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High River

Groundwater modelling study for sustainable water management in Town of High River

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WaterTech, April 12, 2013

EcoNomics

Acknowledgements

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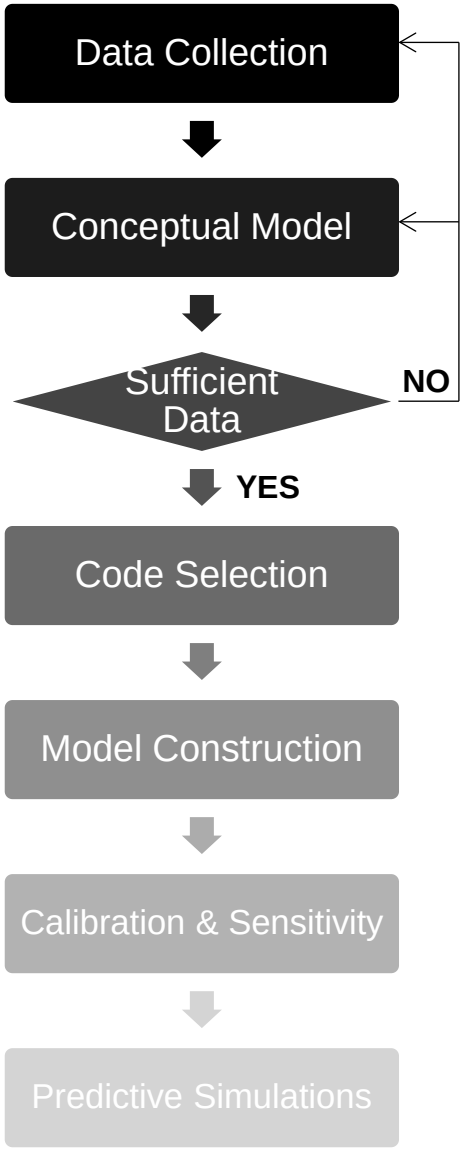
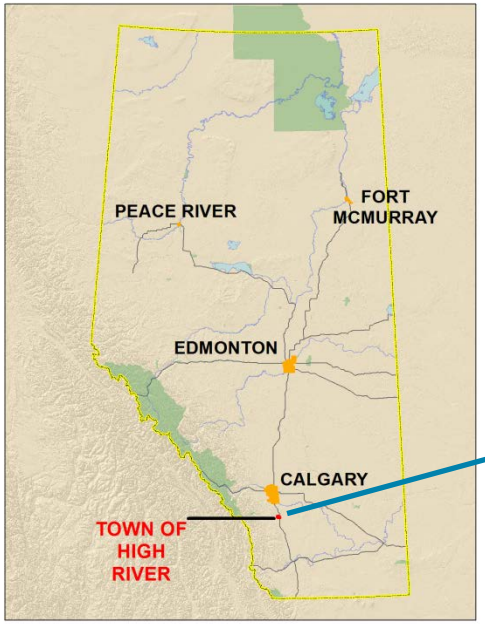
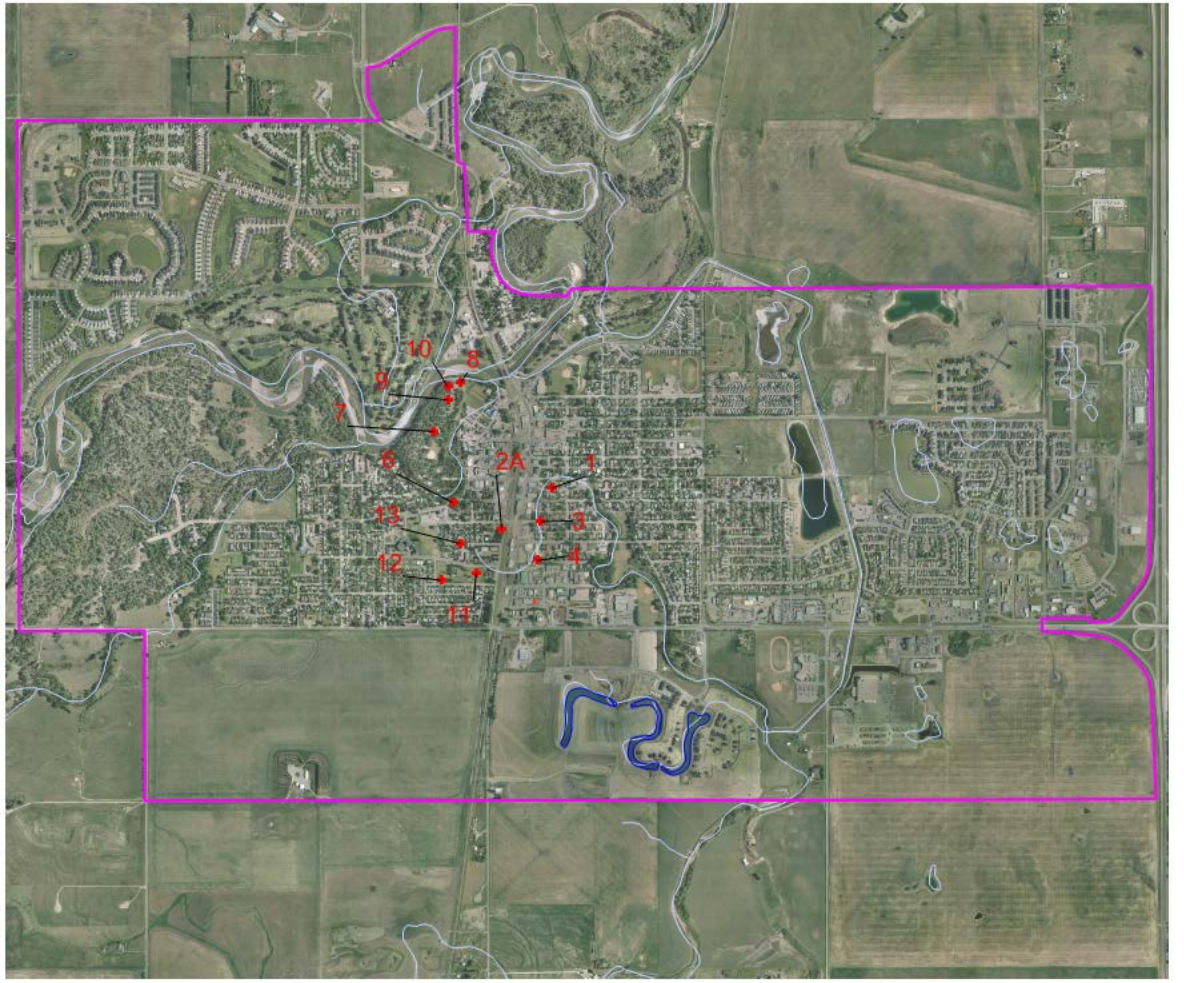
Outline

- Site Location
- Objectives
- Hydrogeological Conceptual Model
- Data Sources
- Groundwater Model Structure
- Hydraulic Parameters/Boundary Conditions
- Model Calibration (steady-state and transient)
- Scenario Simulations
- Conclusions



Site Location





LEGEND

- Montrose Stormwater Pond
- Town of High River
- Town Wells

0 500 1000 1500
metre

Objectives

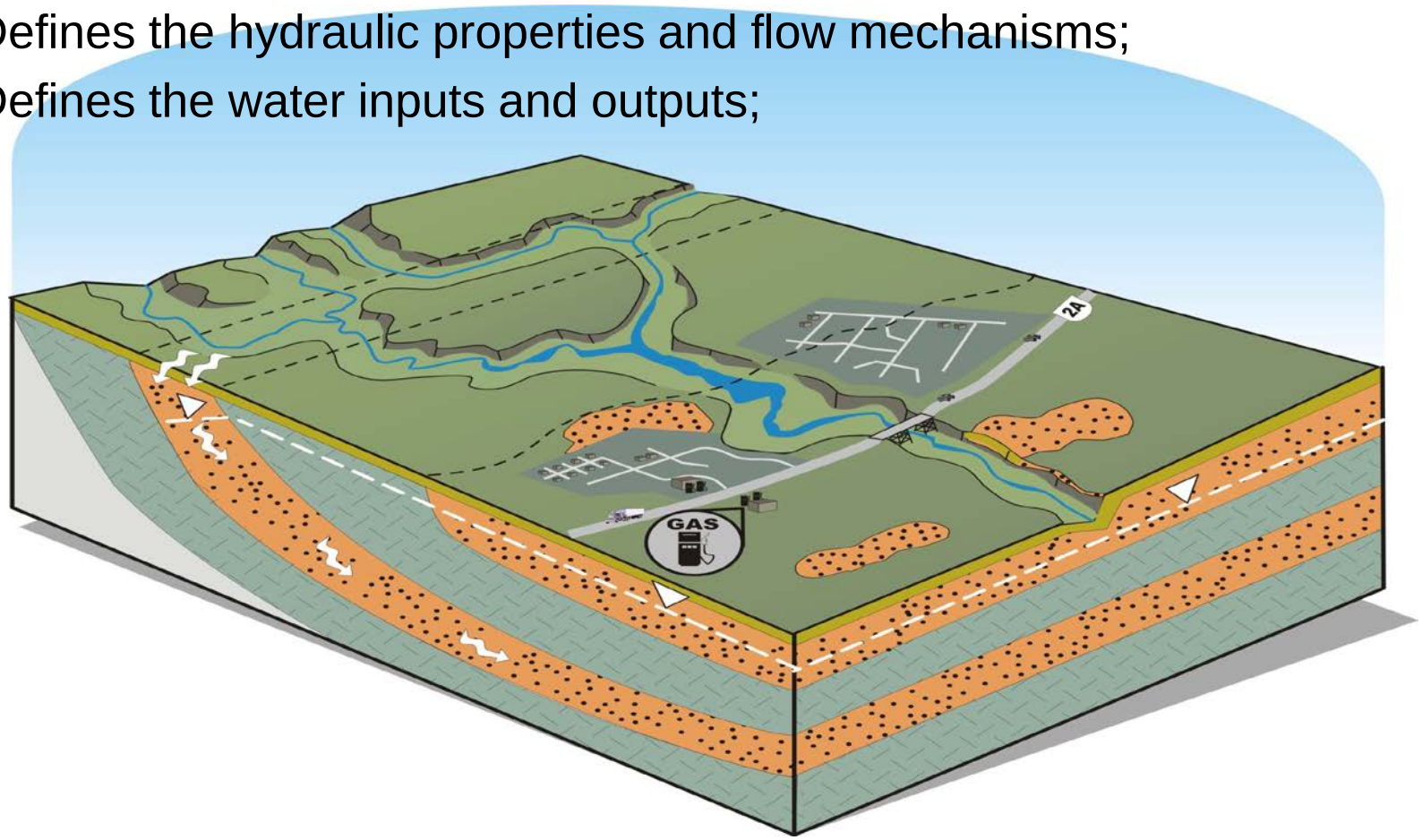
- Support a sustainable water management plan for the Town;
- Determine sustainable yield of the well field in the aquifers underlying and abutting the Town;
- Assessment of surface water/groundwater interactions from current and (proposed future) wells;
- Quantitatively predict/estimate effects of pumping by different sectors, under different climatic scenarios;
- Identify additional data needs.

Data Sources

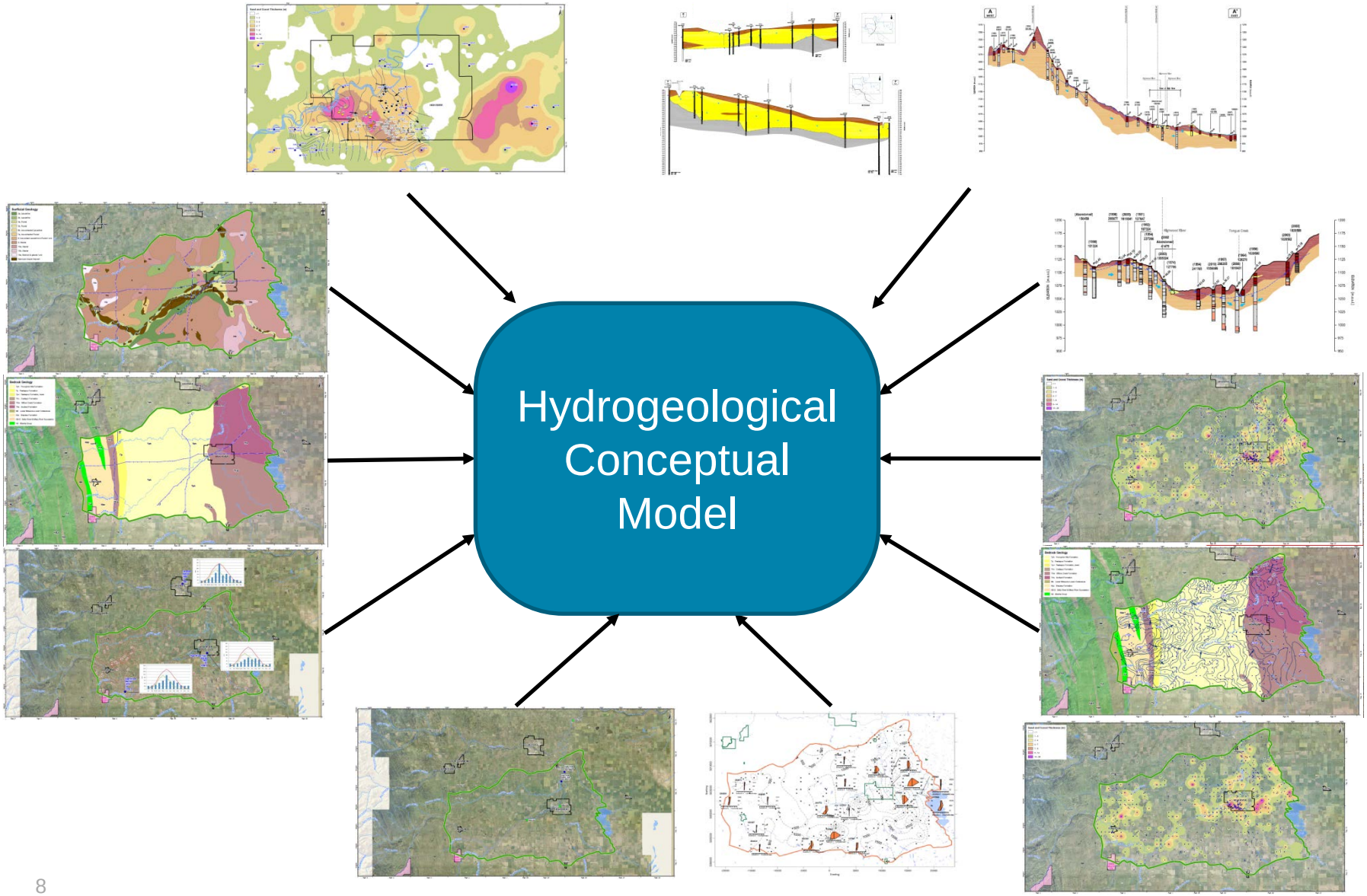
- 1,637 wells records selected from the well database (ESRD)
- Surficial and consolidated geological maps (AGS);
- Regional scale geological and hydrogeological studies (ARC);
- Hydrogeological investigation reports commissioned by the Town of High River;
- Base map (IHS Accumap 2011);
- Digital elevation model (CCG);
- Surface water monitoring (WSC); and
- Town well field operational data (Town of High River);

Hydrogeological Conceptual Model

- What is a hydrogeological conceptual model?
  - Defines the structure of the system;
  - Defines the hydraulic properties and flow mechanisms;
  - Defines the water inputs and outputs;



Hydrogeological Conceptual Model



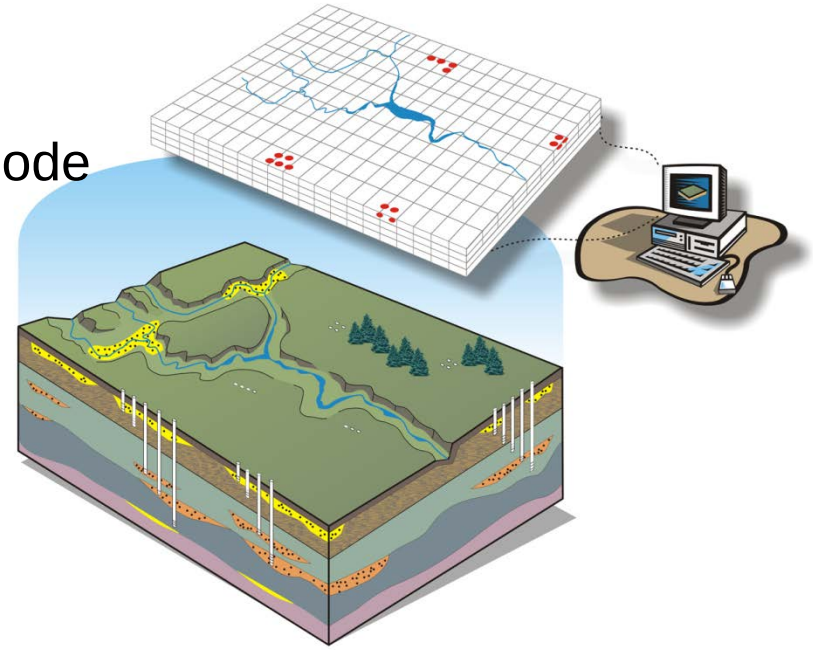
Limitations and Assumptions

- Model provides a simplified representation of the real system
- Hydraulic parameters were averaged over zones of relatively uniform characteristics
- Quick recovery rates in pumping wells consistent with fairly direct hydraulic communication with the river

Code Selection

- Three-Dimensional groundwater model
  - Simulate flow & yield in main aquifers
  - Predict effects of natural (climatic change) & artificial (pumping) stresses

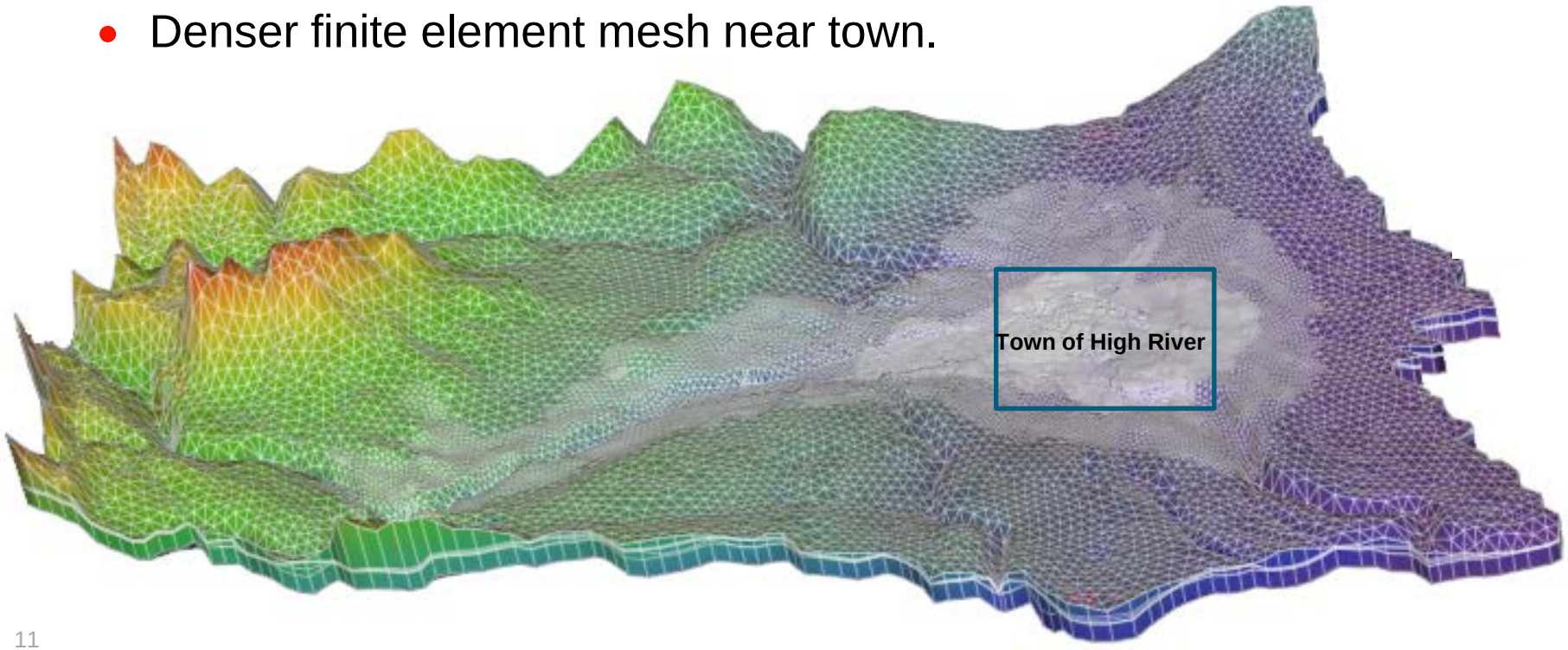
- FEFLOW® 6.0
  - Finite element flow and transport code (WASY, GmbH)
  - Flexibility in gridding
  - Groundwater density, and coupled solute transport and heat



Model Structure

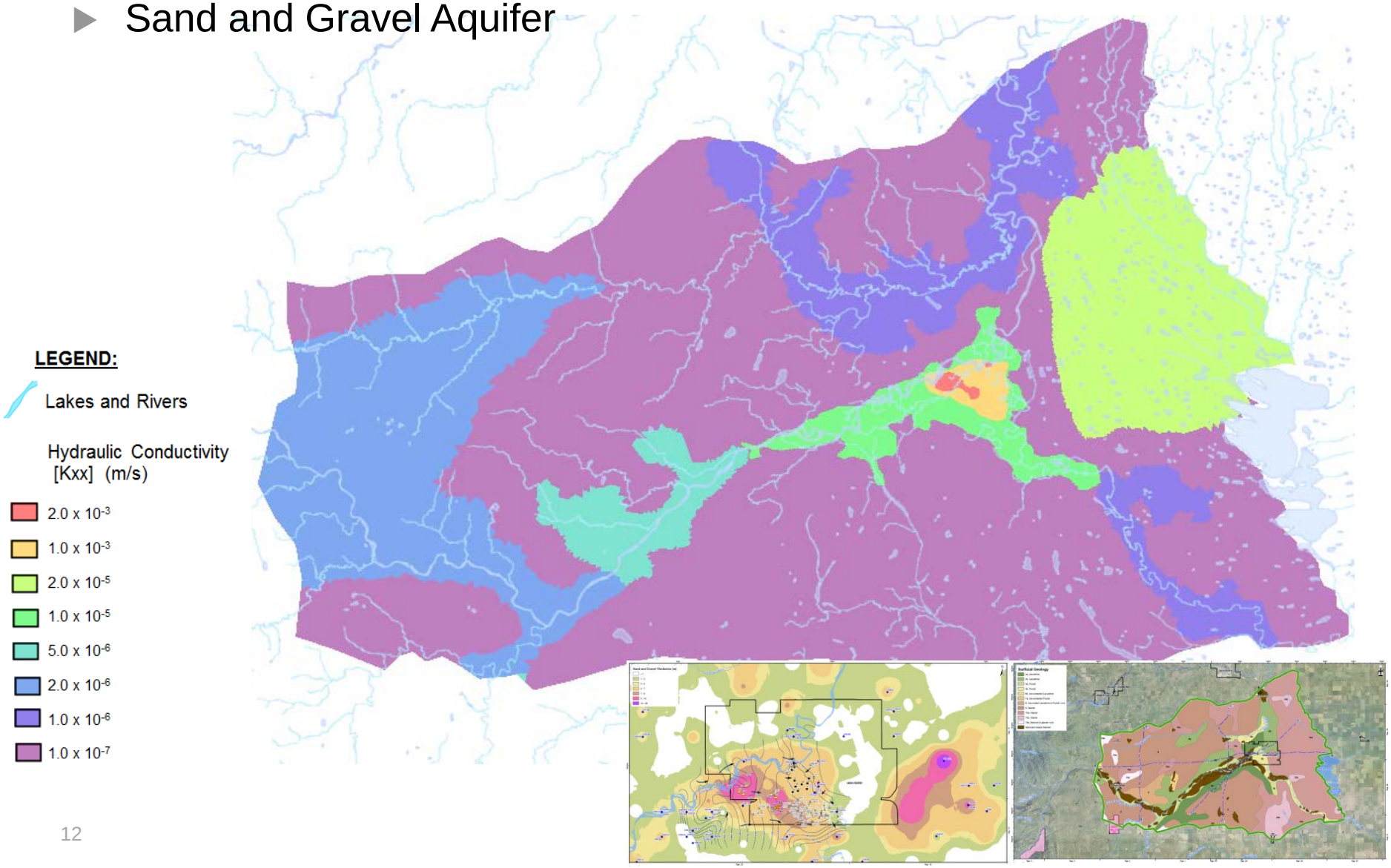
Lithological Unit	Aquifer/Aquitard	Model Layer
Surficial Deposit	Aquitard	1
Sand and Gravel	Aquifer	2 and 3
Confining Unit 1	Aquitard	4
Confining Unit 2	Aquitard	5
Interbedded Sandstone	Aquifer	6

- Model construction
  - Model domain 840 km^2;
  - Six layer model;
  - Element size (horizontal) 30 m^2 to 0.1 km^2; and,
  - Denser finite element mesh near town.



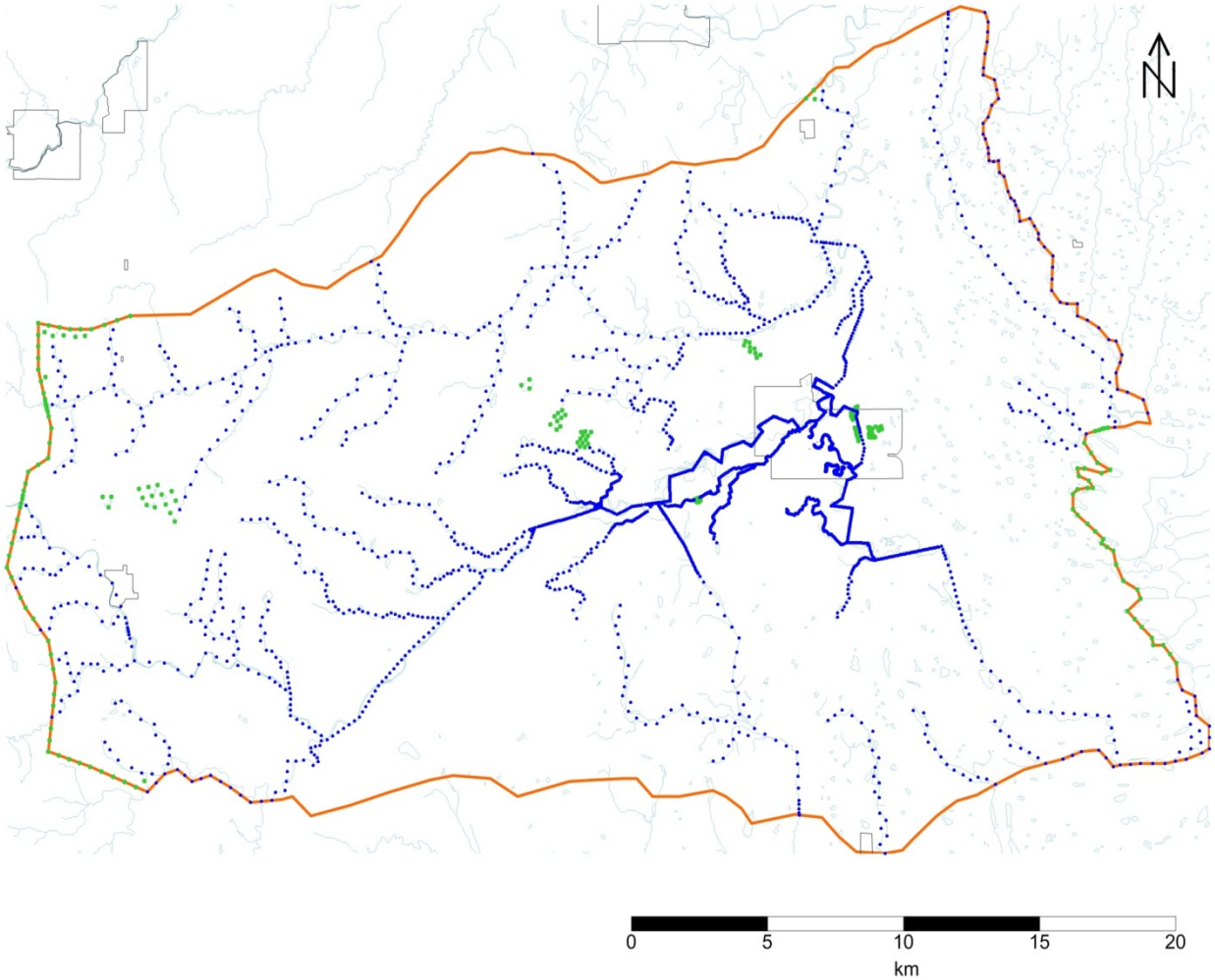
Hydraulic Conductivity Distribution

- Sand and Gravel Aquifer



Boundary Conditions

- Sand and Gravel Aquifer

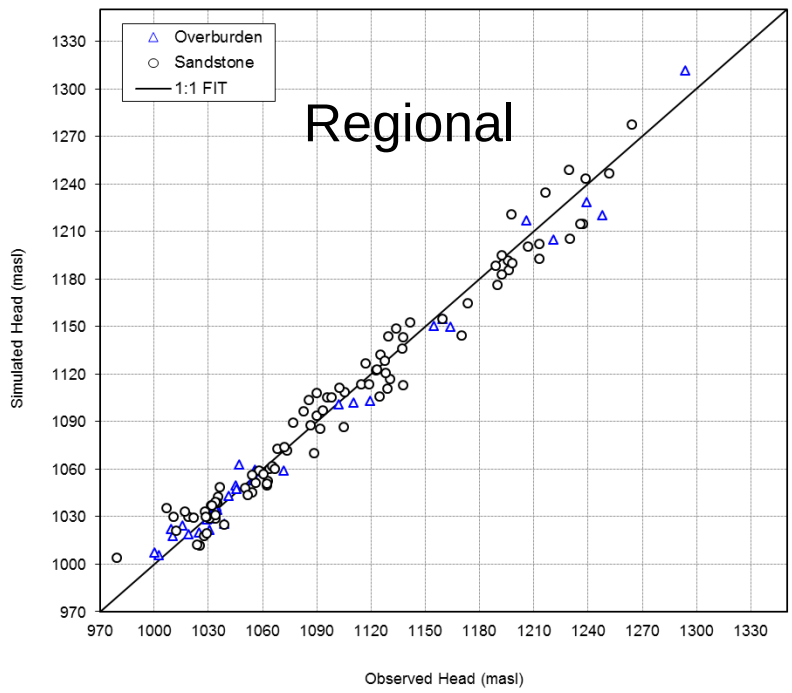


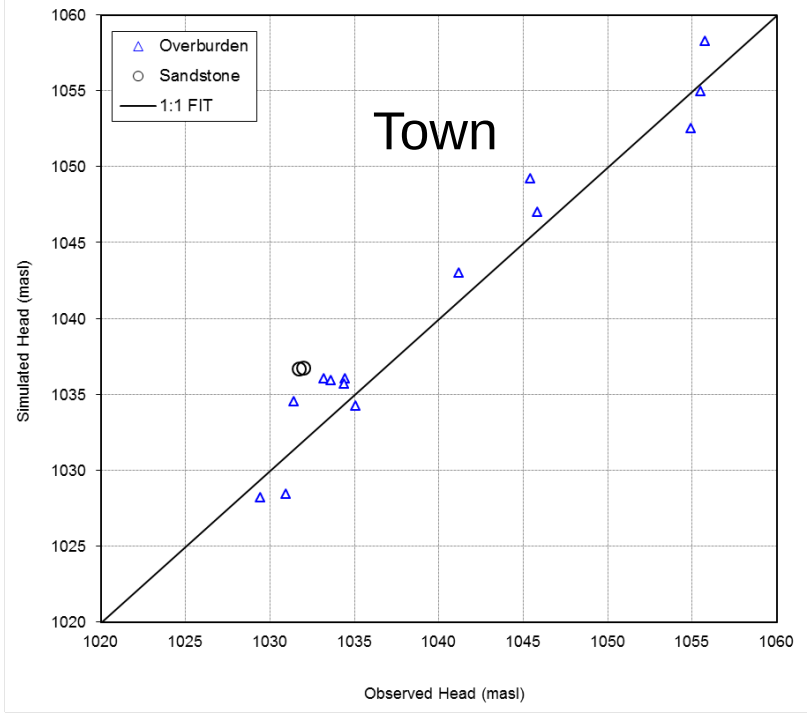
LEGEND:

- Lakes and Rivers
- Numerical Model Boundary
- Urban Boundaries
- Dirichlet (Type 1) Boundary
- Cauchy (Type 3) Boundary

Model Calibration

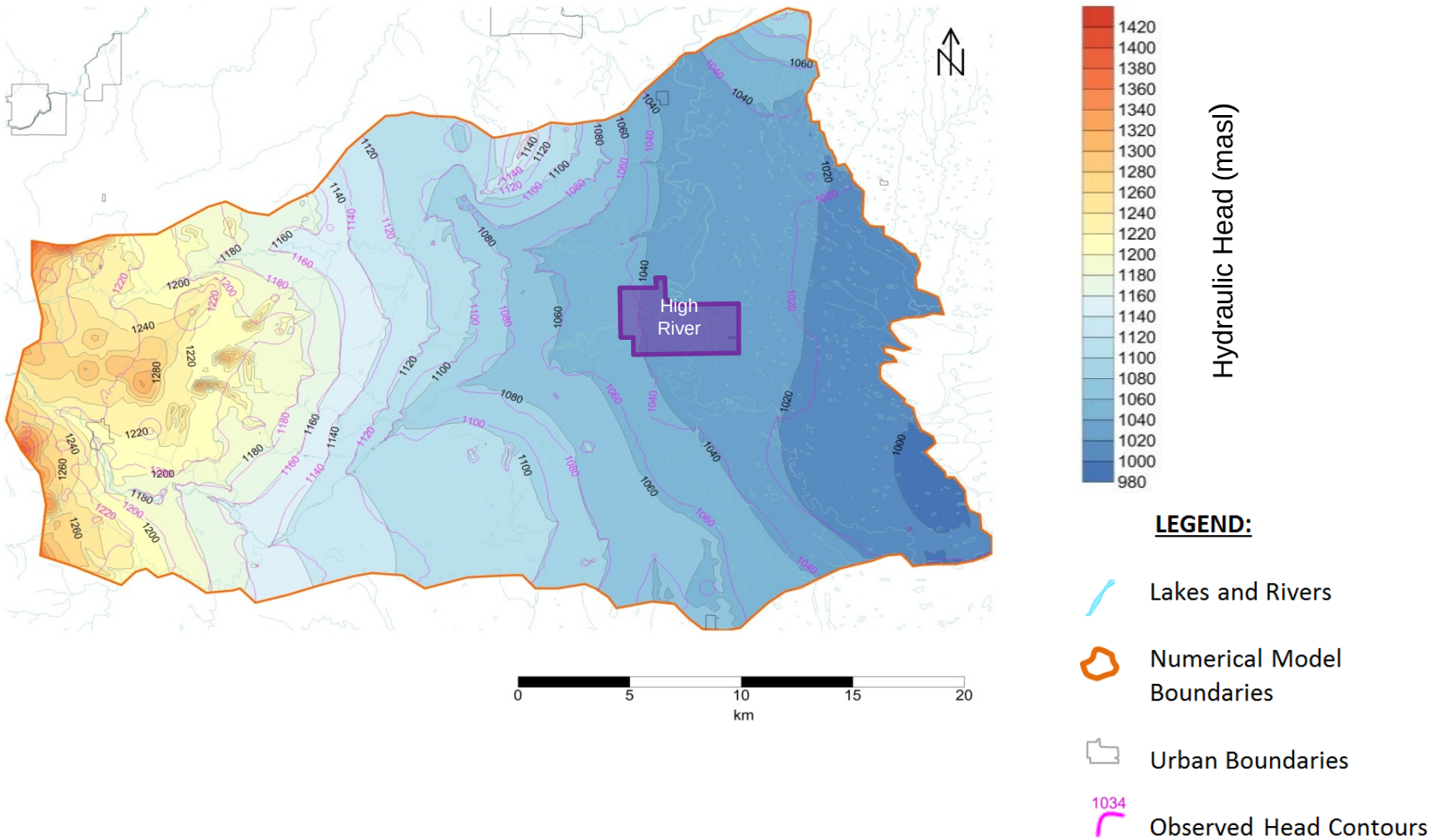
- Steady State Calibration
  - 39 groundwater levels in the sand and gravel aquifer, and 94 groundwater levels in the sandstone aquifer
  - For pre-pumping conditions, oldest data used as calibration targets





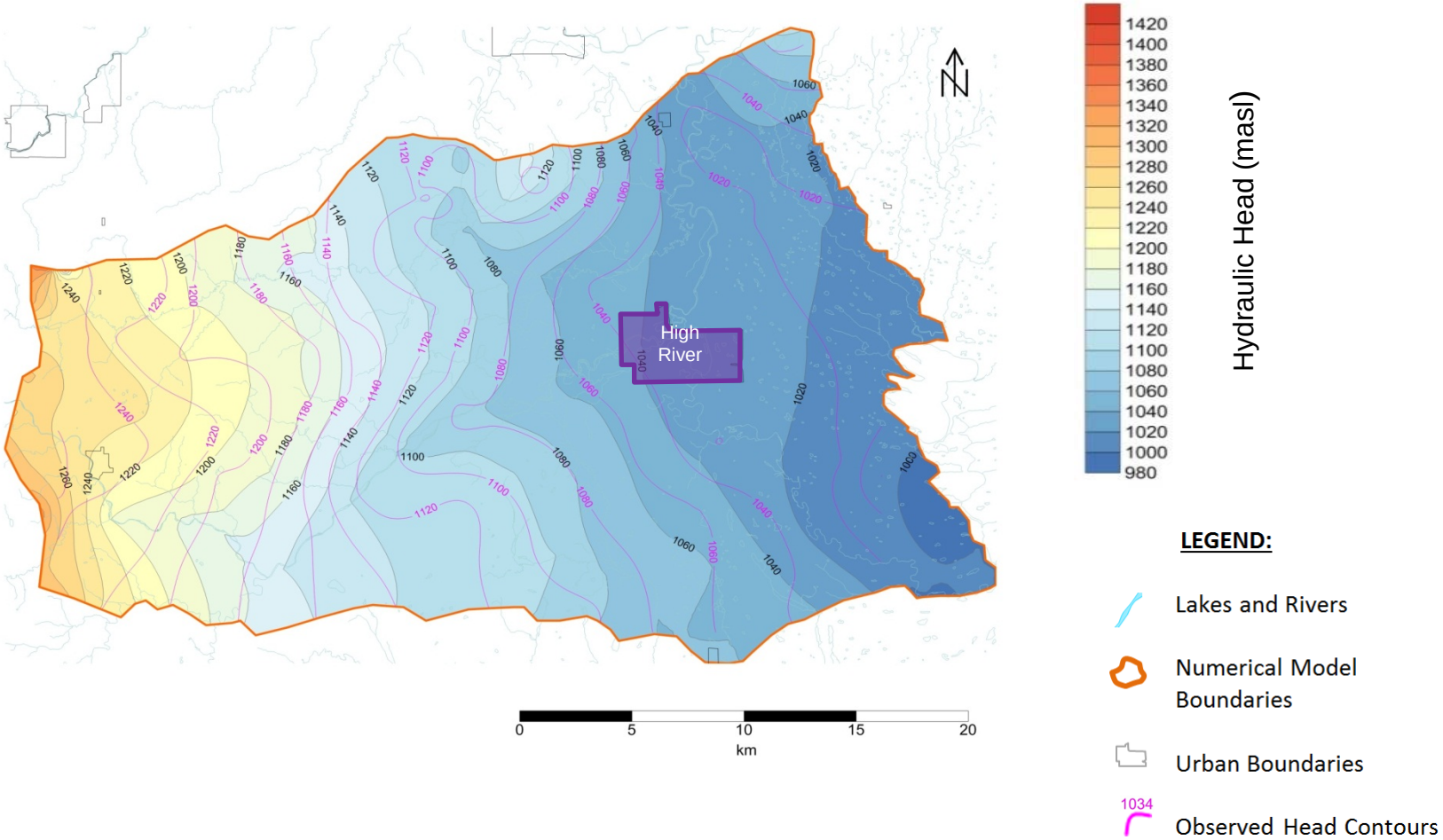
Model Calibration

- Steady State Calibration
  - Regional hydraulic head distribution in the **sand and gravel** unit



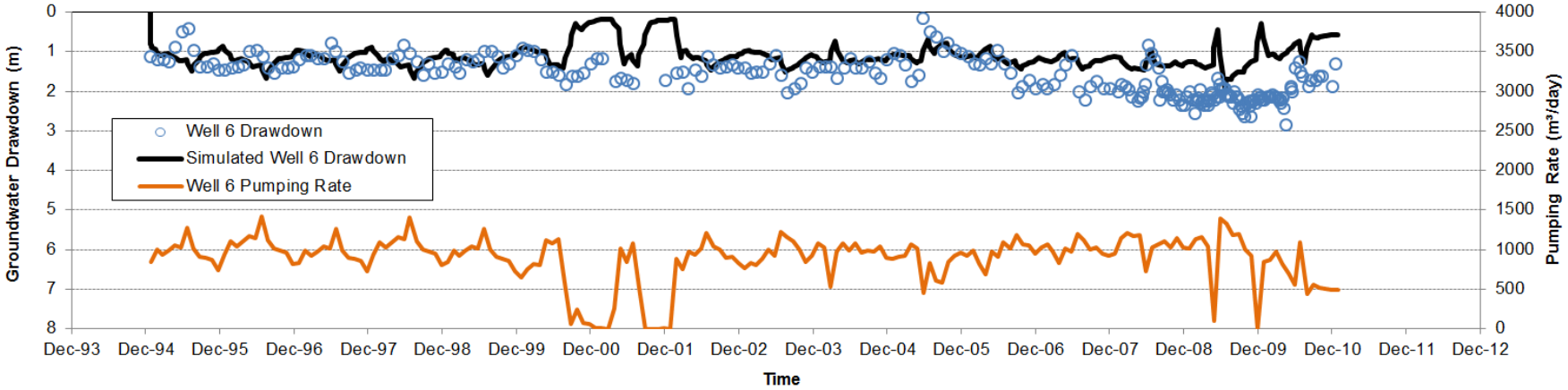
Model Calibration

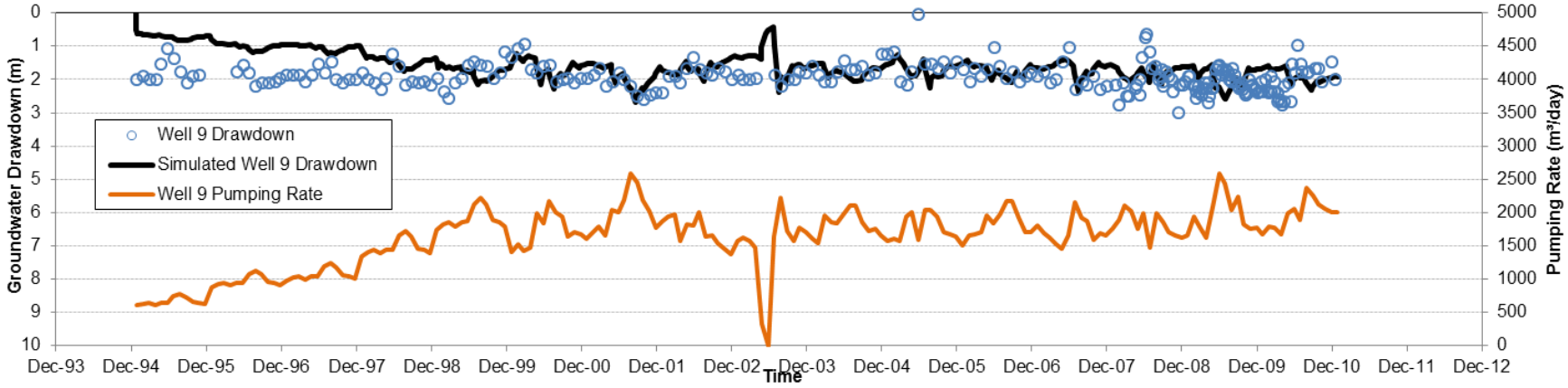
- Steady State Calibration
  - Regional hydraulic head distribution in the **sandstone aquifer**



Model Calibration

- Transient Calibration
  - Focus on representing aquifers' response to pumping around Town
  - Simulated vs. to observed responses in 12 town wells





Calibrated Hydraulic Parameters

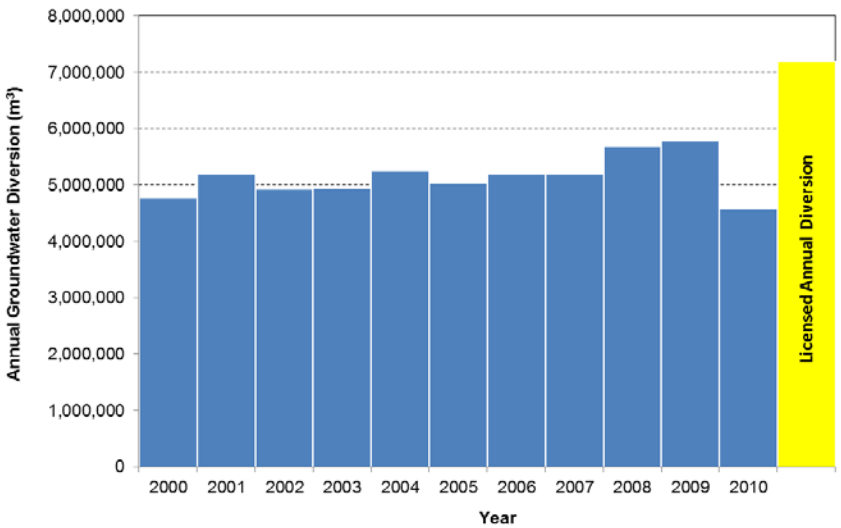
- Hydraulic conductivity and recharge rate

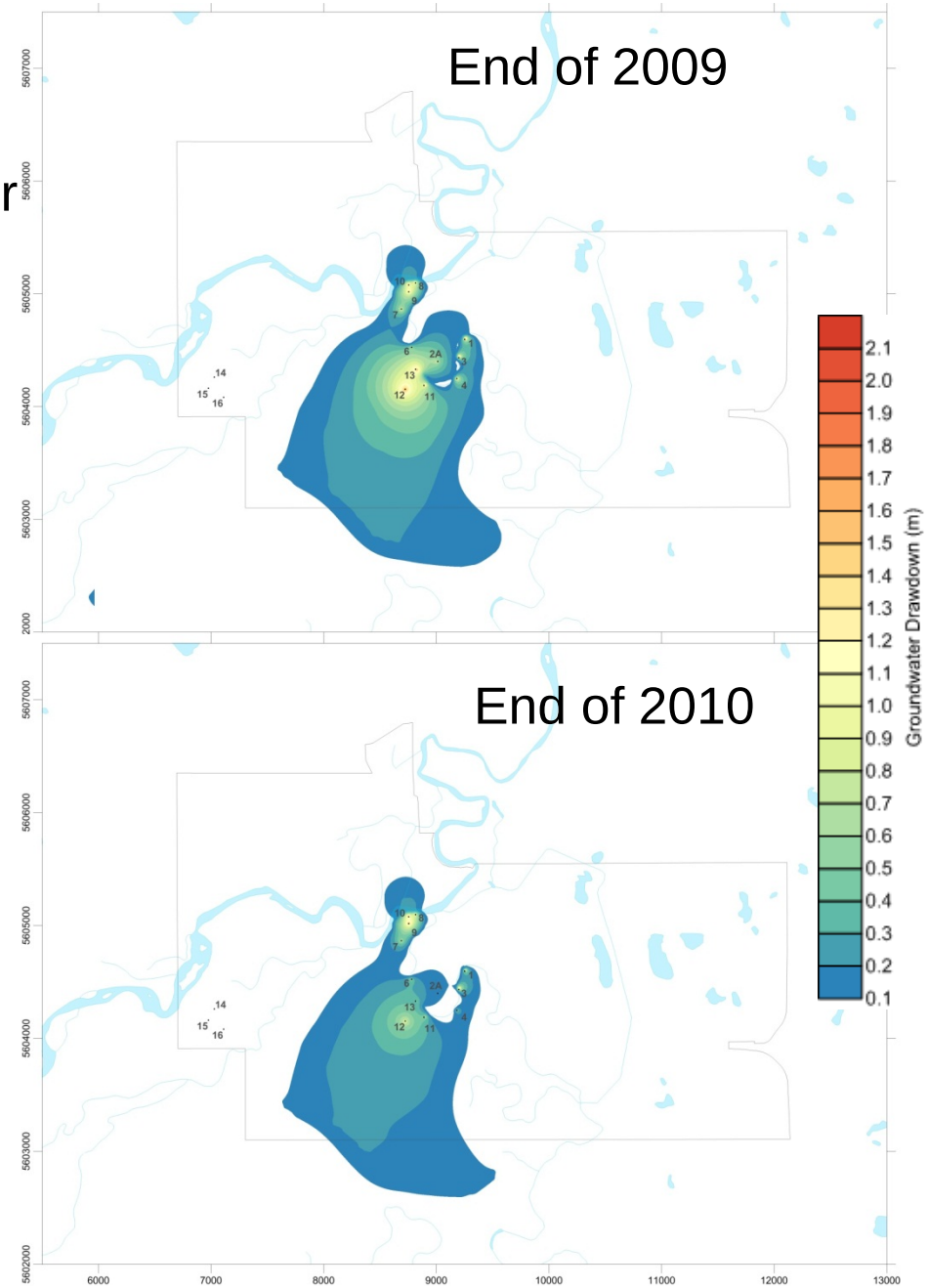
Lithological Unit	Horizontal hydraulic conductivity [Kxy] (m/s)	Vertical hydraulic conductivity [Kz] (m/s)	Recharge (mm/y)
Surficial Deposit (above sand and gravel)	$1.0x10^{-6}$ to $1.5x10^{-5}$	$1.0x10^{-7}$ to $2.0x10^{-4}$	4 to 40
Surficial Deposit (clay and till)	$1.0x10^{-7}$	$1.0x10^{-8}$	less than 1
Sand and Gravel	$1.0x10^{-7}$ to $2.0x10^{-3}$	$5.0x10^{-7}$ to $2.0x10^{-3}$	-
Confining Unit 1	$1.0x10^{-9}$ to $1.0x10^{-7}$	$1.0x10^{-10}$ to $1.0x10^{-8}$	-
Confining Unit 2	$1.0x10^{-9}$ to $1.0x10^{-7}$	$1.0x10^{-10}$ to $1.0x10^{-8}$	-
Interbedded Sandstone	$5.0x10^{-6}$	$5.0x10^{-7}$	-

- Specific storage value of $1x10^{-4}$ m^{-1} and a effective porosity of 0.2 were assumed for the entire model domain.

Groundwater Drawdown

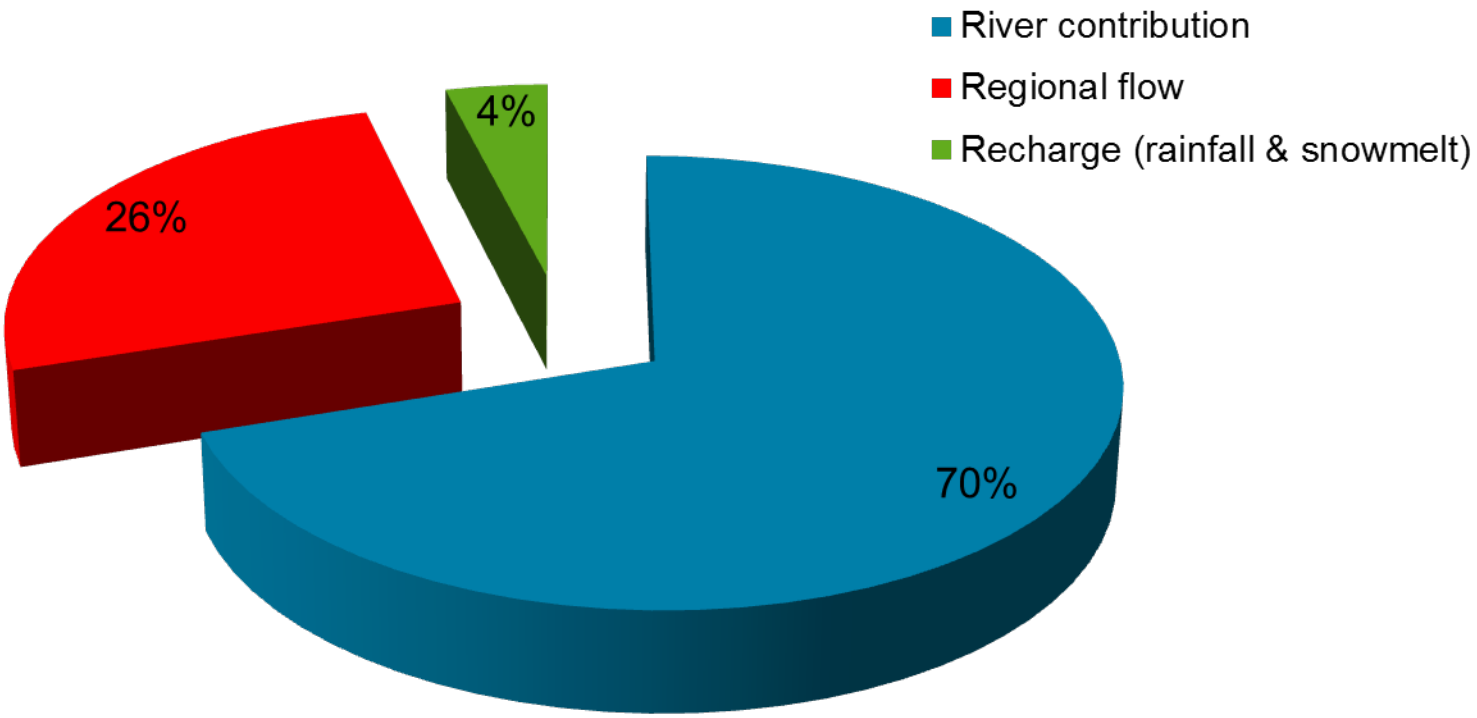
- 2009 / 2010 simulated groundwater drawdown in sand and gravel aquifer
  - Simulated using operational data
  - Groundwater drawdown is less than 3 m.





Contribution of Various Components

- Source of water withdrawn by Town wells
  - Simulated for 2010 using operational data.



Scenarios

- Simulation period from 2010 to 2040 (30 years)
- Scenarios with various pumping rates and number of wells
- 12 well scenarios - Scenario 1 (4.9 Mm3/y)
  - Scenario 2 (7.2 Mm3/y)
- 15 well scenarios - Scenario 3 (4.9 Mm3/y)
  - Scenario 4 (7.2 Mm3/y)

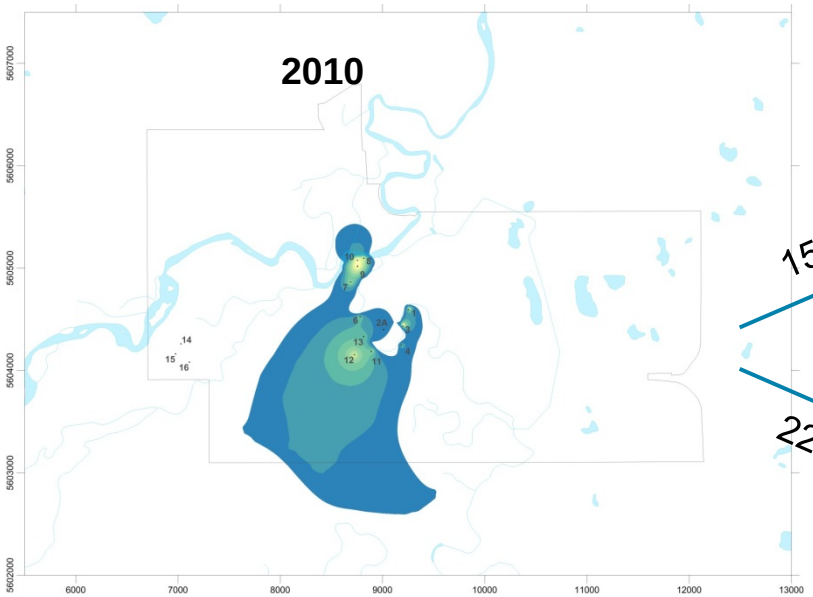
River Contribution on Pumping

- Predicted river contribution with increased withdrawals.

	2010	Scenario 1 12 wells (4.9 Mm^3/y)	Scenario 2 12 wells (7.2 Mm^3/y)	Scenario 3 15 wells (4.9 Mm^3/y)	Scenario 4 15 wells (7.2 Mm^3/y)
Withdrawal	4.6 Mm^3/year	4.9 Mm^3/year	7.2 Mm^3/year	4.9 Mm^3/year	7.2 Mm^3/year
% GW originating from river	70	84	84	78	82
% of minimum monthly river flow	16	20	30	19	29

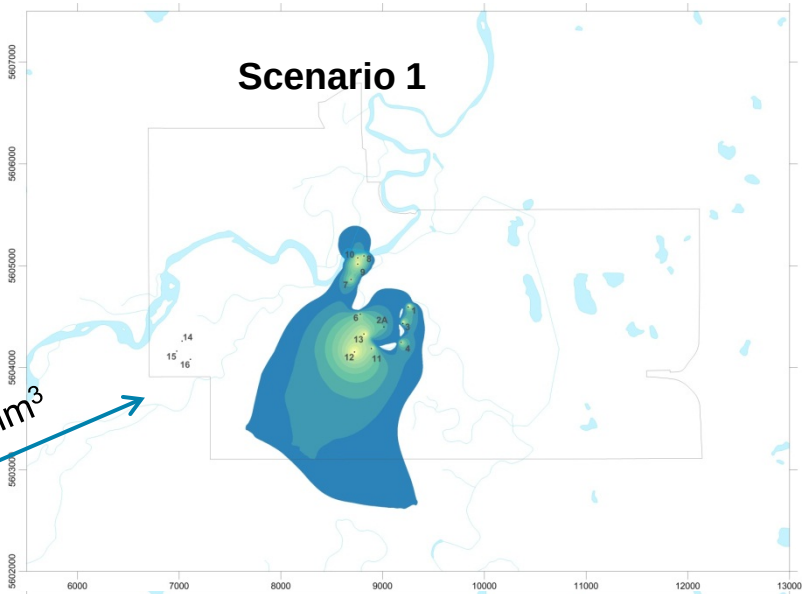
Groundwater Drawdown (end of 2040)

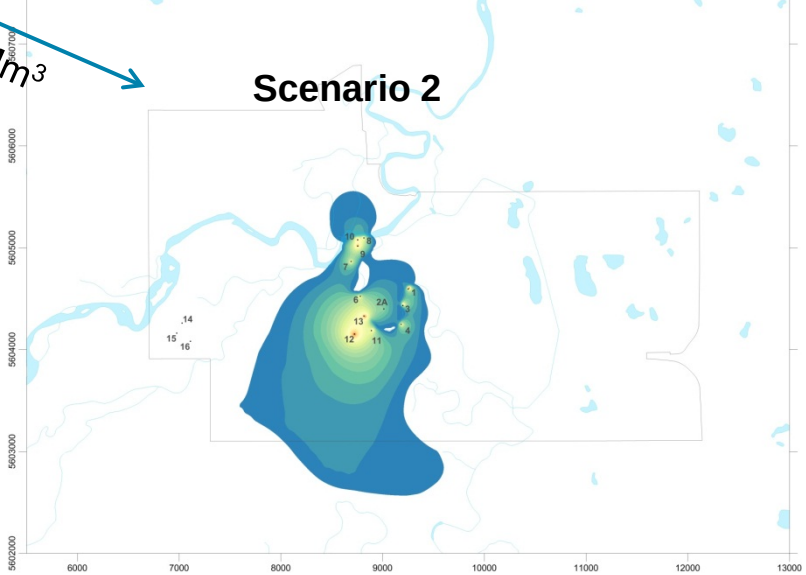
- 12 well scenarios

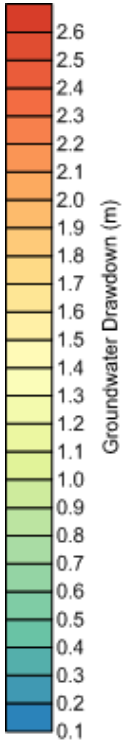


150 Mm^3

220 Mm^3







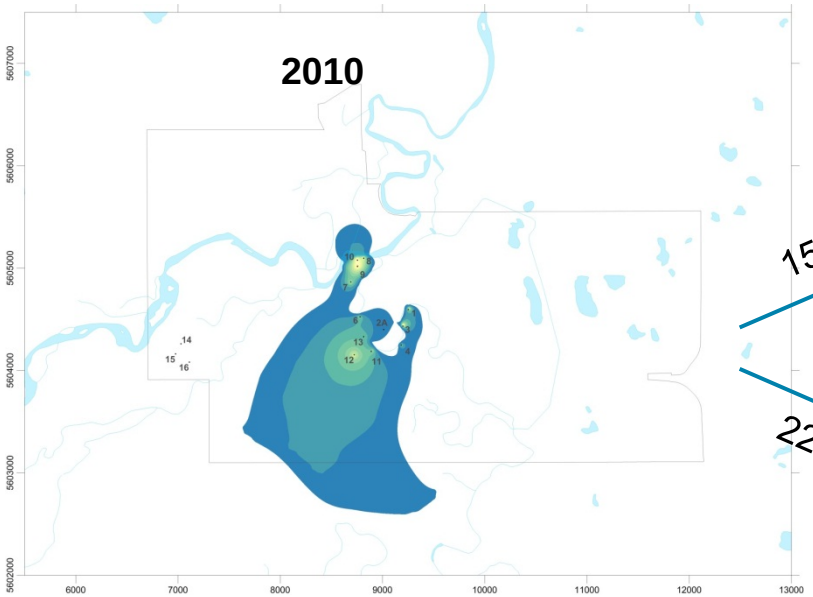
LEGEND:

Lakes and Rivers

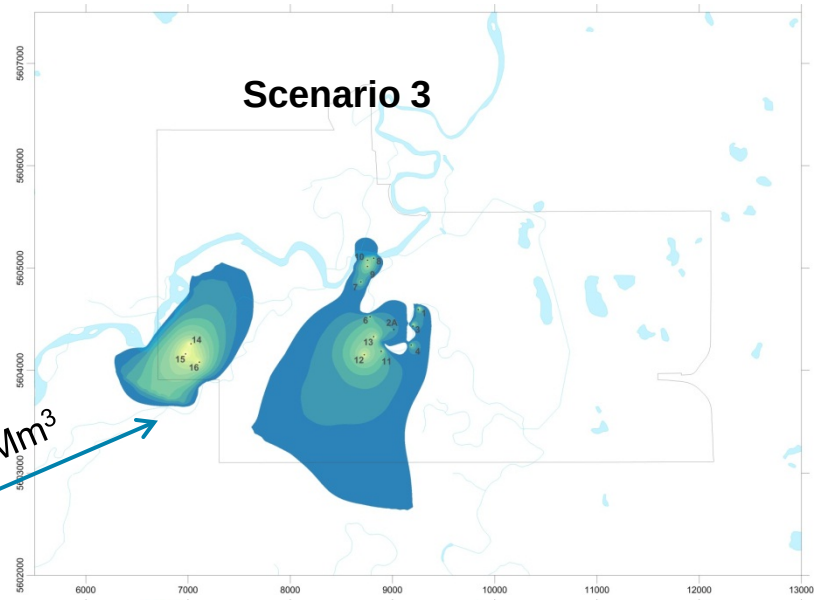
Urban Boundaries

Groundwater Drawdown (end of 2040)

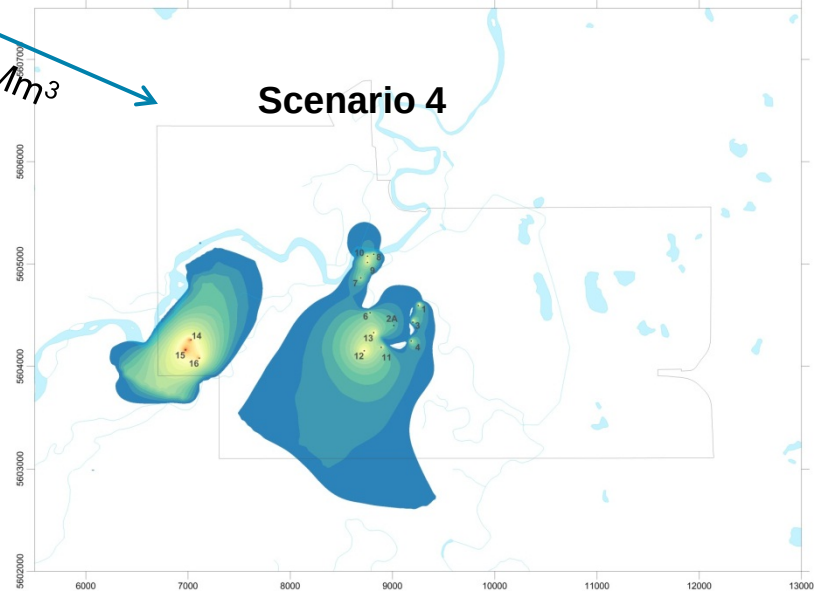
- 15 well scenarios

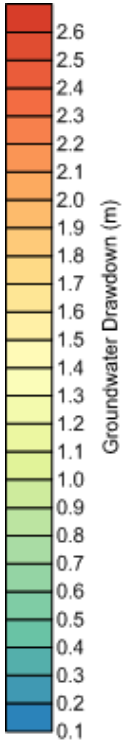


150 Mm^3



220 Mm^3





LEGEND:

Lakes and Rivers

Urban Boundaries

Predictions – Climate Change

- Shifts in Climate

  Simulated climate change scenarios indicate relatively low impact on the groundwater system if river flow is still maintained

		Upstream GW Inflow	Rivers and Lakes	Recharge	Pumping	Imbalance	
		m3/d	m3/d	m3/d	m3/d	m3/d	%
Steady Run (before pumping)	Inflow	8,887.6	45,933.2	2,081.7	0.0		
	Outflow	-4,311.1	-52,535.9	0.0	0.0		
	Net flow	**4,576.5**	**-6,602.6**	**2,081.7**	**0.0**	**55.5**	**0.8**
Steady Run (Regional Wells)	Inflow	10,556.0	122,411.3	2,081.7	0.0		
	Outflow	-3,733.1	-30,479.2	0.0	-100,838.0		
	Net flow	**6,822.9**	**91,932.1**	**2,081.7**	**-100,838.0**	**-1.3**	**0.0**
Transient Run (Climate Change)	Inflow	3,513.0	123,575.0	2,082.0	0.0		
	Outflow	-	-28,544.0	0.0	-100,799.0		
	Net flow	**3,513.0**	**95,031.0**	**2,082.0**	**-100,799.0**	**-173.0**	**-0.2**

Conclusions

- Current groundwater use ’ no major impact on the groundwater system
- 70% of produced water originates from surface water
- With continuous pumping for next 30 years, river contribution over 80%
- Flow from the river to the aquifer equals 30% of monthly minimum river flow when pumping rate of 7.2 Mm^3/y was simulated
- Climate change scenario* ’ relatively low impact on the groundwater system

* Assuming that river contribution to groundwater remains constant

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