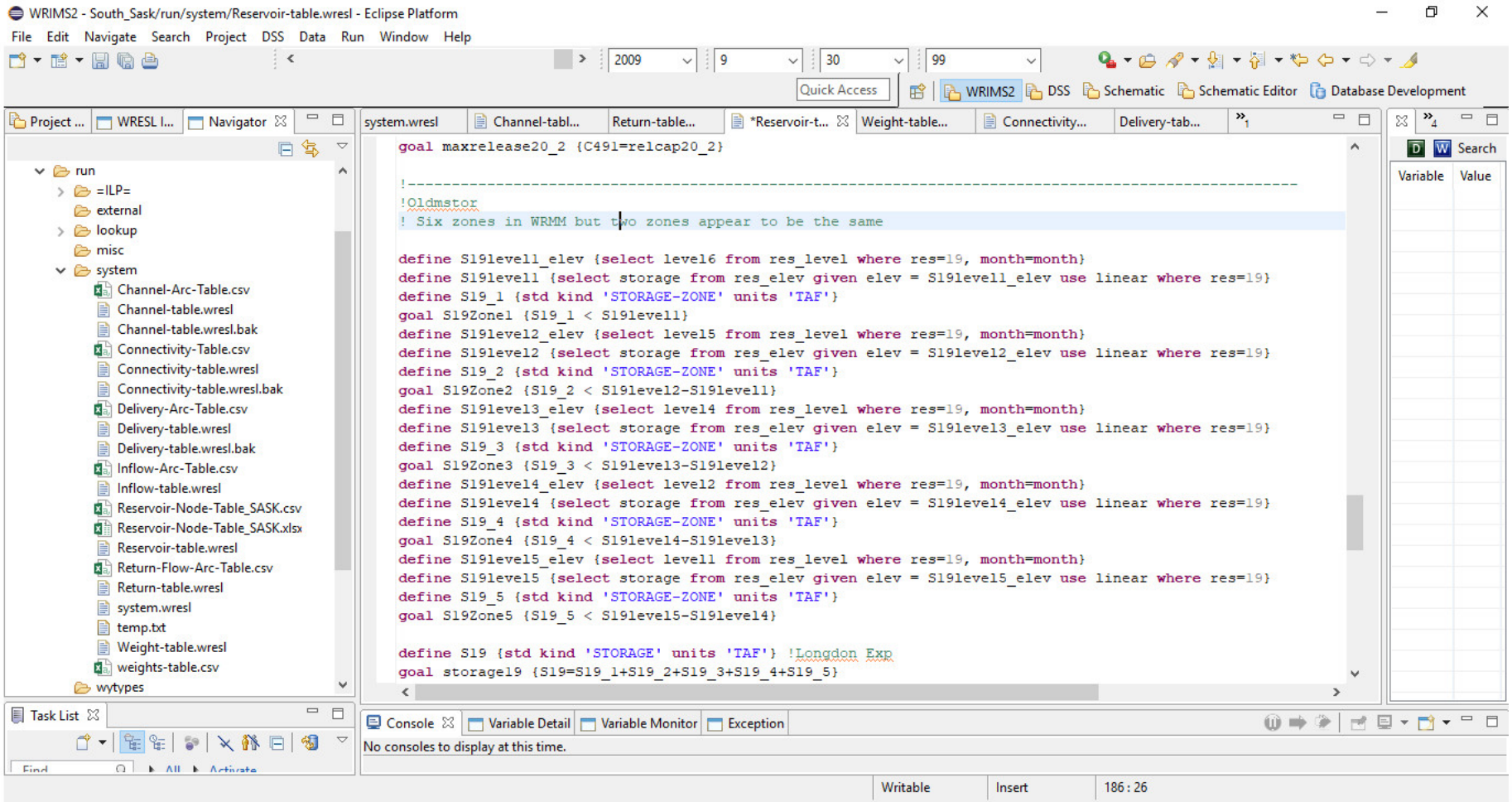

WRIMS flexibility

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- Can WRIMS represent the complex WRMM operating policy for SaskRB?
- Multiple operating zones for:
  - Reservoirs ✓
  - Natural channels ✓
  - Diversion channels ✓
- Unlimited priorities ✓
- Representation of the apportionment channel ✓
- Lookup tables
- Input of time series state variables
- Output of time series decision variables

} HEC-DSS files

- Debugging facilities
- Link to external DLLs

Some disadvantages of WRIMS

- Uses imperial units
- Monthly or daily time step
- No GIS interface – policy description through WRESL script
- Difficult to learn and easy to break – no safety net

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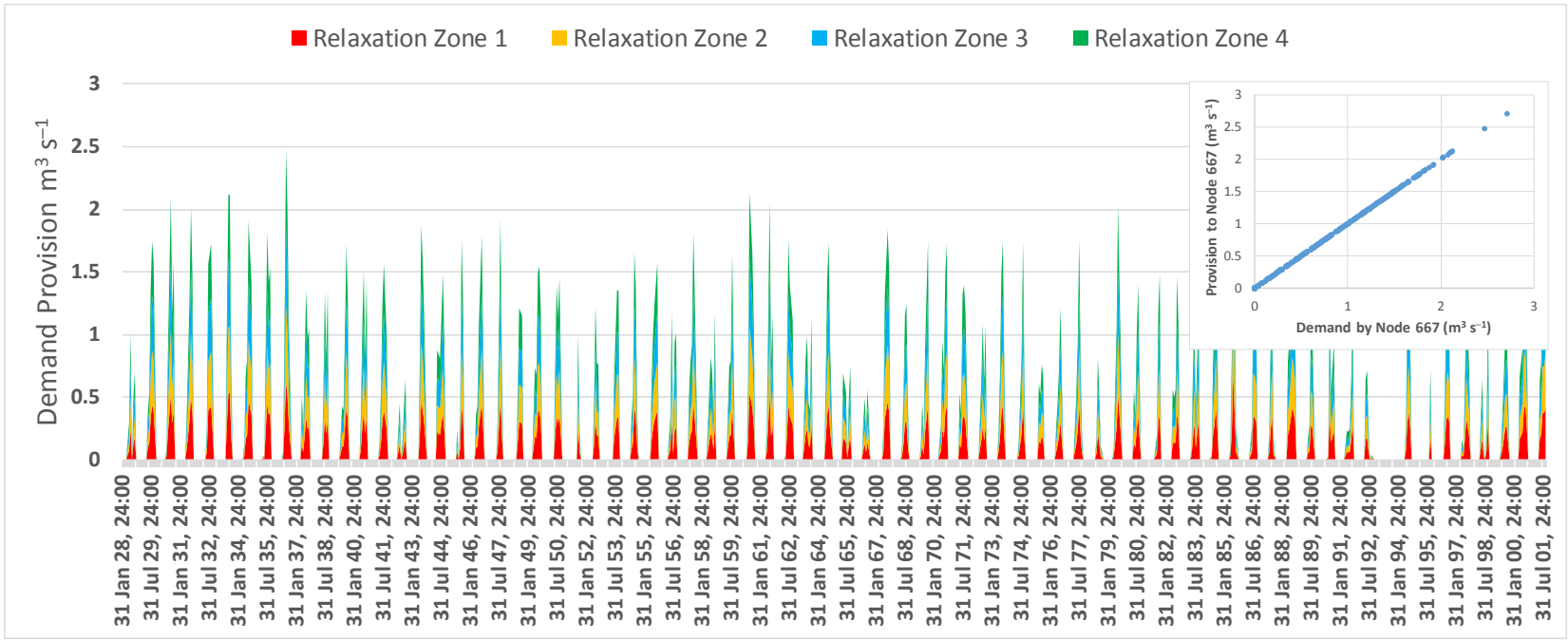
Some initial results for Alberta

Water to a irrigation demand node in Oldman tributary catchment:



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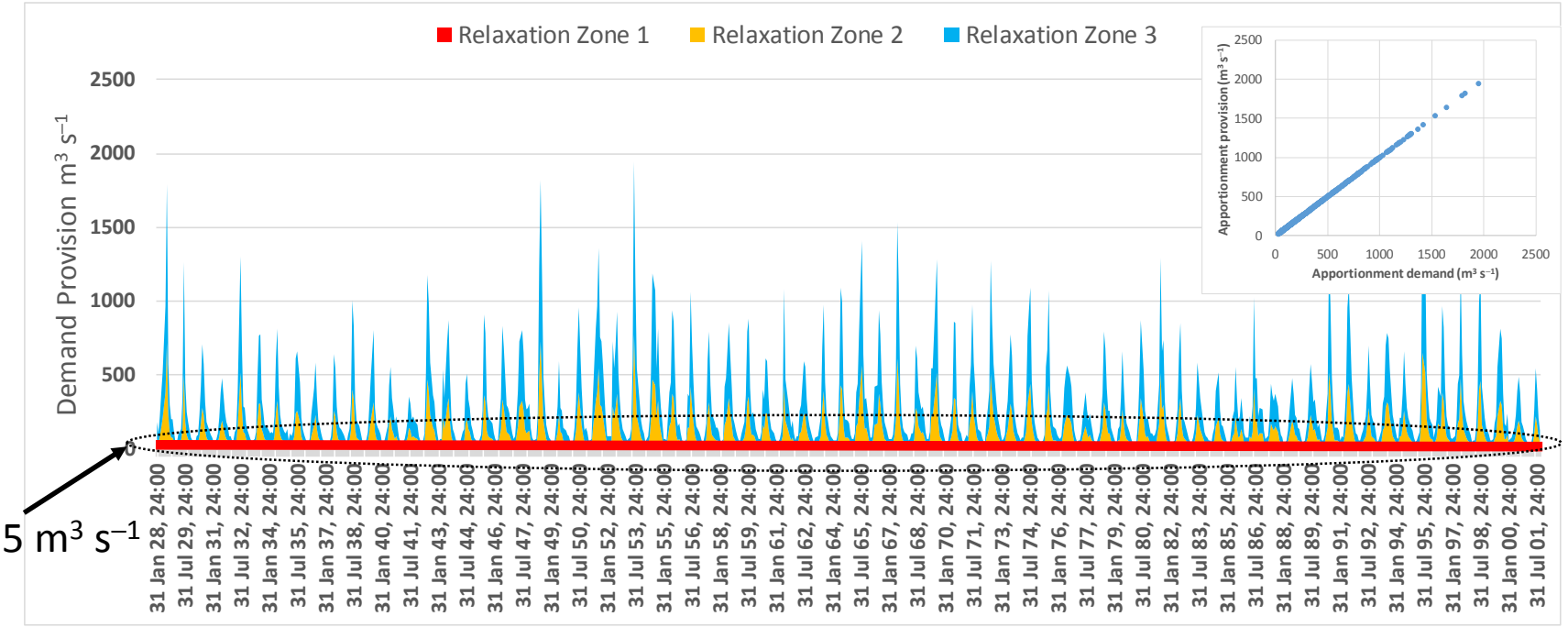
Some initial results for Alberta

Apportionment channel to Saskatchewan:



Conclusions

1. **WRIMS has good potential for inclusion into MESH**

2. **Sufficiently flexible to represent complex operating policies**

3. **Some current limitations such as units**

Future work

- **For all models under future scenarios in the SaskRB:**
  - **Applying the models to the entire SaskRB**
  - **Achieving equitable sharing of water**
  - **Viability of the current transboundary apportionment agreements**
  - **Meeting future irrigation demands**
- **Integration of models into a hydrological framework**

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