



Chaire industrielle CRSNG-Polytechnique-UQAT

Environnement et gestion des rejets miniers

# Reclamation of the Manitou tailings site using neutral tailings from Agnico-Eagle's Goldex mine

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Montréal - NSERC-Polytechnique-UQAT Chair in  
environment and mine waste management

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de la Faune du Québec

# Site description

- Manitou, abandoned site (1942-1979)
- 15 km s-e of Val-d'Or, Quebec
- 11 million tonnes acid generating tailings
- Approx. 200 ha

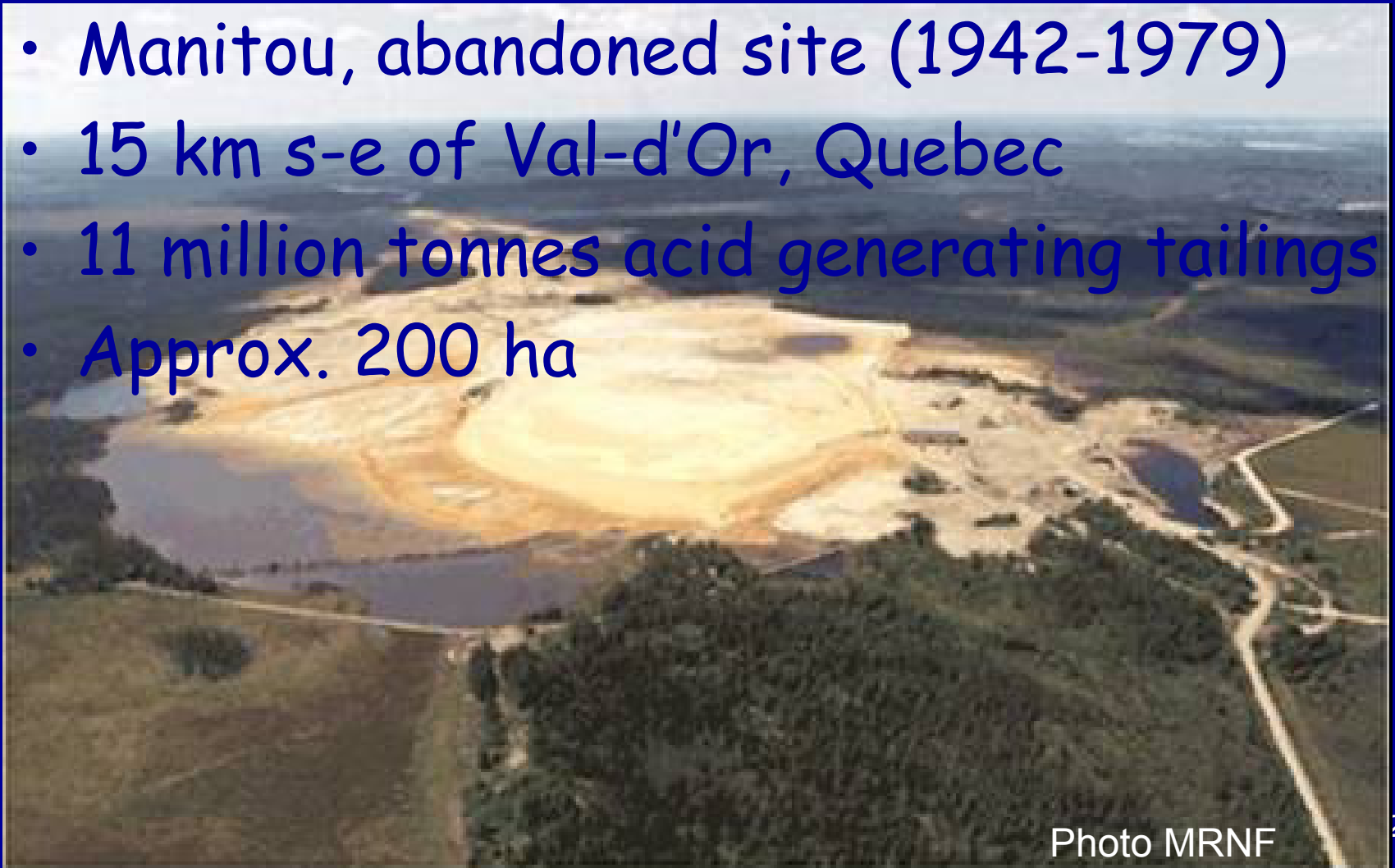


Photo MRNF

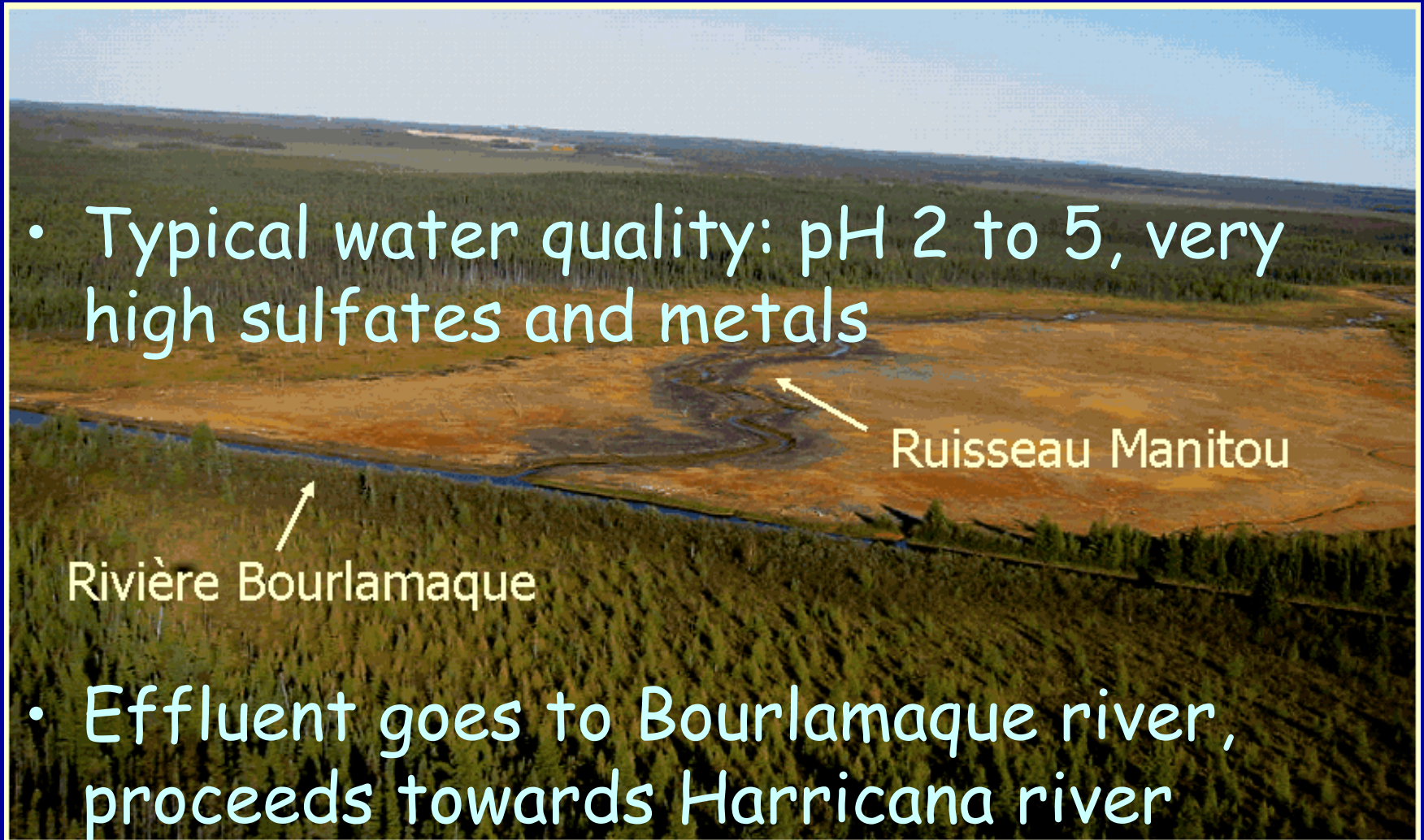






# Site description

- Typical water quality: pH 2 to 5, very high sulfates and metals



- Effluent goes to Bourlamaque river, proceeds towards Harricana river



# Goldex mine

- Gold mine owned and operated by Agnico-Eagle Mines
- Operation started in 2008 (for 12 years)



Photo AE





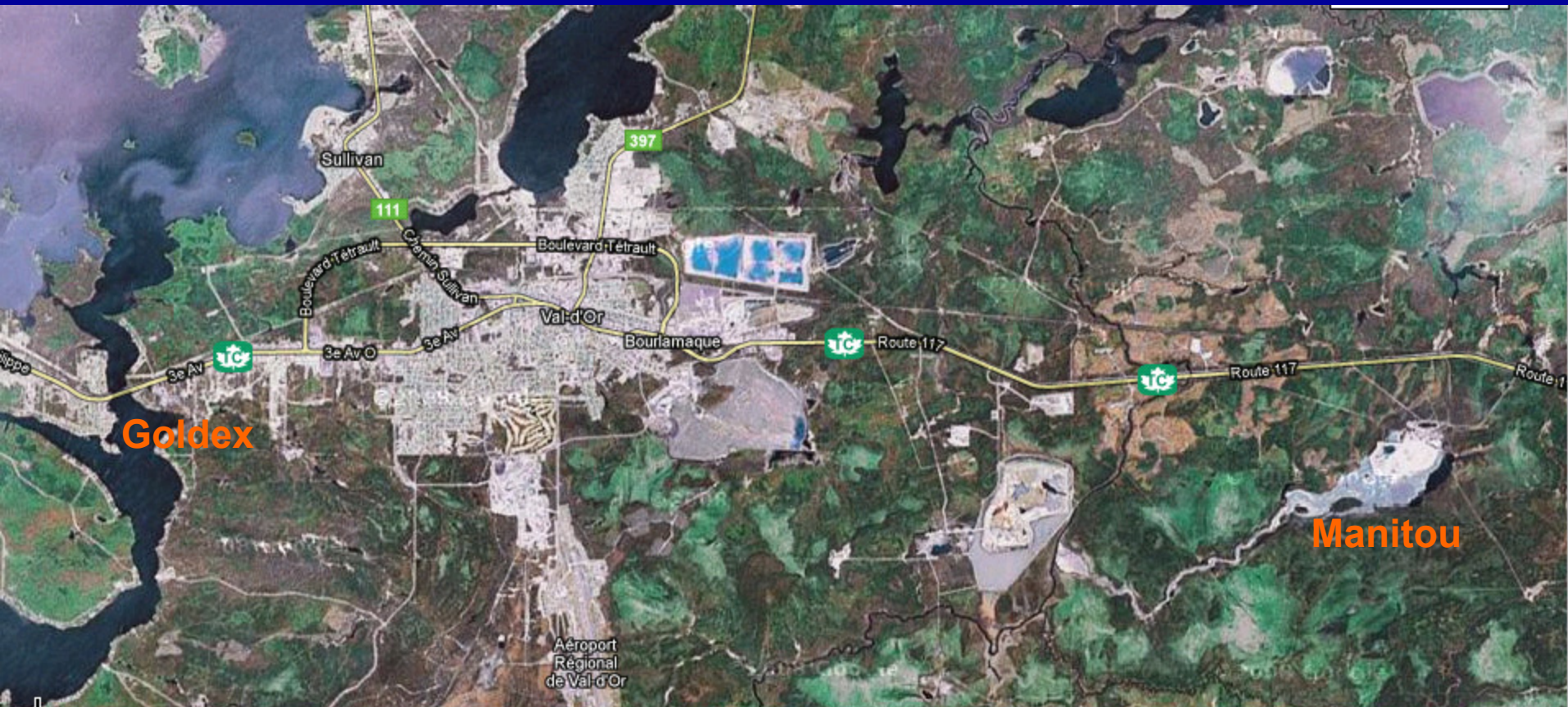
# Goldex mine

- Located in Val d'Or (urban area) next to Thompson river
- Tailings are neutral ( $1.8 \text{ Mm}^3/\text{year}$ )
- To reduce footprint, they looked for old facilities for tailings deposition
- Chosen option: deposition of Goldex tailings on Manitou site



# Goldex mine

- Transport of tailings over 24 km





# Partnership: MRNF and Goldex

- Benefits for Goldex:
  - No need to build new tailings facilities: reduced footprint
  - Use of natural soils (sand, gravel) reduced
  - Mine production and tailings deposition can begin earlier





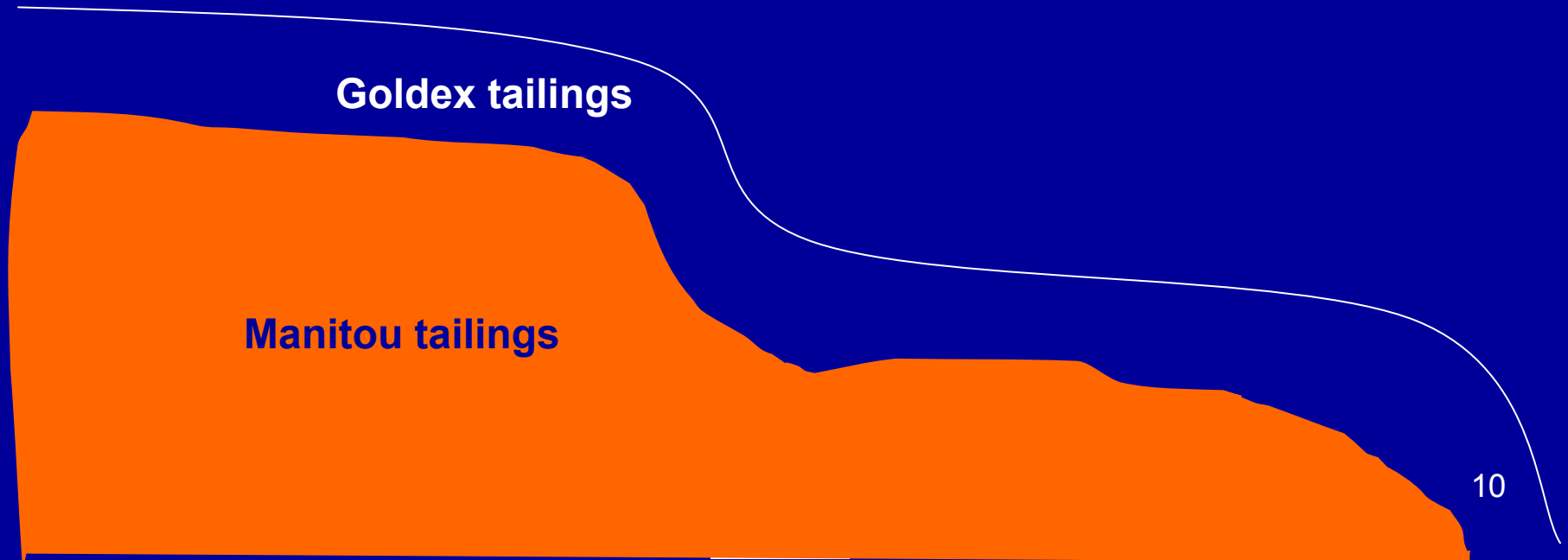
# Partnership: MRNF and Goldex

- Benefits for MRNF:
  - Restoration of Manitou site at lower cost: AE contribution equivalent to new tailings facilities for 24 Mt (12 M\$)



# Restoration scenario

- Reshaping of area
- Cover made of Goldex tailings (single- or multi-layer)
- Raising of the water table



# Assumptions

- Neutralizing Goldex tailings (NNP= 57) may improve water quality
- Goldex tailings may increase water table level
- Further oxydation would be prevented by the cover with a high degree of saturation (oxygen barrier)





# Research project

- To refine the conceptual model:
- Research project given to URSTM and NSERC-Polytechnique-UQAT Chair in environment and mine waste management by MRNF
- Objective: Physical modelling of cover scenarios and study of the hydrogeological behaviour



# Research project

Research project  
Manitou-Goldex 2008 to 2011

## Part 1: Geochemistry

**Objective:** optimal cover scenario  
(single-layer with Goldex tailings)

- Sampling
- Characterisation
- Column tests

## Part 2: Hydrogeology

**Objective:** knowledge of  
hydrogeological behaviour  
of Manitou site

- Piezometer installation
- Piezometer monitoring



# 1. Geochemistry - sampling

- Fine Manitou tailings



Oxidized

Non oxidized

Goldex tailings provided by the mine





# 1. Geochemistry - characterisation

	USCS	D <sub>50</sub> (µm)	P <sub>80</sub> (%)	Density
Manitou coarse non oxidized	SM	219	22	2,85
Manitou coarse oxidized	SM	145	38	2,80
Manitou fine non oxidized	ML	30	76	3,17
Goldex tailings	ML	22	83	2,76

	Ca (ppm)	Fe (ppm)	Mg (ppm)	S (ppm)	Zn (ppm)	PN (kg CaCO <sub>3</sub> /t)	PA (kg CaCO <sub>3</sub> /t)
Manitou coarse non oxidized	0,25	8,51	1,73	4,63	0,07	0	175
Manitou coarse oxidized	0,07	8,56	2,27	0,14	0,02	0	4
Manitou fine non oxidized	0,49	16,10	0,26	13,60	0,51	0	425
Goldex tailings	4,20	3,40	1,90	0,33	0,004	67	10



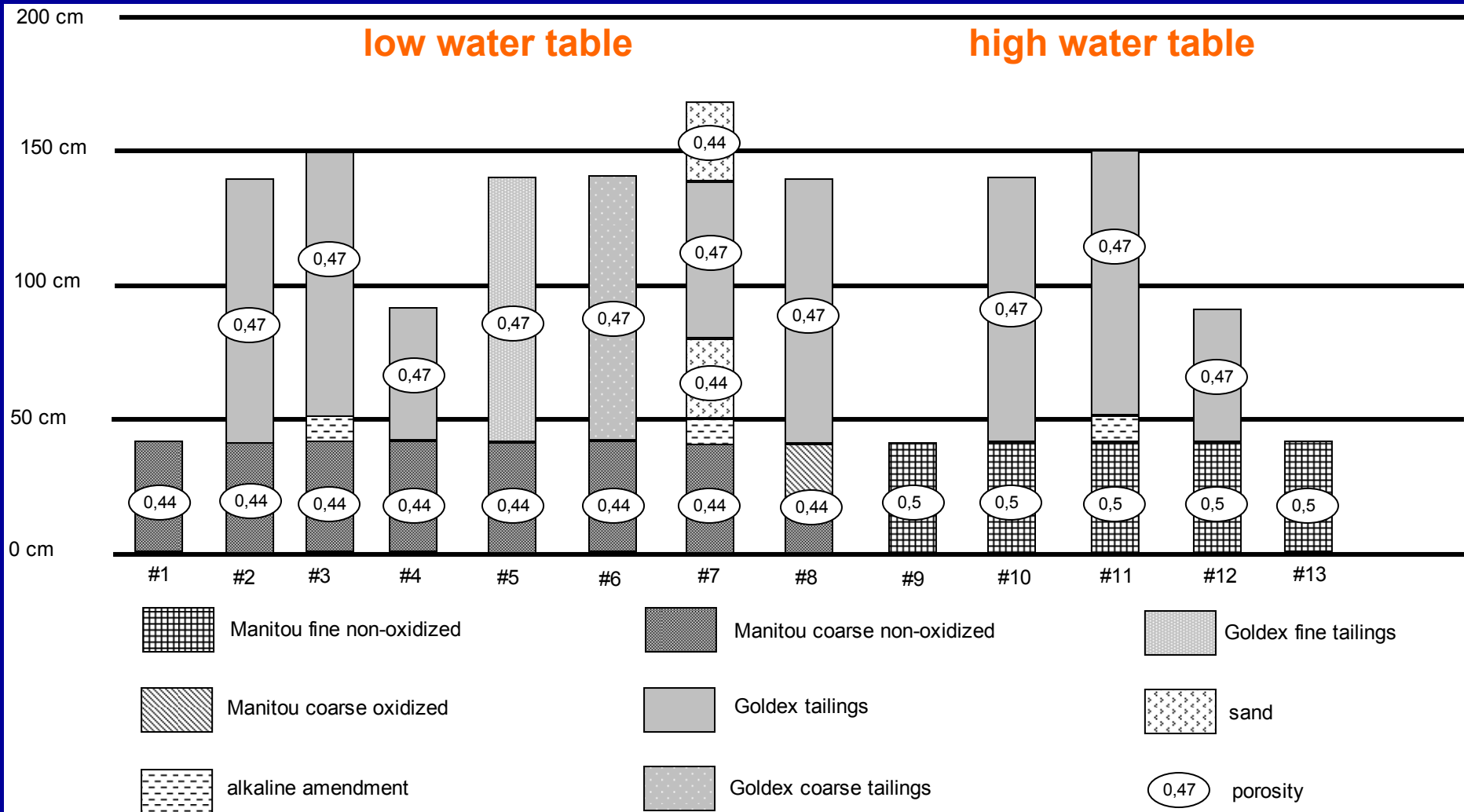
# 1. Geochemistry - characterisation

	Quartz	Chlorite	Muscovite	Pyrite	Gypsum	Albite	Calcite
Manitou coarse non oxidized	72,2	9,1	10,9	7	< 1	< 1	< 1
Manitou coarse oxidized	67,7	19,3	12,7	< 1	< 1	< 1	< 1
Manitou fine non oxidized	46,9	3,6	26,9	17,1	2,8	< 1	< 1
Goldex tailings	21,8	8,5	< 1	< 1	< 1	55	7,2

XRD analyses



# 1. Geochemistry - column tests





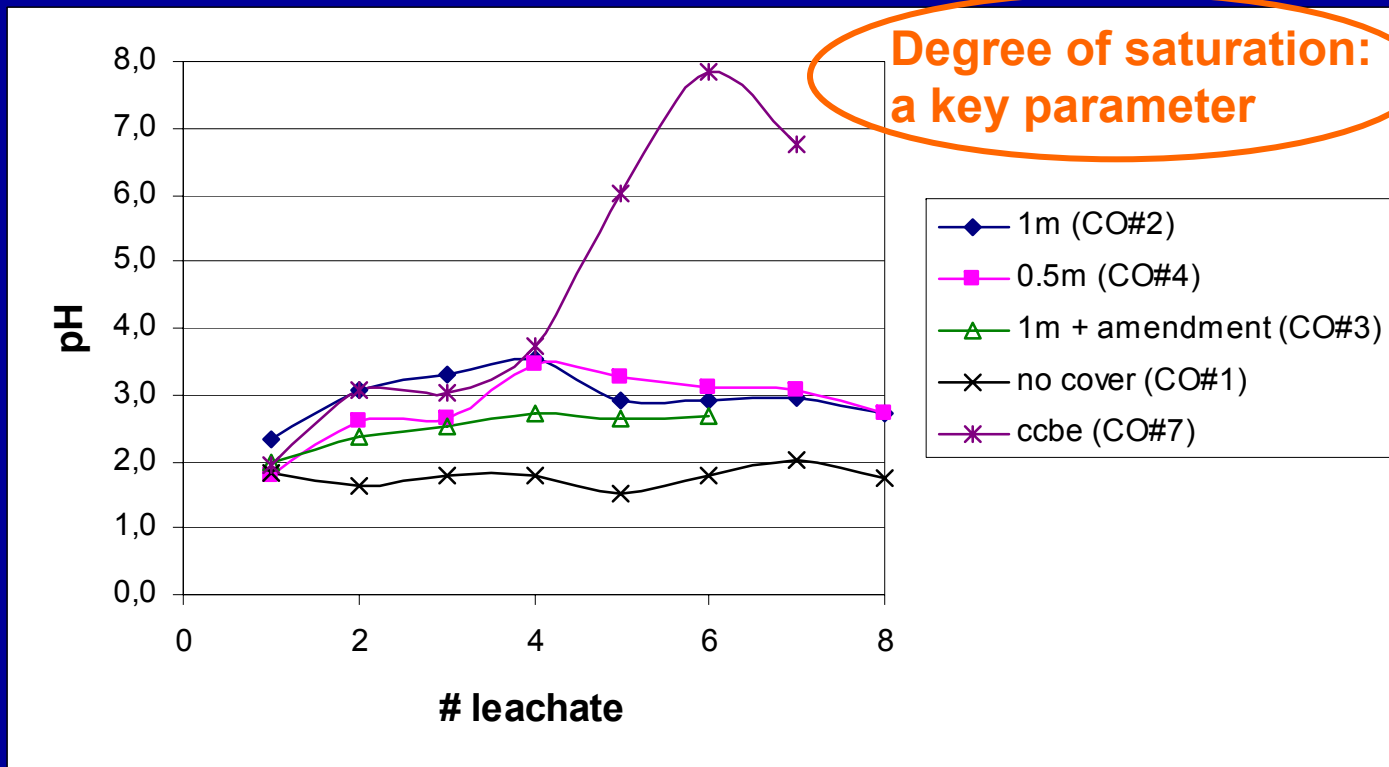
# 1. Geochemistry - column tests

- Leaching: 4 weeks open to atmosphere, then leaching with 2 L Goldex process water, collected at bottom of column for 1 week.
- Data:
  - Chemical analysis of leachate (metals, pH...)
  - AP and NP
  - Suction and volumetric water content
  - Oxygen content of pore air and oxygen consumption



# 1. Geochemistry - column tests

- Sample results: pH evolution for the low water table condition (Manitou coarse non oxidized tailings covered with Goldex tailings)



# 1. Geochemistry - ongoing work

- Column tests: continue for 12-14 cycles
- Verify impact of water table elevation on cover performance
- Column dismantling and analyses
- Modelling: water movement and geochemistry using Vadose/W and Min3p (work done by Thomas Pabst at École Polytechnique de Montréal)



# Research project

Research project  
Manitou-Goldex 2008 to 2010

## Part 1: Geochemistry

**Objective:** optimal cover scenario  
(single-layer with Goldex tailings)

- Sampling
- Characterisation
- Column tests

## Part 2: Hydrogeology

**Objective:** knowledge of  
hydrogeological behaviour  
of Manitou site

- Piezometer installation
- Piezometer monitoring





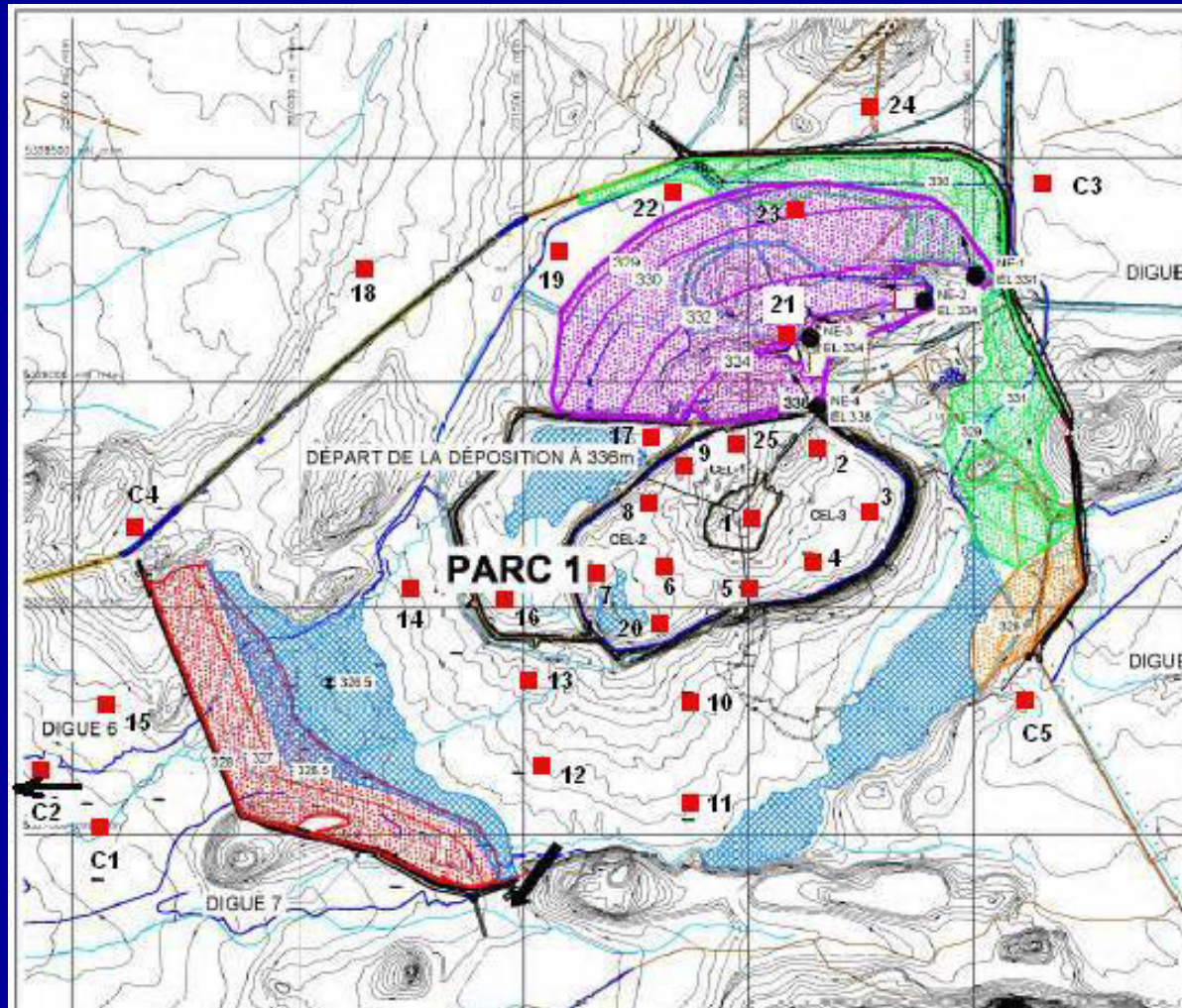
## 2. Hydrogeology - background

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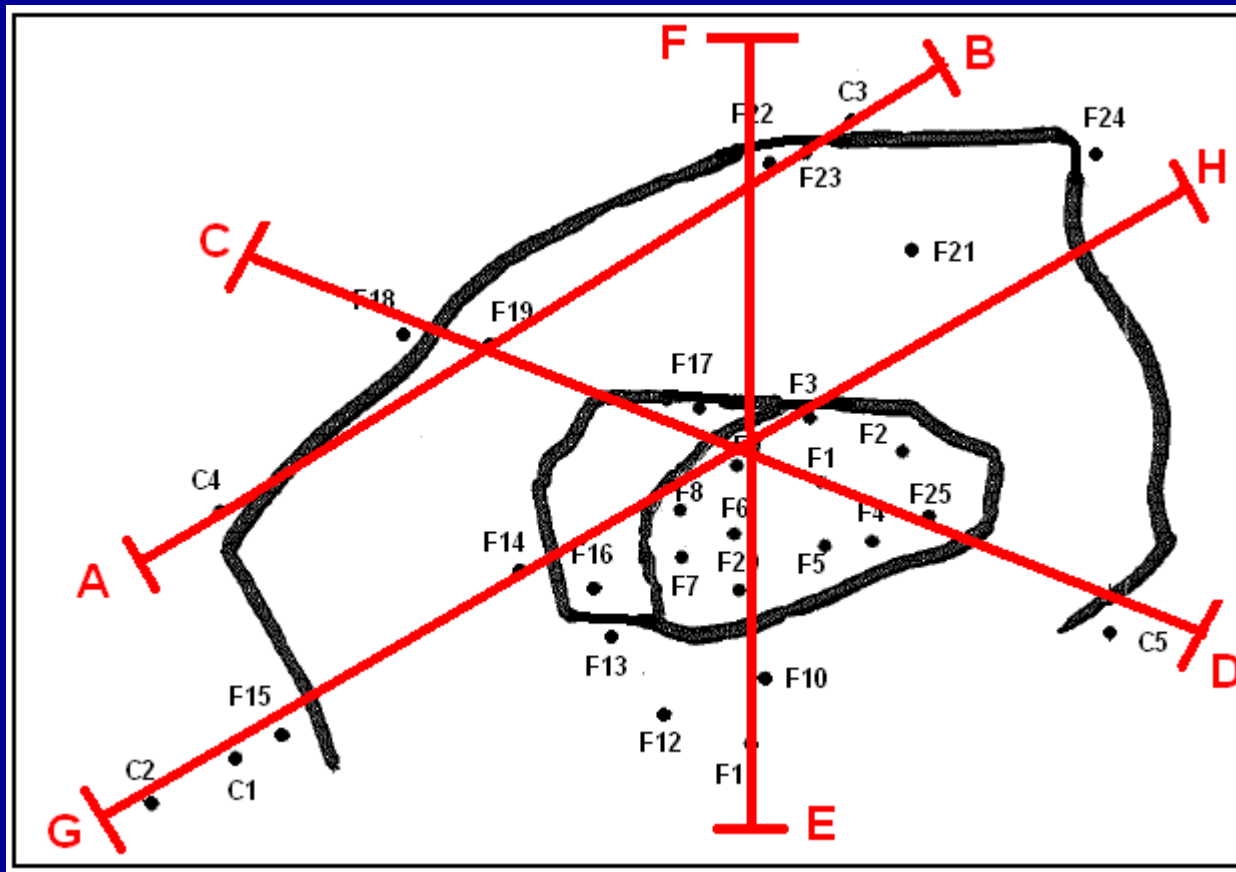
- Justification: understanding of underground structure
  - Info on water movement
  - Info on underground water quality
- Hydrogeological behaviour before, during and after?
- Contamination of underground water?



# 2. Hydrogeology - piezometers installation



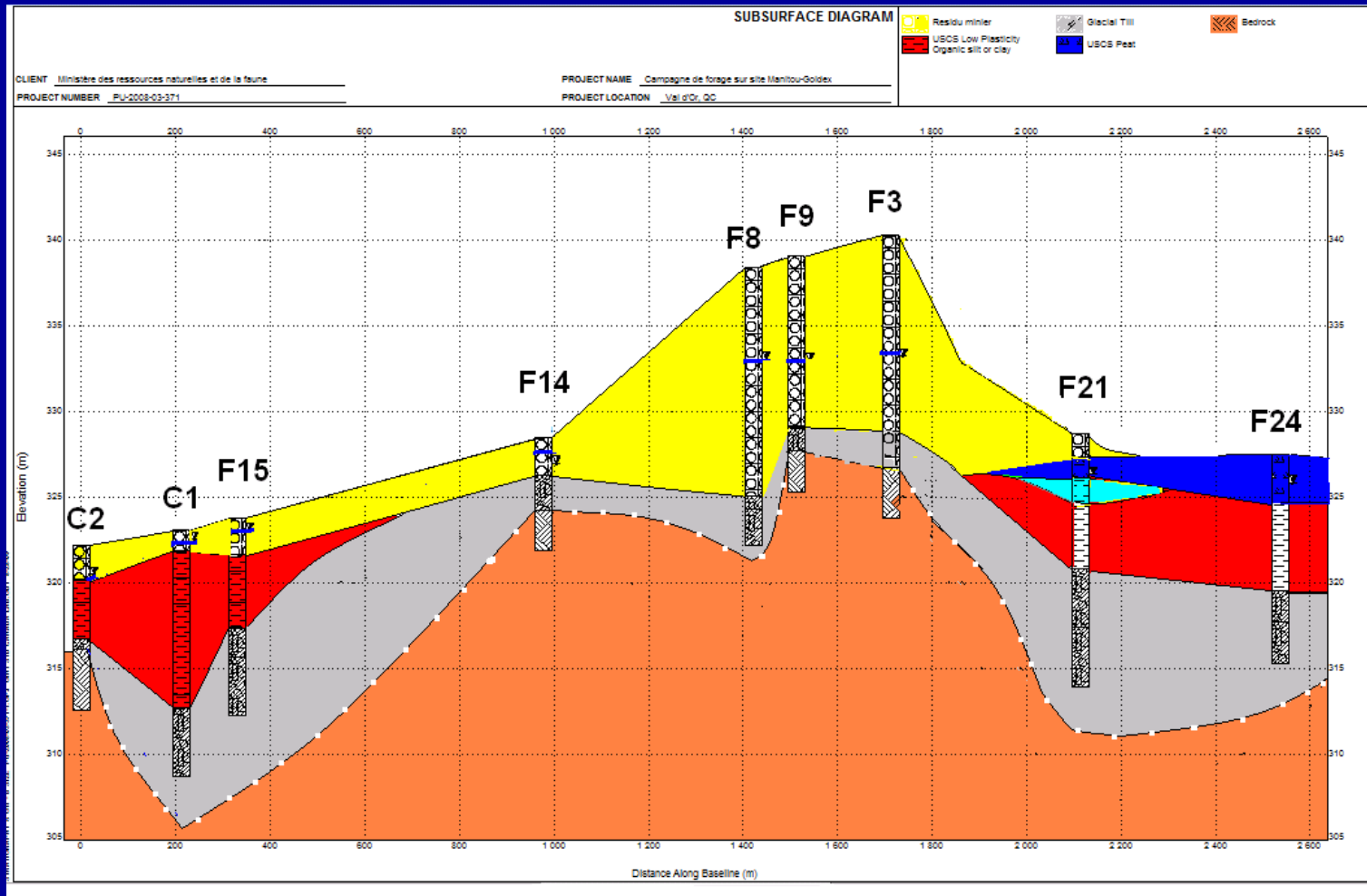
# 2. Hydrogeology - piezometers installation



# 2. Hydrogeology - piezometers installation

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## 2. Hydrogeology - piezometer monitoring

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- Instrumentation with pressure sensors, data recorded every 6 hours (obtained with a team grant led by R. Chapuis)
  - Pressure
  - Water temperature
  - Electrical conductivity



## 2. Hydrogeology - piezometer monitoring





## 2. Hydrogeology - piezometer monitoring

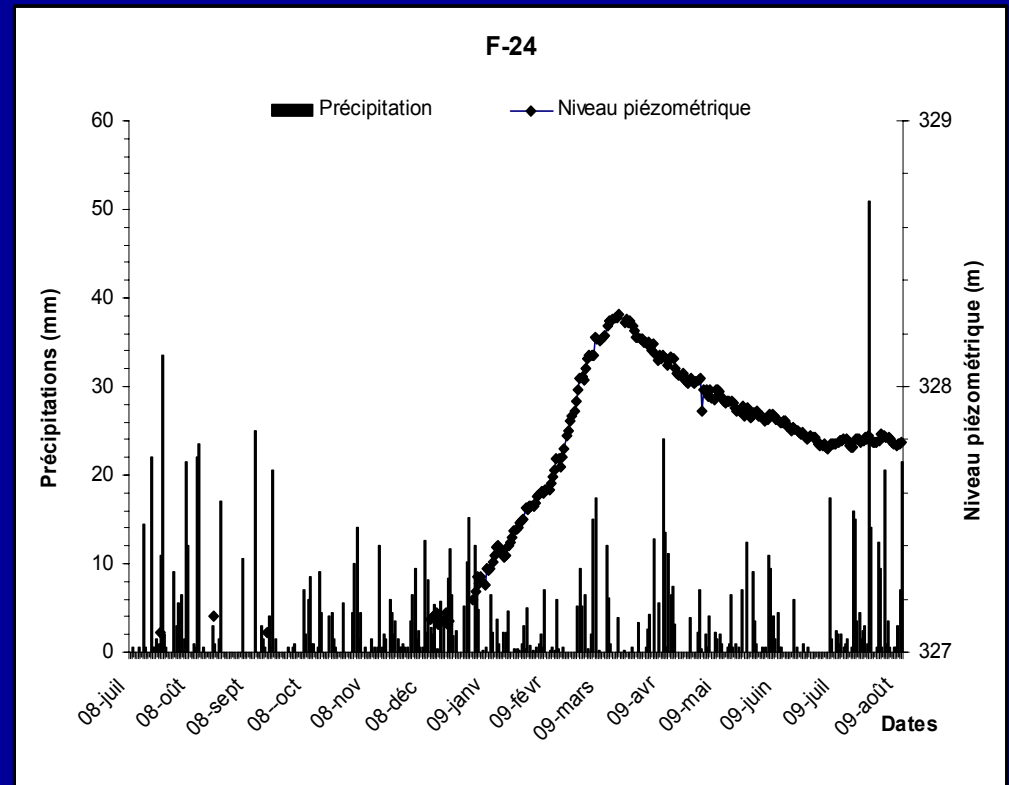


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## 2. Hydrogeology - piezometer monitoring

- Sample preliminary results:  
Increase in water level during winter, due to tailings deposition (NE section)





## 2. Hydrogeology - ongoing work

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- Piezometer monitoring
- Interpretation of data
- Geological model



# Anticipated outcomes

- Proposition for an effective reclamation scenario using Goldex tailings based on:
  - Understanding of geochemistry of the tailings
  - Understanding of hydrogeological behaviour of the area
- Work in progress: column tests, piezometer monitoring



# Remaining questions

- Can a mono-layer be efficient for the entire site?
- Can AMD be partially neutralised by the Goldex tailings?
- Will it be possible to maintain the elevated water table after closure?
- Representativity of small scale lab tests to reflect real conditions?



# Acknowledgements

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Ressources naturelles  
et Faune

Québec



**AEM**



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## NSERC-Polytechnique-UQAT Chair Industrial partners 2006-2012



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