



# Seismic Microzonation of the Greater Montréal Area

Prof. Luc Chouinard

Department of Civil engineering and Applied Mechanics  
luc.chouinard@mcgill.ca

*Front steps of the Montreal East City Hall after the Saguenay earthquake (11/25/1988, Ms=6)*



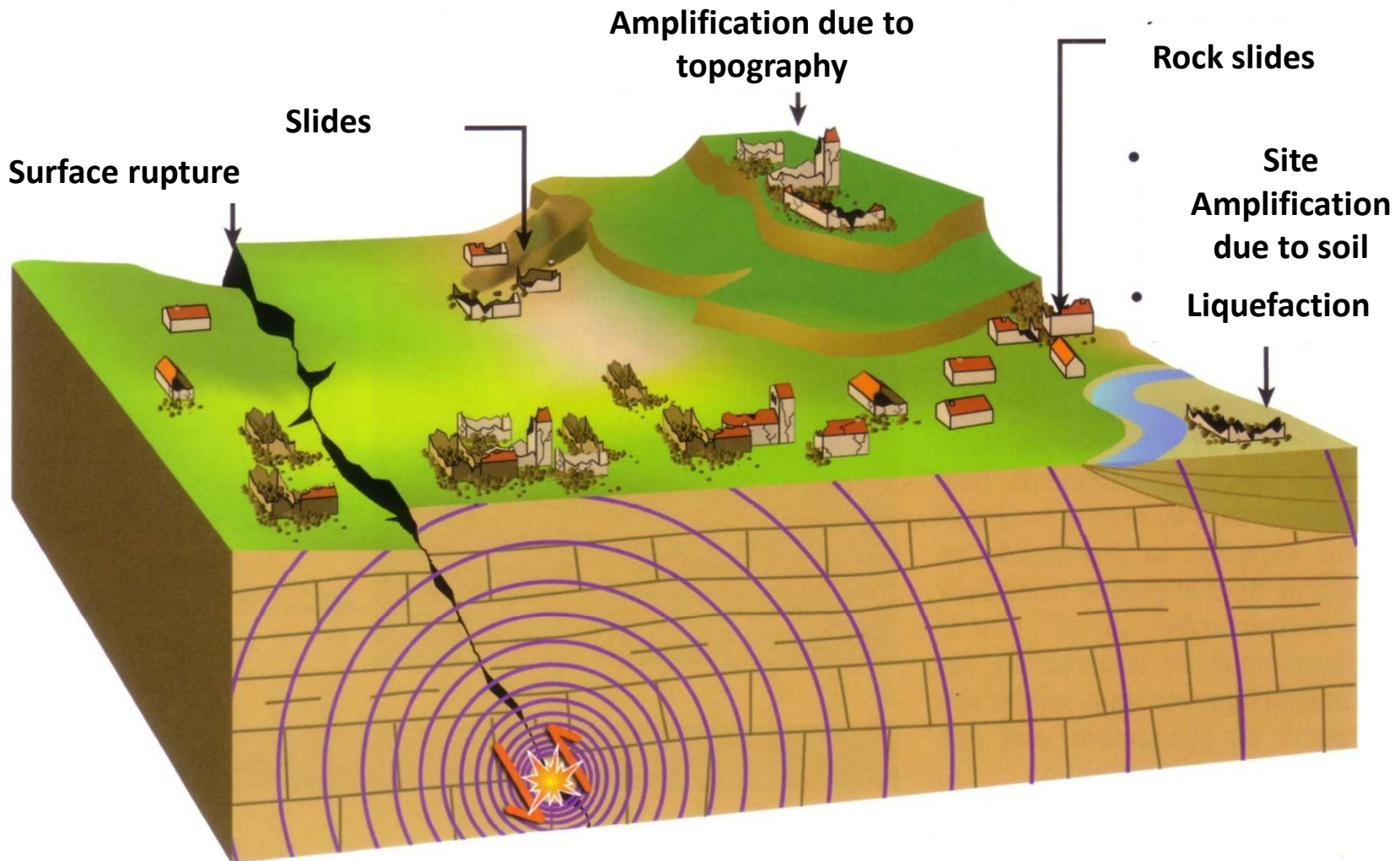
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**RCRP**

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# SEISMIC EFFECTS

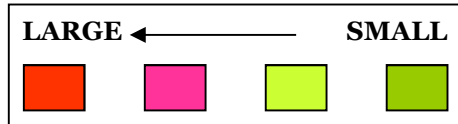


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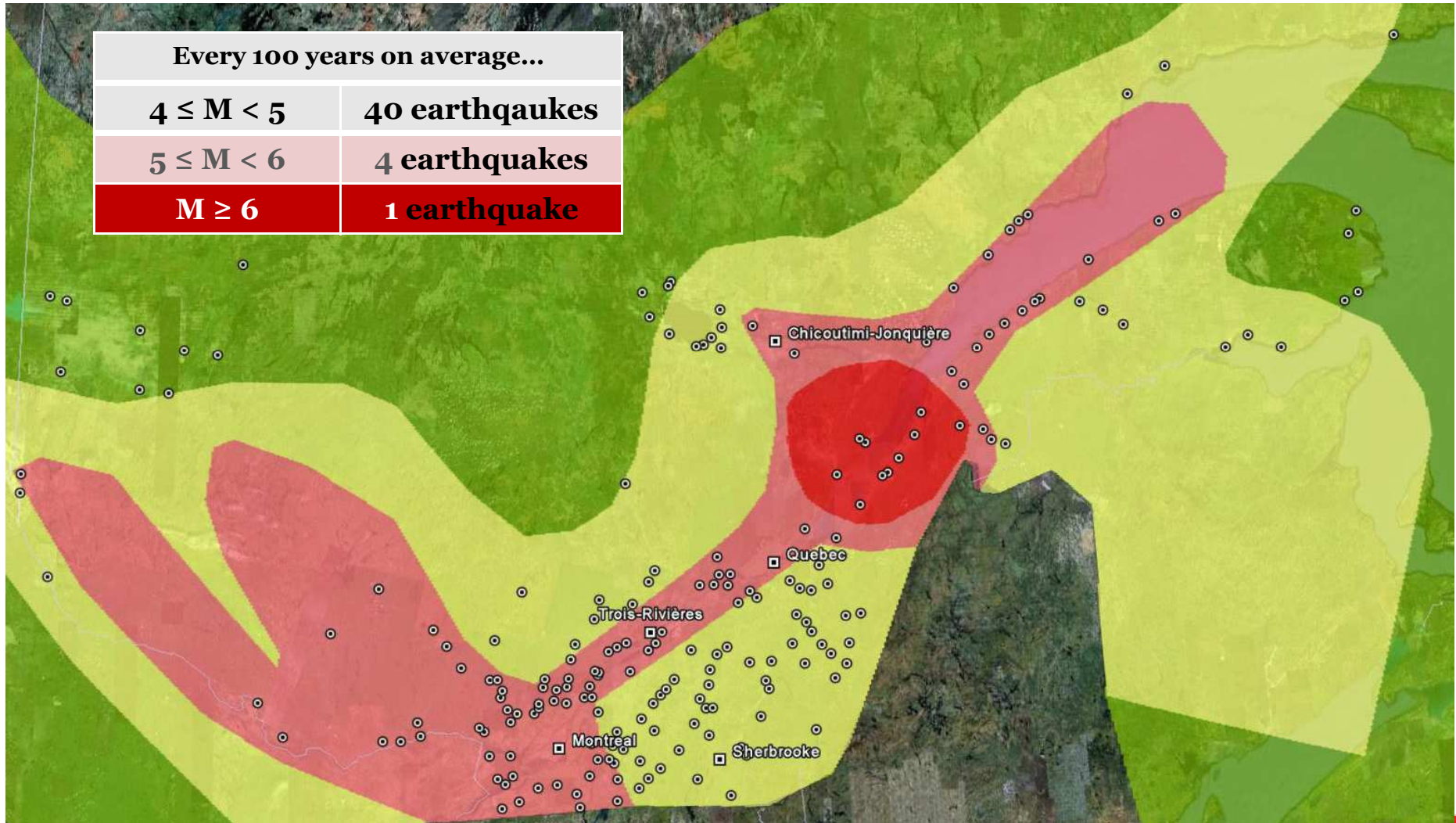
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# SEISMIC HAZARDS IN QUEBEC



Every 100 years on average...	
$4 \leq M < 5$	40 earthquakes
$5 \leq M < 6$	4 earthquakes
$M \geq 6$	1 earthquake



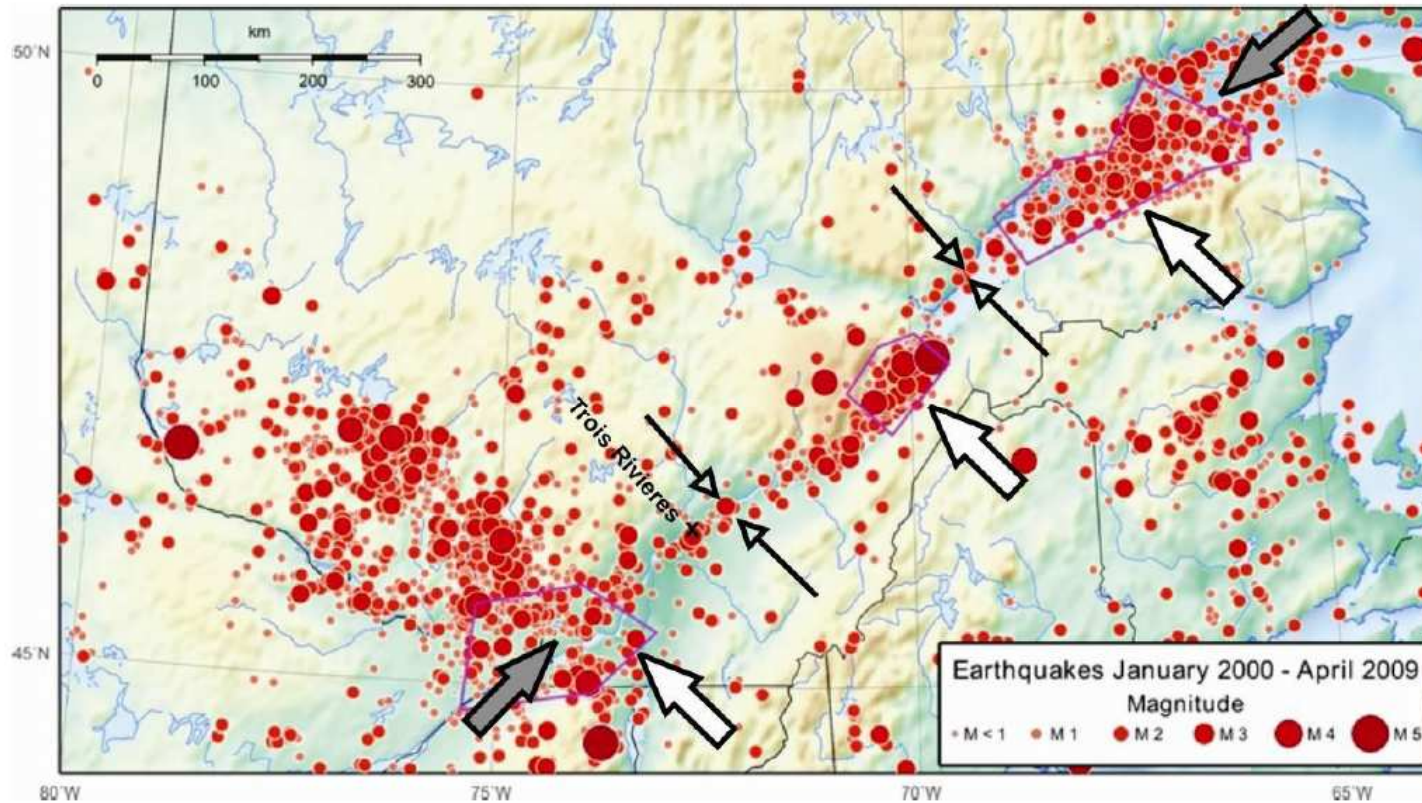
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D'après Séisme Canada



# RECENT SEISMIC ACTIVITY



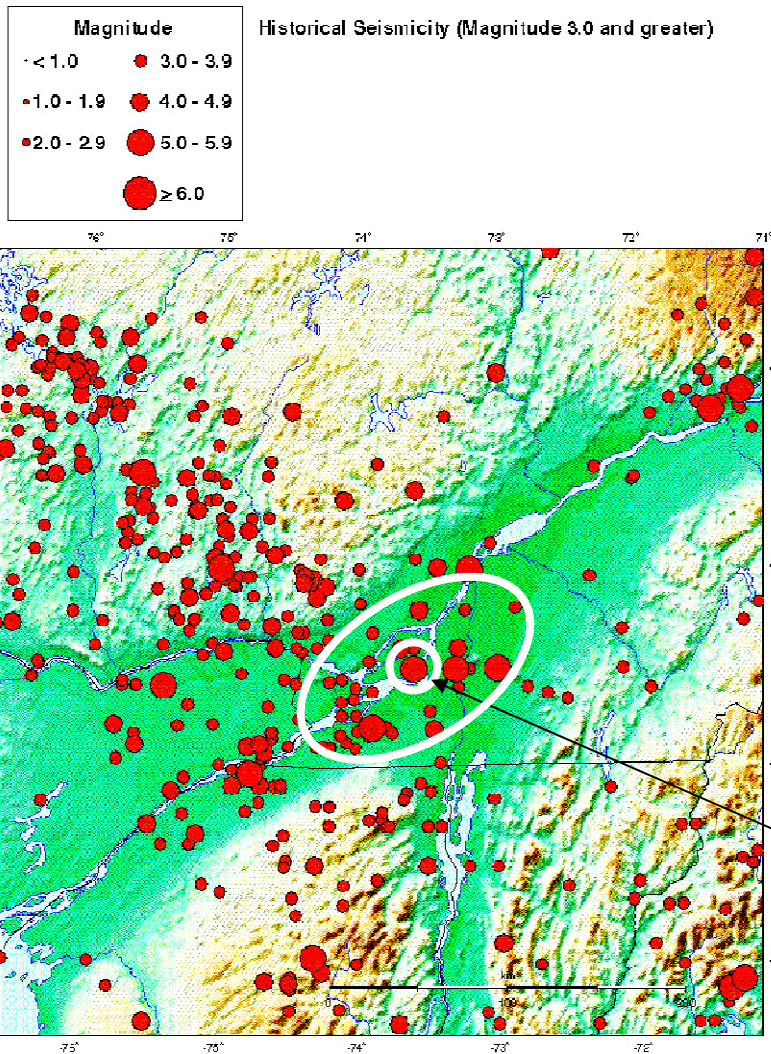
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(Source : Adams, 2011)

# SEISMIC ACTIVITY CLOSE TO MONTREAL



**I<sub>MM</sub>=VI** General alert, moderate amount of damages to buildings and non-structural elements

**I<sub>MM</sub>=VII** Considerable damage to poorly built or poorly designed buildings.

**I<sub>MM</sub>=VIII** General panic, considerable damage to general building stock and non-structural elements.

- ✓ March 23, 1897 - I<sub>MM</sub>=VI
- ✓ November, 1893 - I<sub>MM</sub>=VI
- ✓ September 16, 1816 - I<sub>MM</sub>=VI
- ✓ September 9, 1816 - I<sub>MM</sub>=VIII
- ✓ **September, 16 1732 I<sub>MM</sub>=VIII**

**Widely felt**

**More than 300 houses damaged**

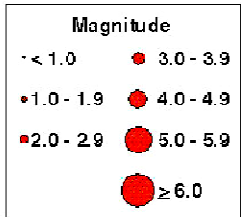


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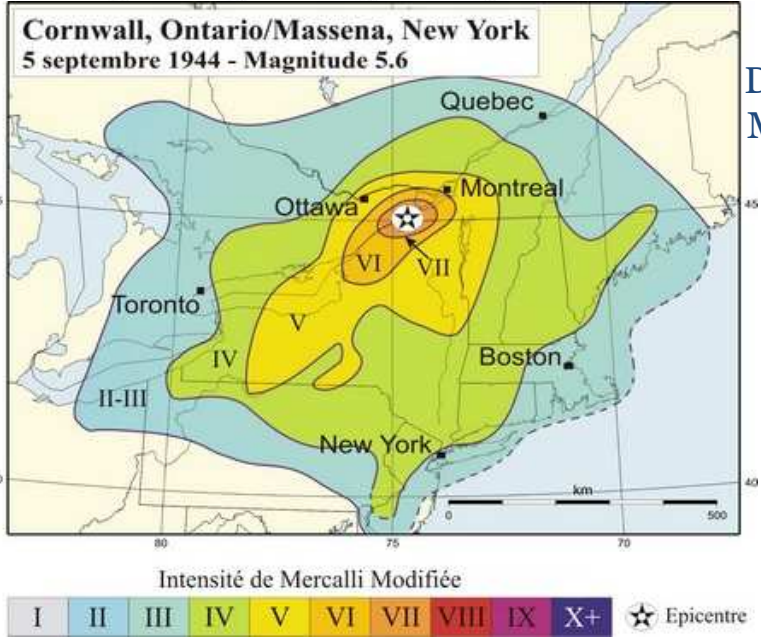
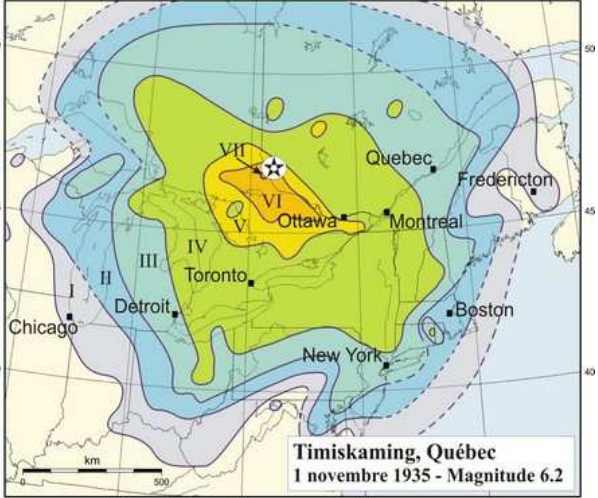
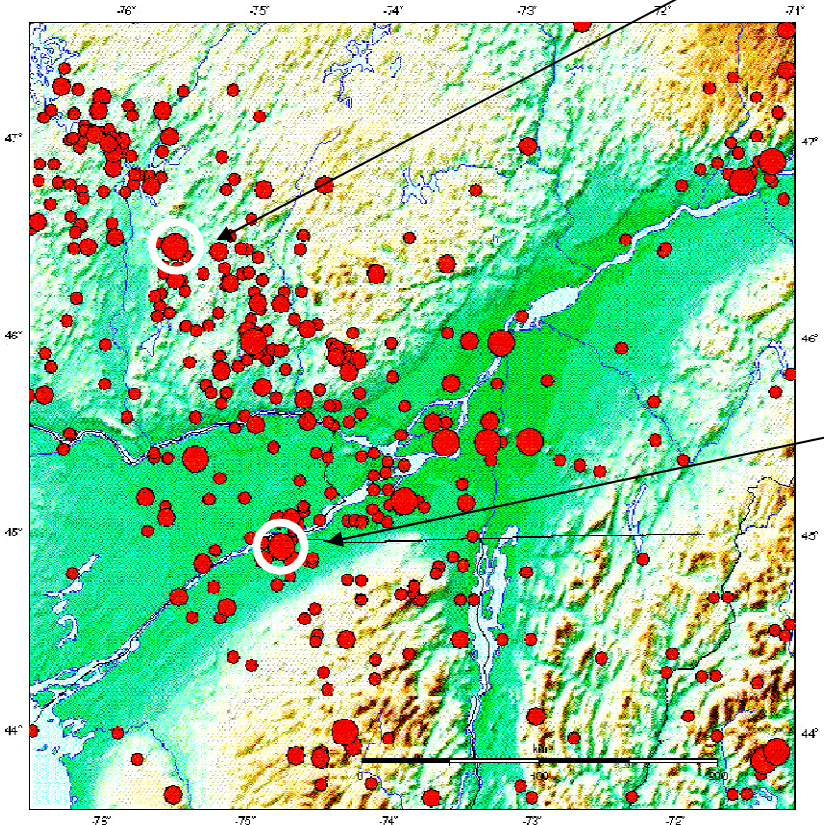
(Source : National Earthquake Hazard Program, Ottawa, Canada)



# SEISMIC ACTIVITY CLOSE TO MONTREAL



Historical Seismicity (Magnitude 3.0 and greater)



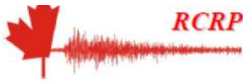
Damages of M\$ in 1944



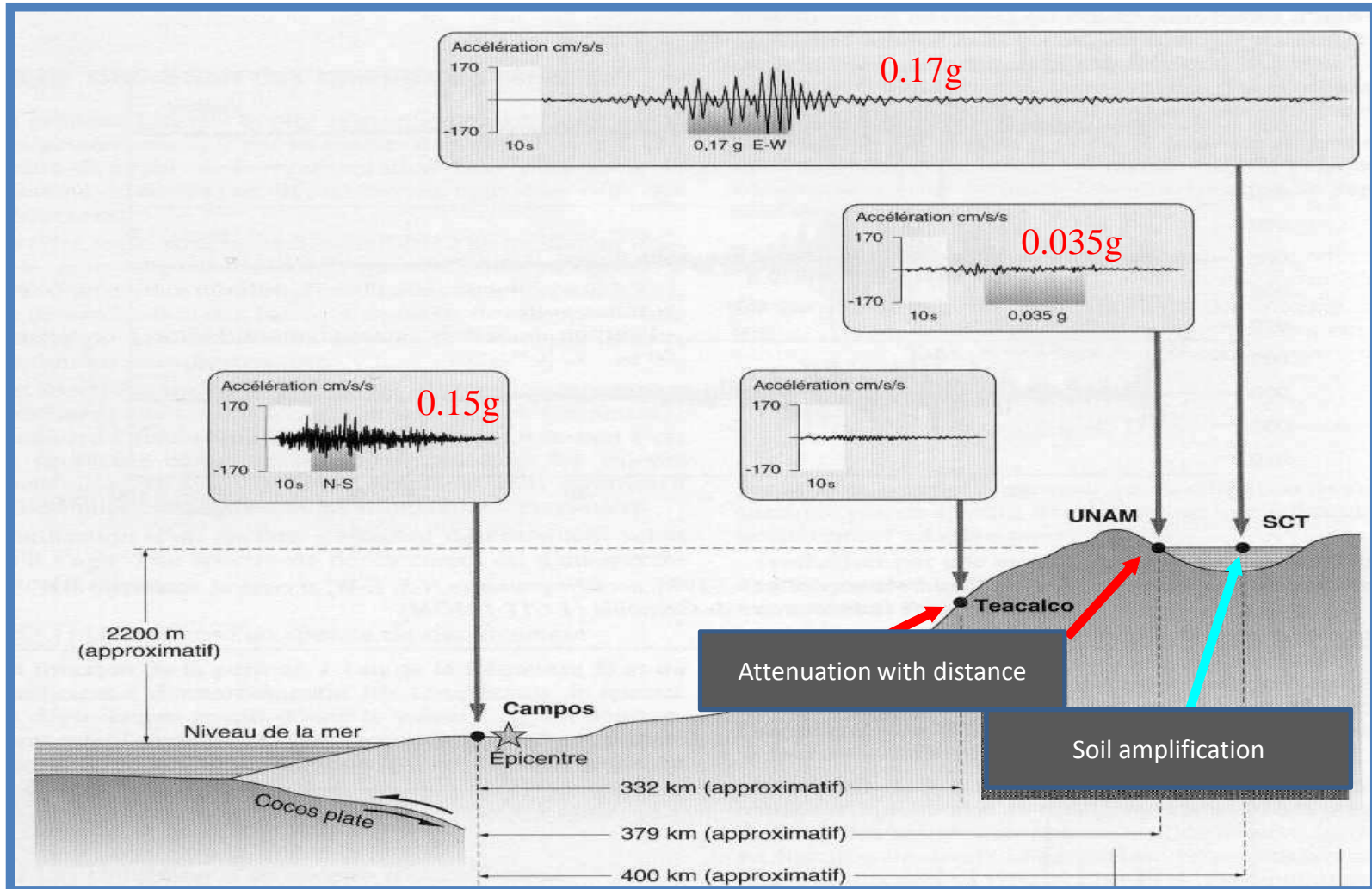
mic Research Network (Source :National Earthquake Hazard Program, Ottawa, Canada)

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# AMPLIFICATION OF SEISMIC WAVES DUE TO SOIL DEPOSITS



## M6.6 Mexico earthquake (1985)

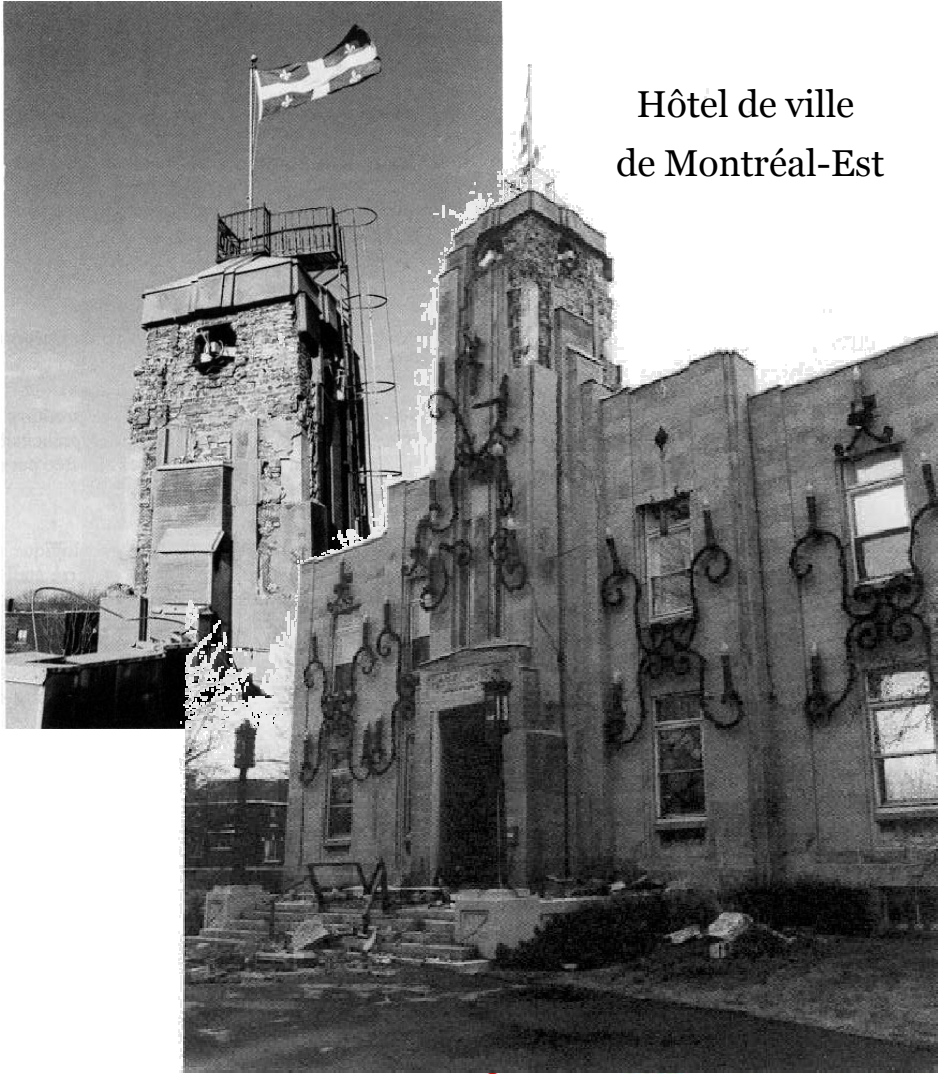


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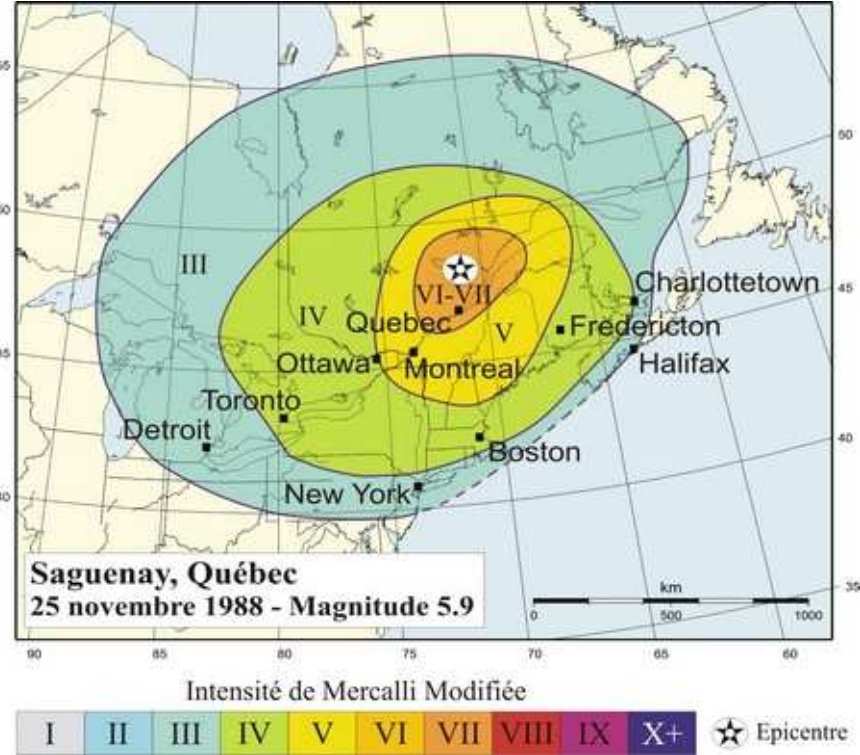
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# LOCAL SITE AMPLIFICATION FROM SOIL DEPOSITS



Hôtel de ville  
de Montréal-Est



Distance > 300km from epicenter  
17m of clay at the site  
Facade was in a poor state



# USING MICROZONATION

Identify within the most critical zones:

- Critical infrastructures (hospitals, schools, fire stations , etc..)
- Critical lifelines (bridges, tunnels, water supply, etc.)
- Industrial sites
- Vulnerability of buildings

Develop earthquake scenarios to estimate :

- Damages to buildings
- Economic losses
- Societal consequences

Better understanding of hazards :

- New constructions
- Retrofit of existing structures



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## Identification of seismic amplification zones

- NBCC 2005 (2010) classification ( $V_{s30}$ )
- Others (e.g.  $V_s$  +  $F_0$ )

## Identification of potential soil instability

- Liquefaction
- Slopes

## Input to ShakeMaps

- Scénario mode
- Operational mode
  - Zones most affected during an earthquake
  - Identification of potential damage to guide inspections and interventions



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# INPUTS FOR THE MICROZONATION

- Soil types and properties
- Soil response
  - Amplification
  - Liquefaction
  - Slope stability



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- Types of deposits
  - Surface geology map
  - Borings (~ 20,000 to bedrock)
  - Detailed borings with soil layers (~ 2,000)
- Geotechnical properties
  - SPT
  - $V_s$  (shear wave velocity)
  - $F_0$  (fundamental frequency)



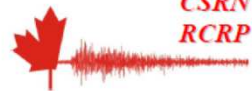
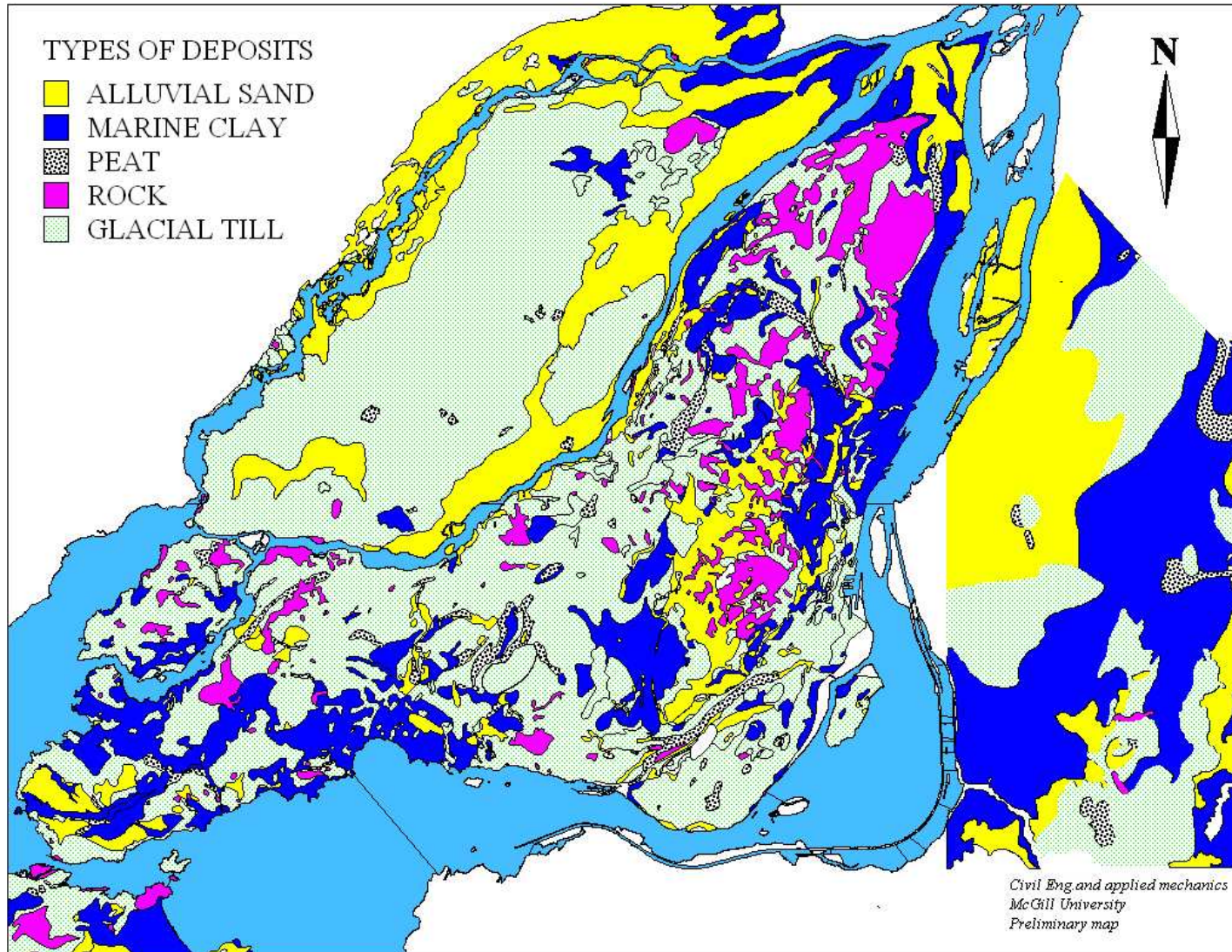
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# SURFACE GEOLOGY MAP

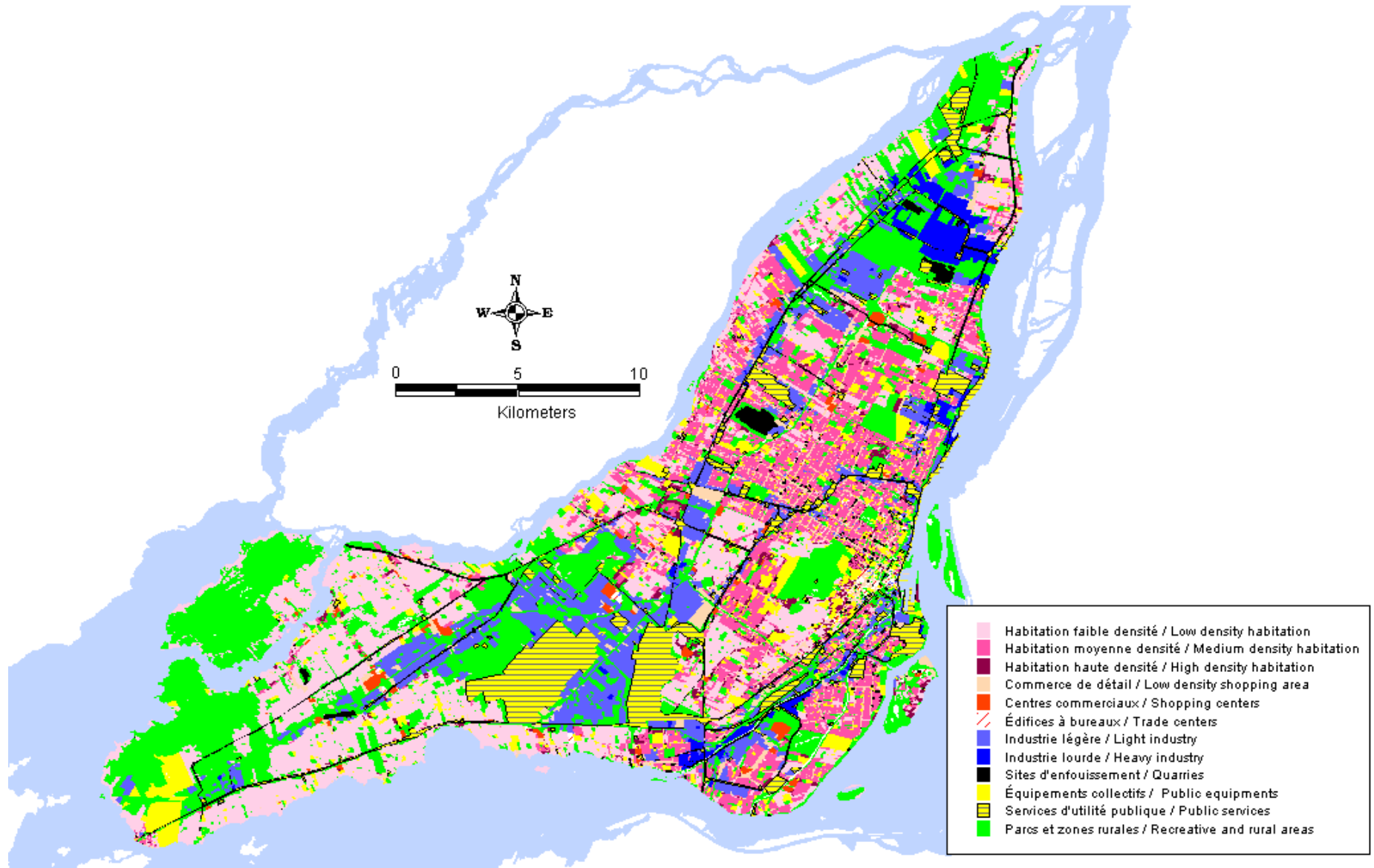


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# LAND USE

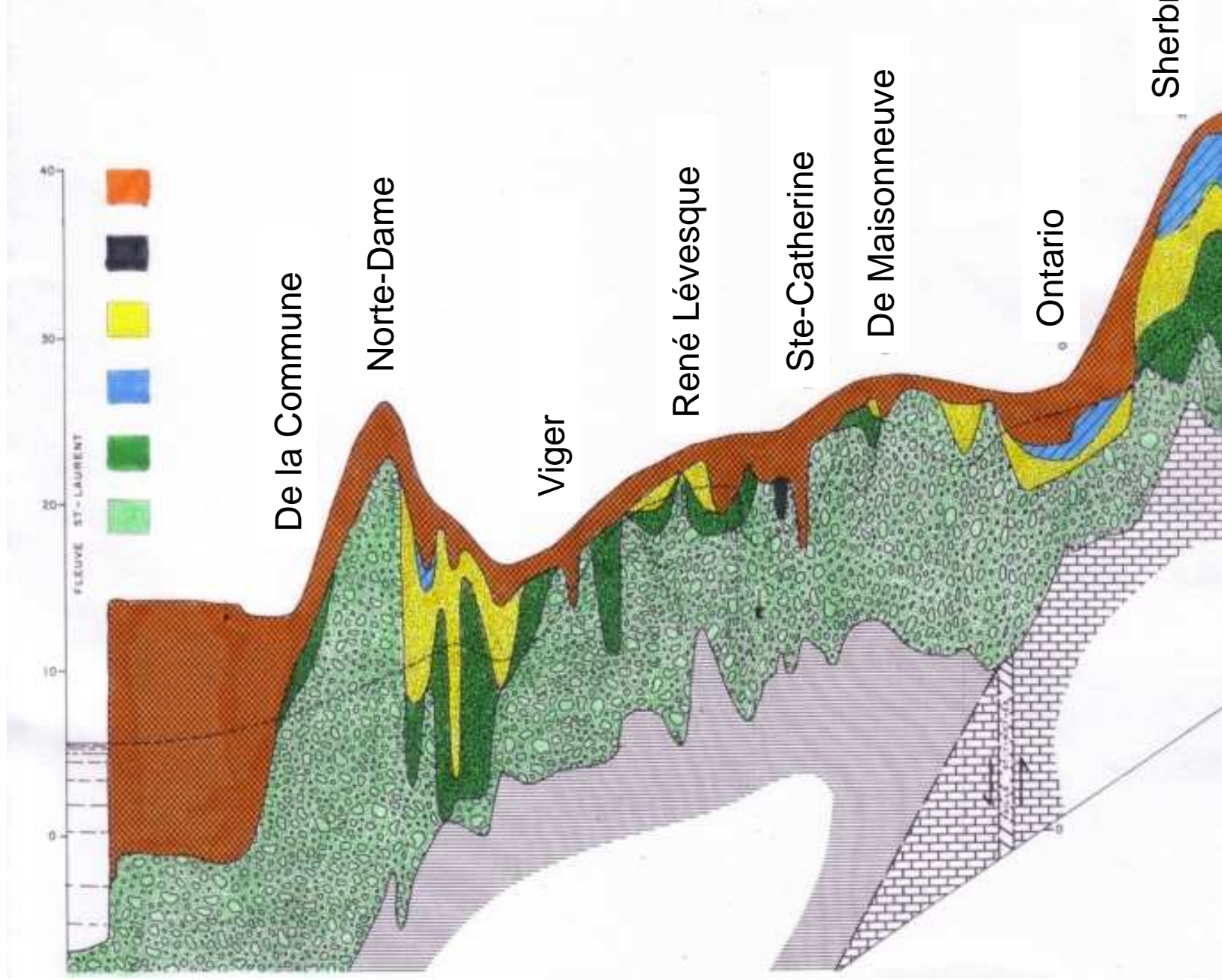


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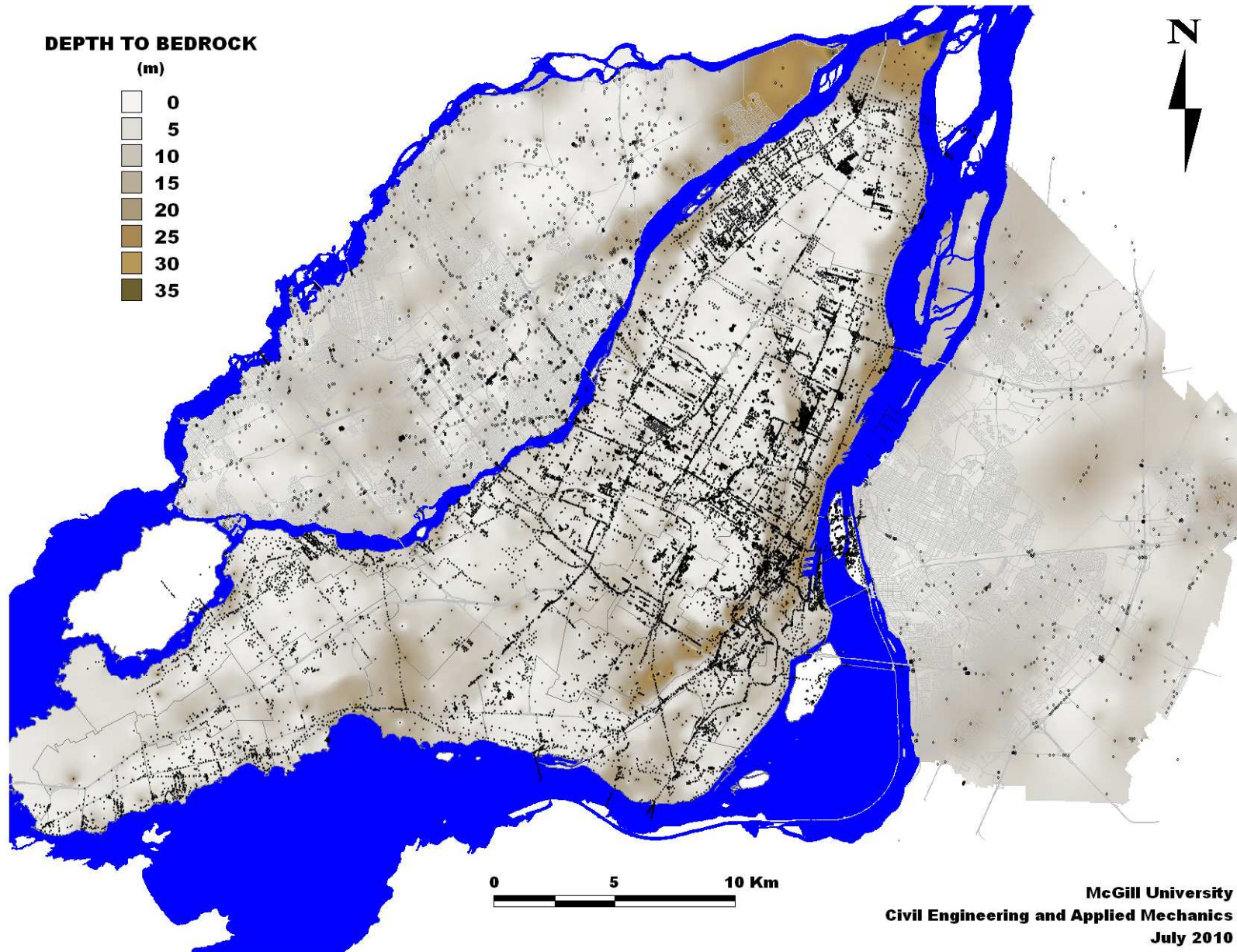


# Cross-sections (~ Old-Montreal)



# Depth to bedrock

( ~ 20,000 borings).



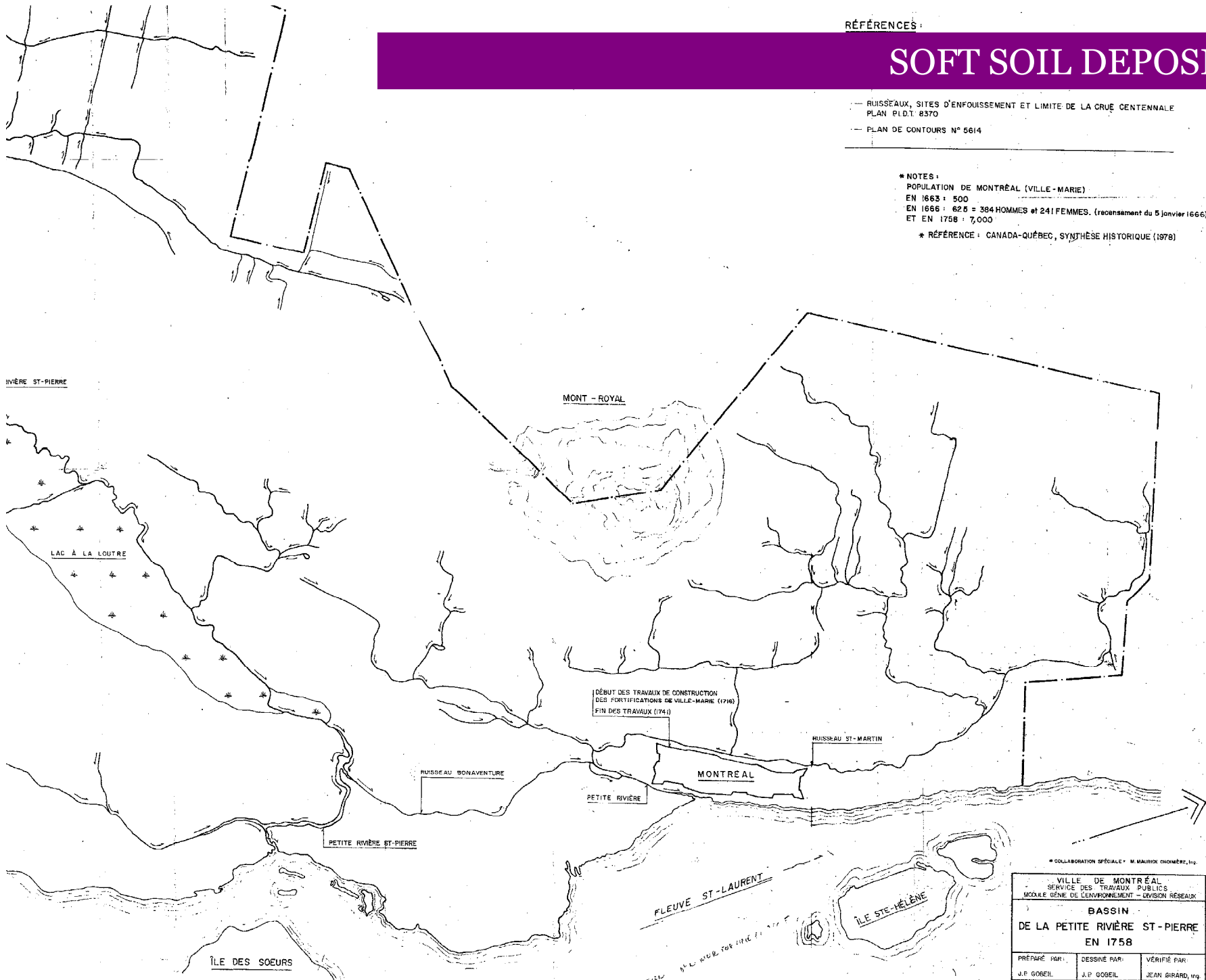


RÉFÉRENCES :

# SOFT SOIL DEPOSITS

- RUISSEAUX, SITES D'ENFOUSSEMENT ET LIMITE DE LA CRUE CENTENNALE  
PLAN P.D.T. 8570
- PLAN DE CONTOURS N° 5614

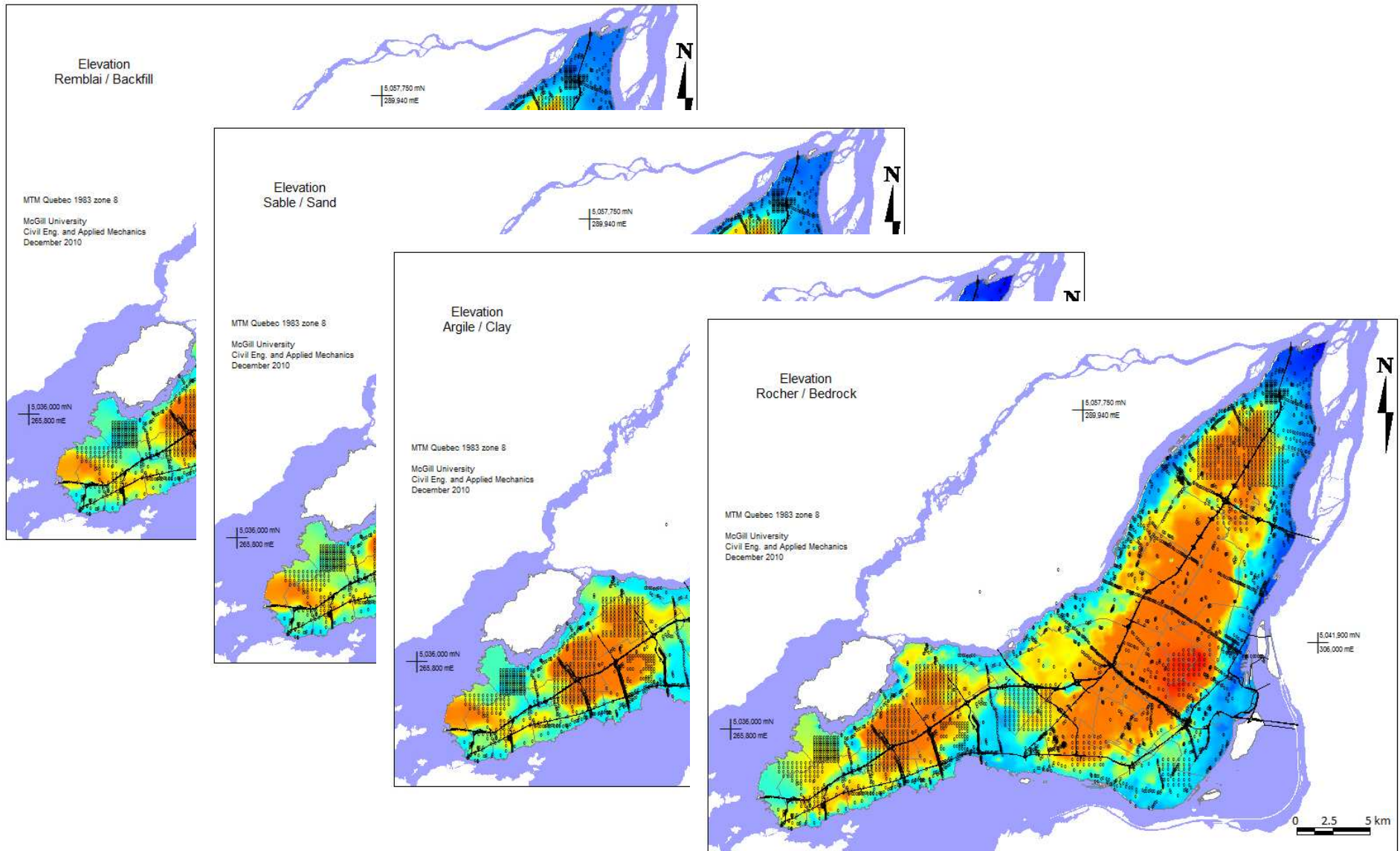
\* NOTES :  
POPULATION DE MONTRÉAL (VILLE-MARIE)  
EN 1663 : 500  
EN 1666 : 625 = 384 HOMMES et 241 FEMMES. (recensement du 5 janvier 1666)  
ET EN 1758 : 7,000  
\* RÉFÉRENCE : CANADA-QUÉBEC, SYNTHÈSE HISTORIQUE (1978)



\* COLLABORATION SPÉCIALE : M. MAURICE CHOMÈRE, Ing.

VILLE DE MONTRÉAL SERVICE DES TRAVAUX PUBLICS MODULE GÉNÉ DE L'ENVIRONNEMENT - DIVISION RÉSEAUX		
BASSIN DE LA PETITE RIVIÈRE ST-PIERRE EN 1758		
PRÉPARÉ PAR :	DESSINÉ PAR :	VÉRIFIÉ PAR :
J.P. GOBEL	J.P. GOBEL	JEAN GIRARD, Ing.

# 3D soft deposits model (~ 2000 boreholes)

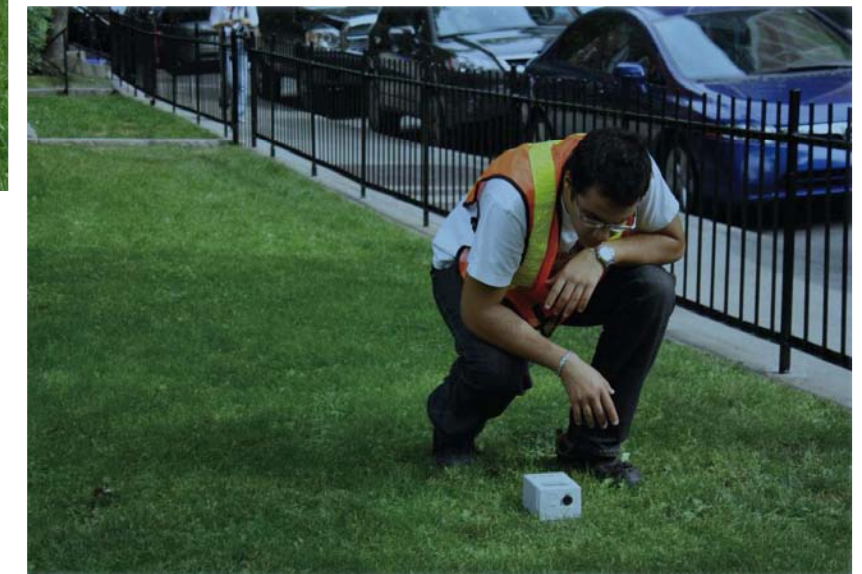
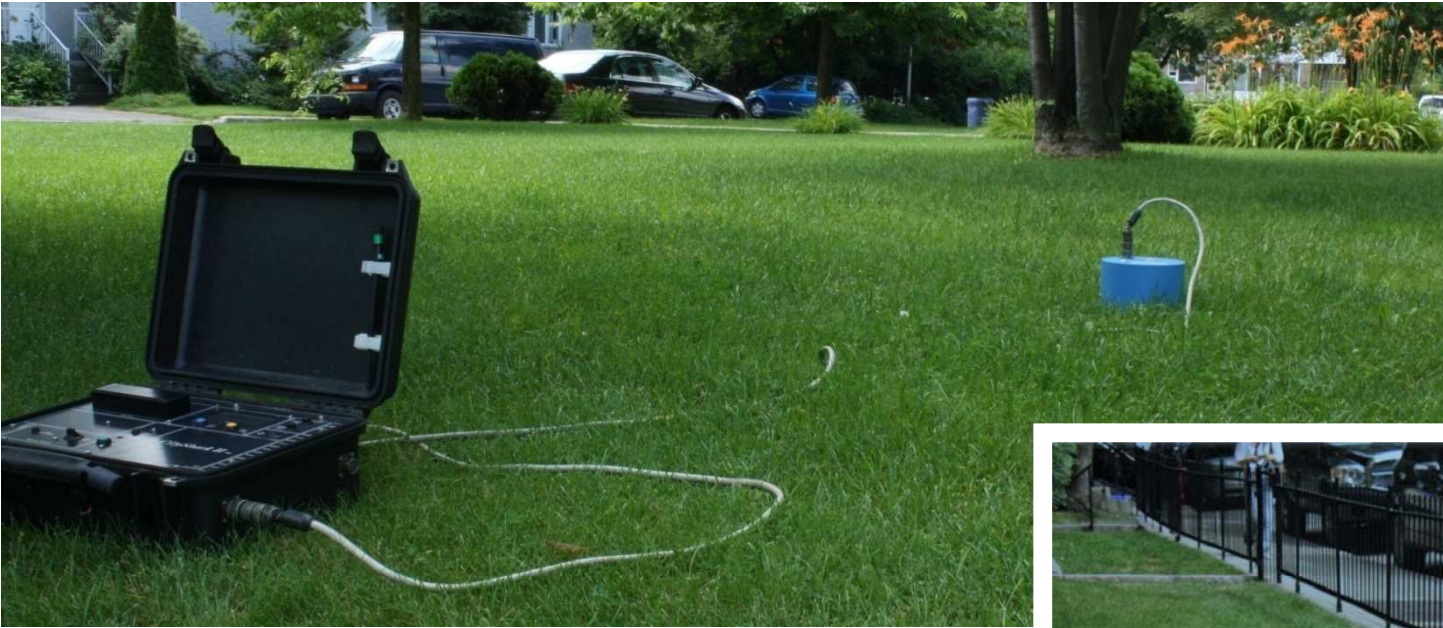


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## SOIL PROPERTIES: HVSR and $F_0$



### Measurements (10 min)

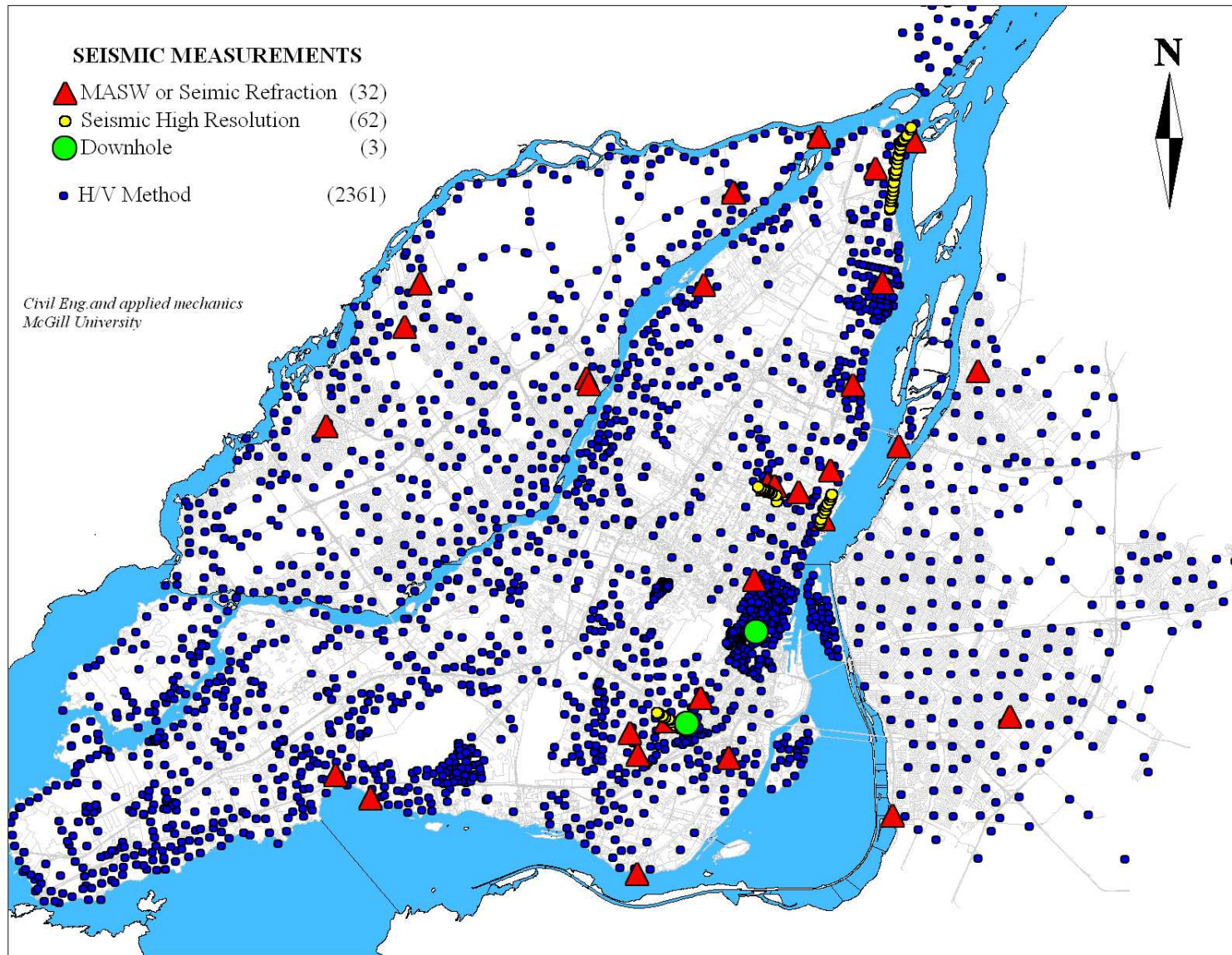
- Avoid sources of large vibrations (heavy traffic industrial sites)
- Avoid windy and rainy days

## Ambient noise measurement

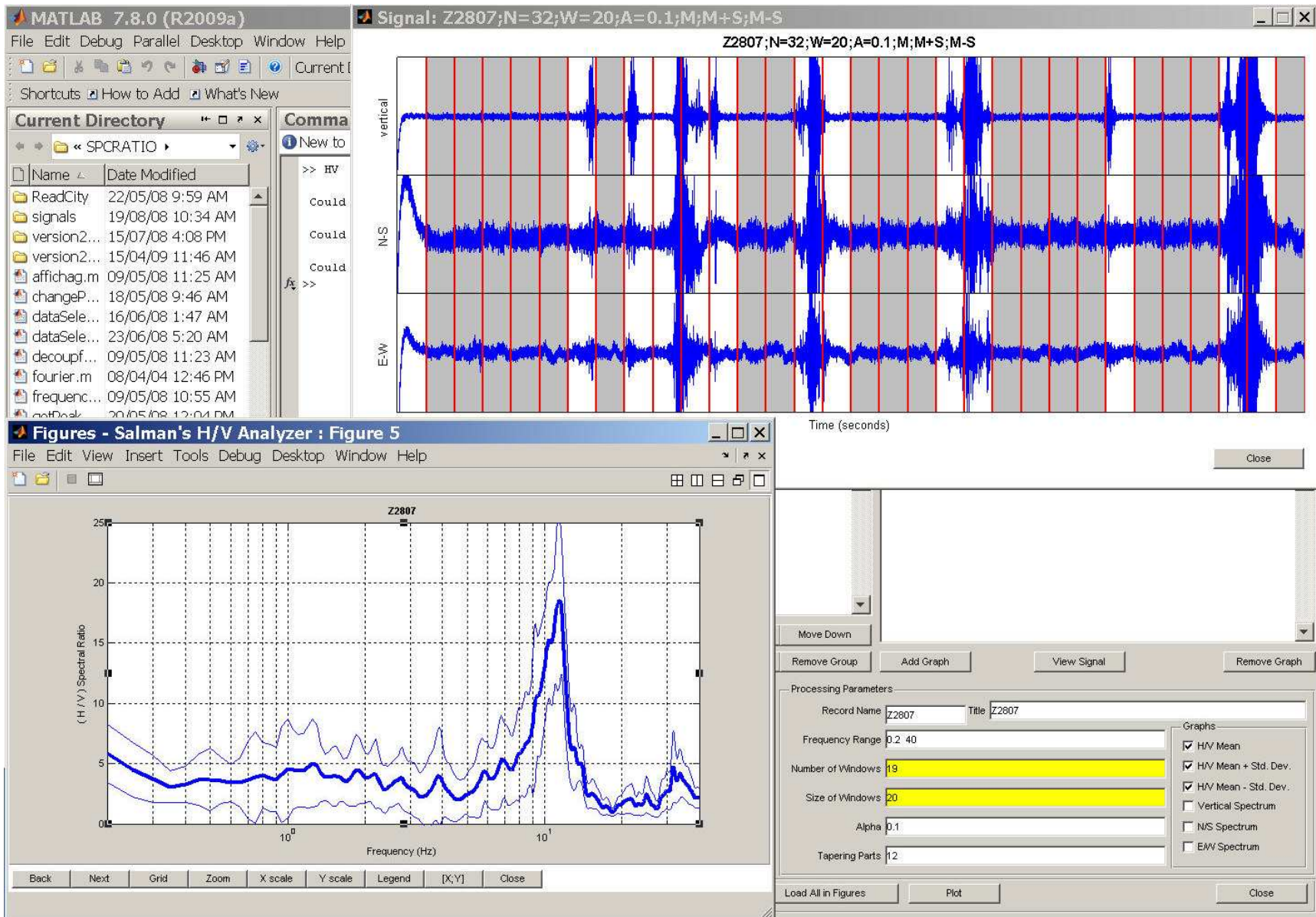


# SOIL PROPERTIES: HVSR and $F_0$

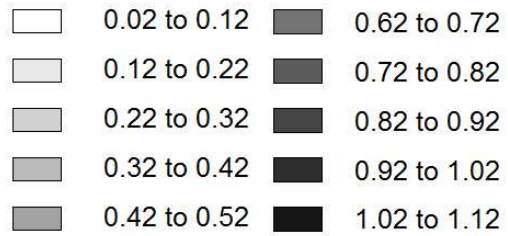
Total number of sites over a 4 year period (~ 1500 sites)



# McGill processing software : Ground Ambient Noise Analysis

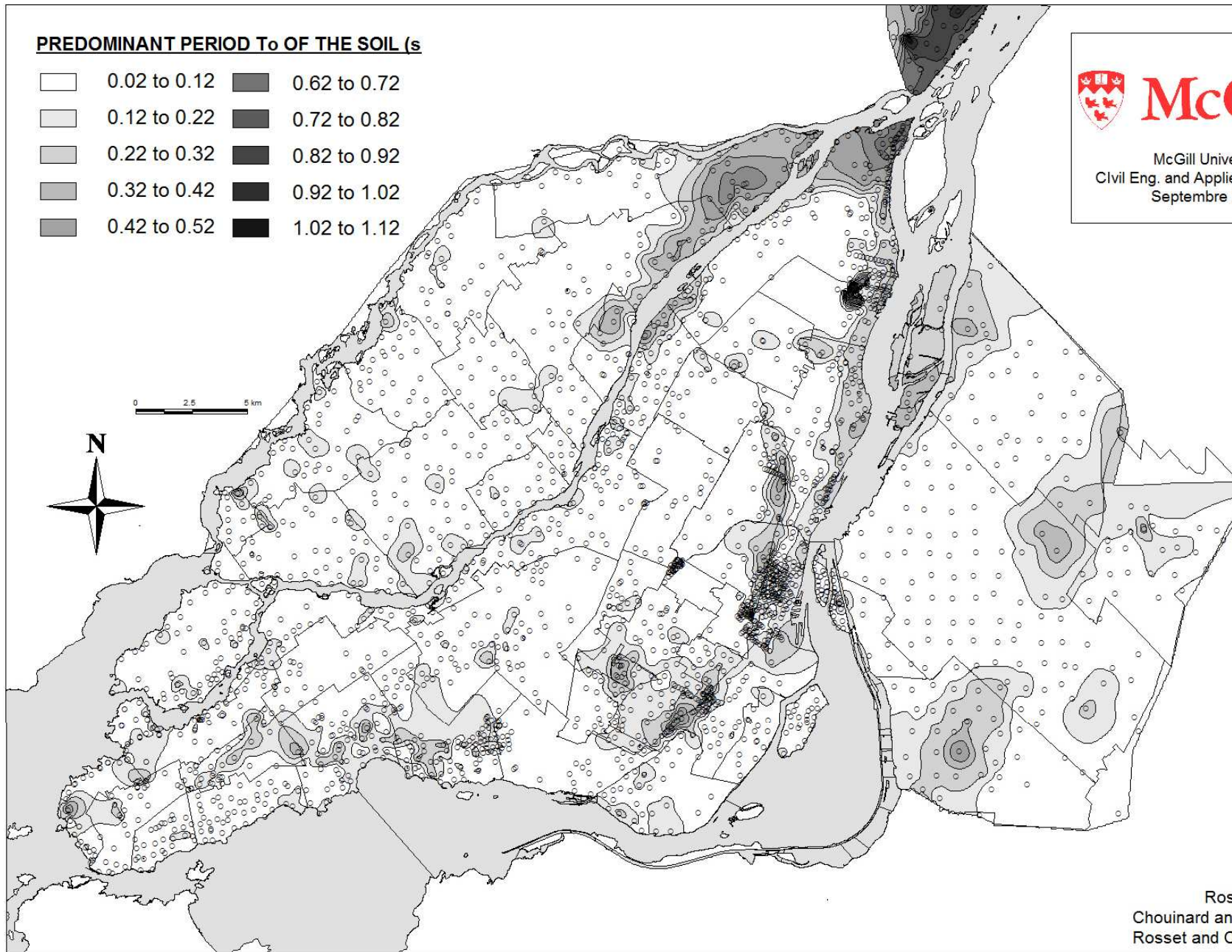


**PREDOMINANT PERIOD  $T_0$  OF THE SOIL (s)**



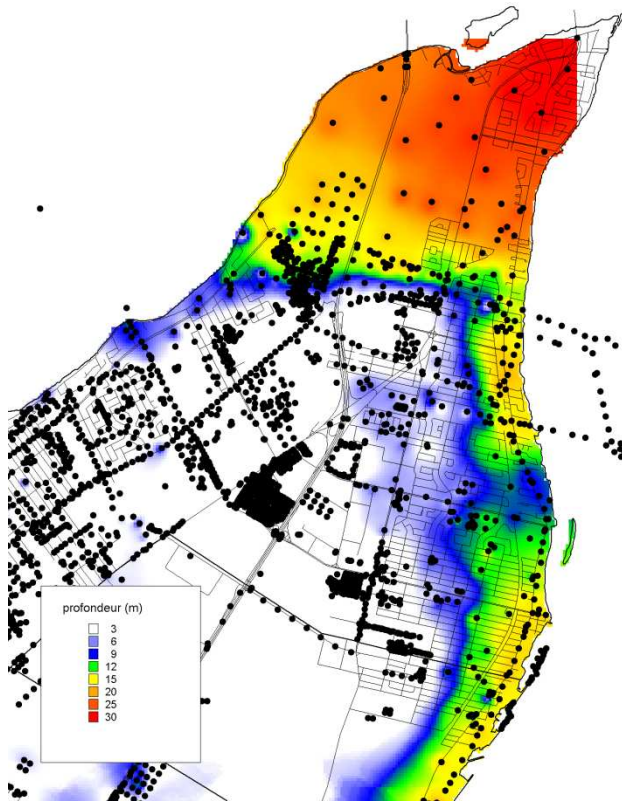
**McGill**

McGill University  
Civil Eng. and Applied Mechanics  
Septembre 2011

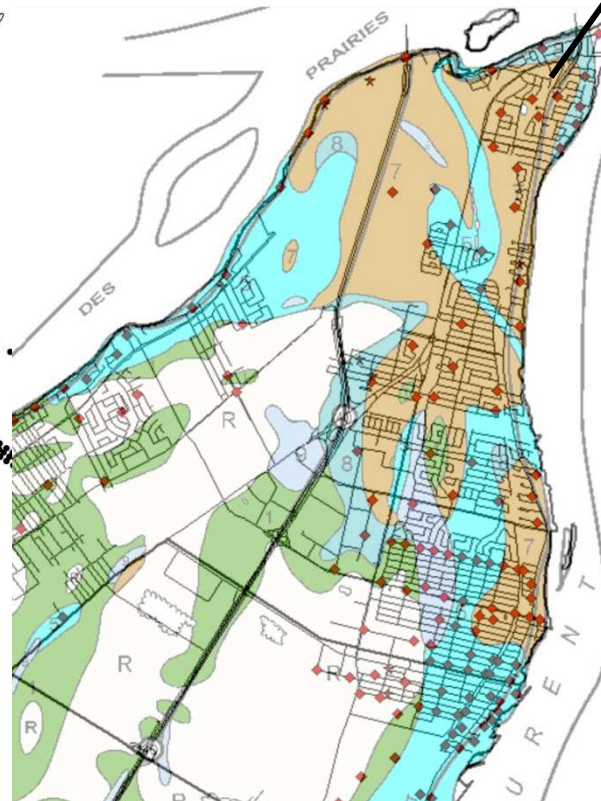


Sources:  
Rosset et al. (2012)  
Chouinard and Rosset (2011)  
Rosset and Chouinard (2009)

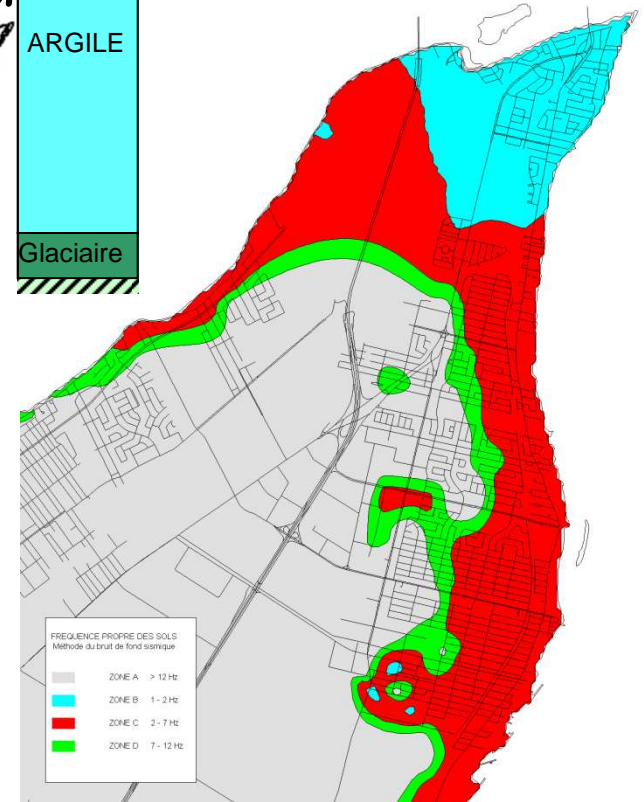
## Depth to bedrock



## Surface deposits



$f_0$



(Prest & Hode-  
Keyser, 1982)

# Correlations

Research Network  
pour la recherche parasismique

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