MBOA Spring Seminar 2017

SOILS & FOUNDATIONS IN MANITOBA

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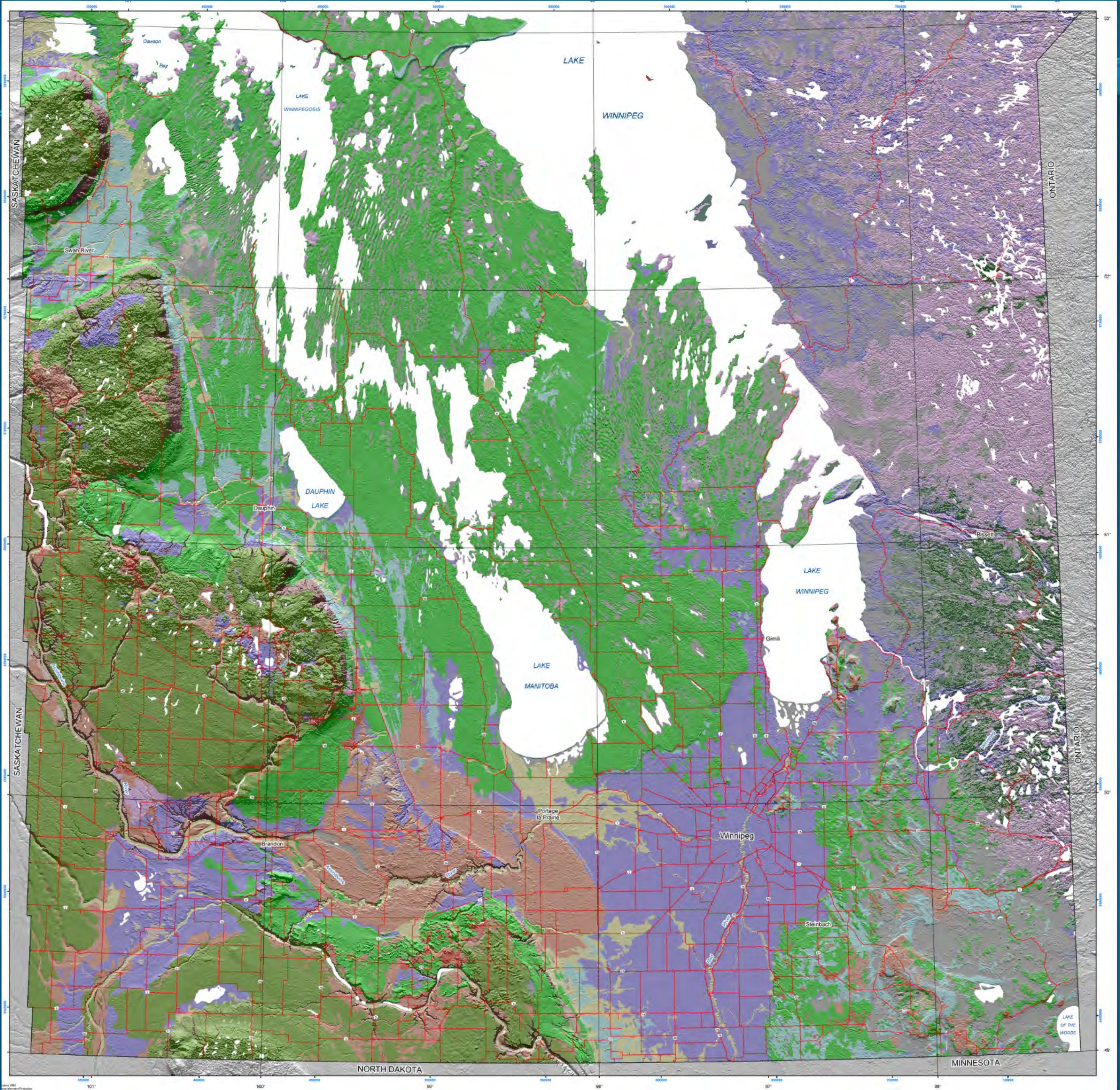
Outline

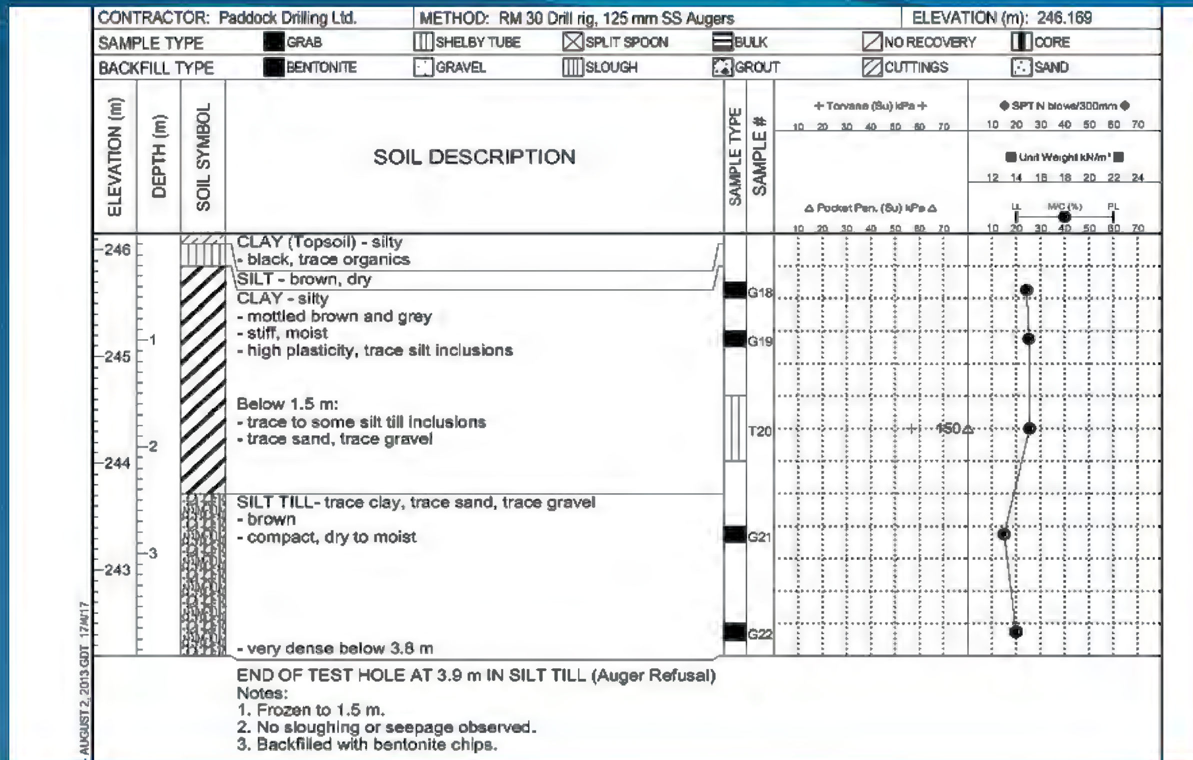
- Manitoba Soil Conditions
- Geotechnical Investigations
- Foundation Types
- Foundation Design
- Foundation Inspection



LAKE
WINNIPEG
LAKE
WINNIPEGOSIS
Swan River
SASKATCHEWAN
ONTARIO
DAUPHIN
LAKE
Dauphin
LAKE
WINNIPEG
Gimli
Bissett
LAKE
MANITOBA
Portage
la Prairie
Winnipeg
Brandon
Steinbach
NORTH DAKOTA
MINNESOTA
LAKE
OF THE
WOODS

Manitoba Soil Conditions

- Clay – low to medium capacity / expansive
- Silt – frost susceptible / groundwater
- Sand – medium capacity / groundwater
- Gravel – good capacity / groundwater
- Glacial Till – medium to high capacity
- Bedrock – high capacity
- Permafrost – discontinuous / continuous



The results of the grain size test are used to classify the soil beyond the rough separation into fine grained and coarse grained. The classification is based on amounts by weight within the respective grain-size fractions, as follows:

noun	gravel, sand, silt, clay	> 35 % and main fraction
"and"	and gravel, and silt, etc.	> 35 %
adjective	gravelly, sandy, silty, clayey, etc.	20 % - 35 %
"some"	some sand, some silt, etc.	10 % - 20 %
"trace"	trace sand, trace silt, etc.	1 % - 10 %

Consistency	Field Identification
Very soft	Easily penetrated several centimeters by the fist
Soft	Easily penetrated several centimeters by the thumb
Firm	Can be penetrated several centimeters by the thumb with moderate effort
Stiff	Readily indented by the thumb but penetrated only with great effort
Very stiff	Readily indented by the thumb nail
Hard	Indented with difficulty by the thumbnail

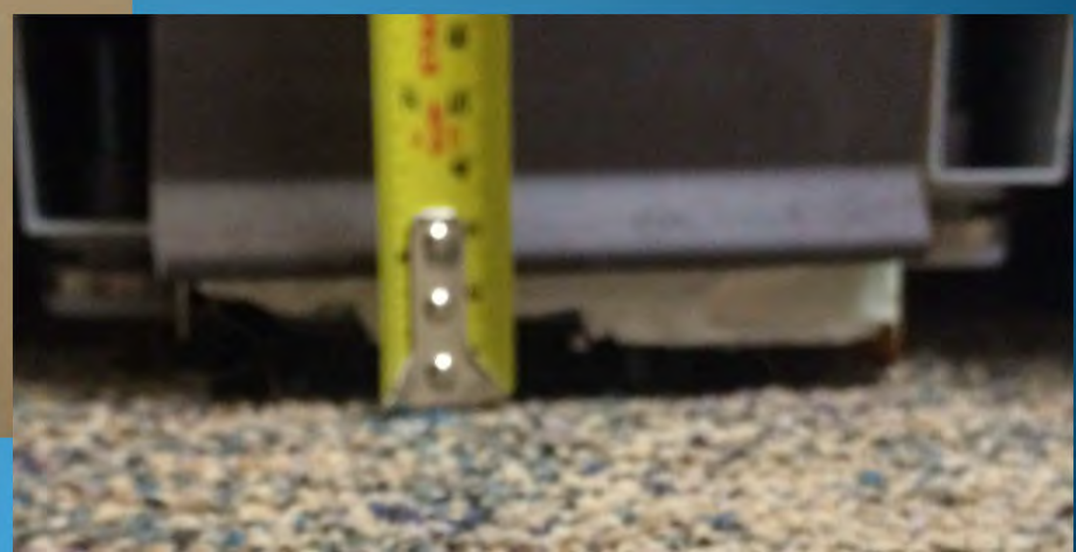
Alluvial Soils


River Rd W
River Rd E
248
Franklin St N
Franklin St
Google earth
Image © 2016 DigitalGlobe
© 2016 Google
N
1 km

CLAY

CLAY – Shrink / Swell

Soil Shrinkage Effects



Swell Effects

SILT

SILT – Frost Susceptible


12/27/2012 15:07

SAND

1 week later

+2 days

Glacial Till

Bedrock

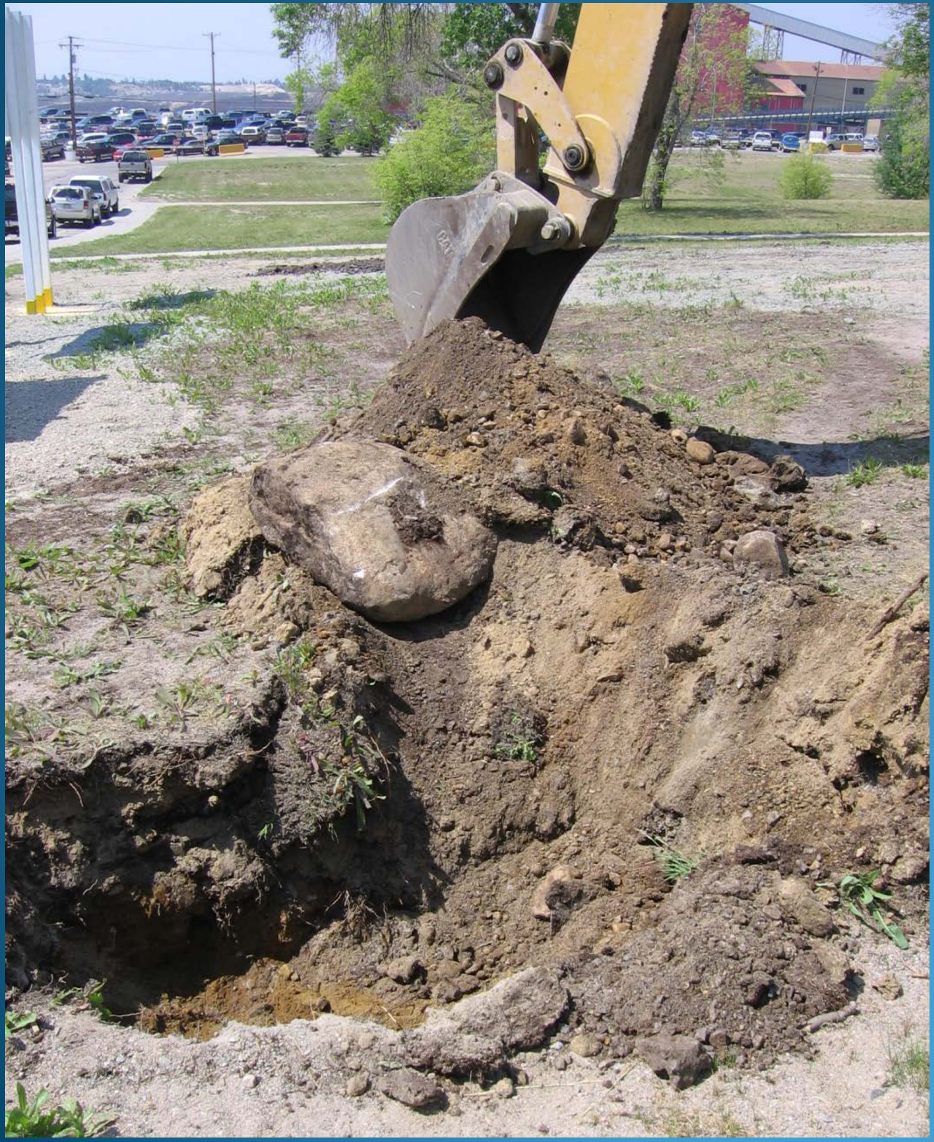
Bedrock - Foundations

Permafrost - Ice at 30 ft

GEOTECHNICAL INVESTIGATIONS

- What is being built and where?
- Expected foundation loads?
- Previously developed site?
- Site Constraints – access / work area / utilities
- Existing information
- Possible foundation types
- How will investigation be performed?

Investigations



Test Pits

Small Diameter TH's

Large Diameter TH's

Foundation Types

- Shallow Foundations
  - Spread footings (square / strip)
  - Mats
- Driven Pile Foundations
  - Timber piles
  - Precast prestressed concrete piles
  - Steel piles (HP / pipe)
- Drilled Shafts
  - CIP friction piles
  - End bearing – straight shaft / belled

Shallow Foundations

- Bearing pressures of 1000 to 3000 psf (48 to 150 kPa) on soil or higher on dense glacial till / bedrock

Driven Pile Types

Timber Piles

- Friction + end bearing piles, lengths to about 15 m
- Douglas fir (300 butt 250 tip diameter)
- Service load: 20 to 25 tons (170 to 225 kN)

Precast Prestressed Concrete Piles

- end bearing pile , lengths (6 to 23 m)
- 3 common sizes (300 / 350 / 400 mm diameter)
- Service loads: 50 / 70 / 90 tons (445 kN / 625 kN / 800 kN)

Steel Piles (HP & pipe sections)

- end bearing piles, cut / splice to length
- many sizes, common HP12 x 89
- Service loads: 110 - 450 tons (1000 - 4000 kN) (HP10 - HP18)

Pile Driving

Drilled Shafts

CIP Friction Piles

- 16” to 36” diameter and larger
- 20 + feet long
- Light building loads (+/- 30 kips / 125 kN)

Caissons End Bearing on Glacial Till

- +/- 28” diameter and larger
- End bearing pressures of 5 to 30 ksf

Drilled Shafts

Rock Socketted Caissons

- +/- 28” diameter and larger
- End bearing pressures of 60 to 350 ksf
- Side shear resistance up to 150 psi
- Loads >1000 tons (10,000 kN)

Foundation Design

- Shallow Foundations – bearing capacity formula

Foundation Design

- Driven Pile Foundations:
  - Local Experience
  - Published formulas
  - Wave equation modeling
    computer modeling of pile / soil / driving system
  - Load testing – static and/or dynamic
-

Foundation Design

- Drilled Shafts
  - Local Experience
  - Published formulas
  - Load testing – static and/or dynamic

NBC - Limit States Design

- Until NBC 2010, foundations designed with Working Stress Design methods (global factors of safety applied to account for uncertainty)
- Limit states design (LSD) requires:
  - Evaluate serviceability limit state (SLS)
  - Evaluate ultimate limit state (ULS)

SLS and ULS

- SLS – service limit state (settlements)
  - Conditions that restrict / constrain intended use
  - Expected loads
  - WSD – ‘allowable’ foundation capacities were related to settlement
- ULS – ultimate limit state
  - Collapse mechanisms
  - Foundations – excessive settlements, bearing capacity failure
  - need to determine an ultimate value
  - Loads / resistances factored to account for uncertainty

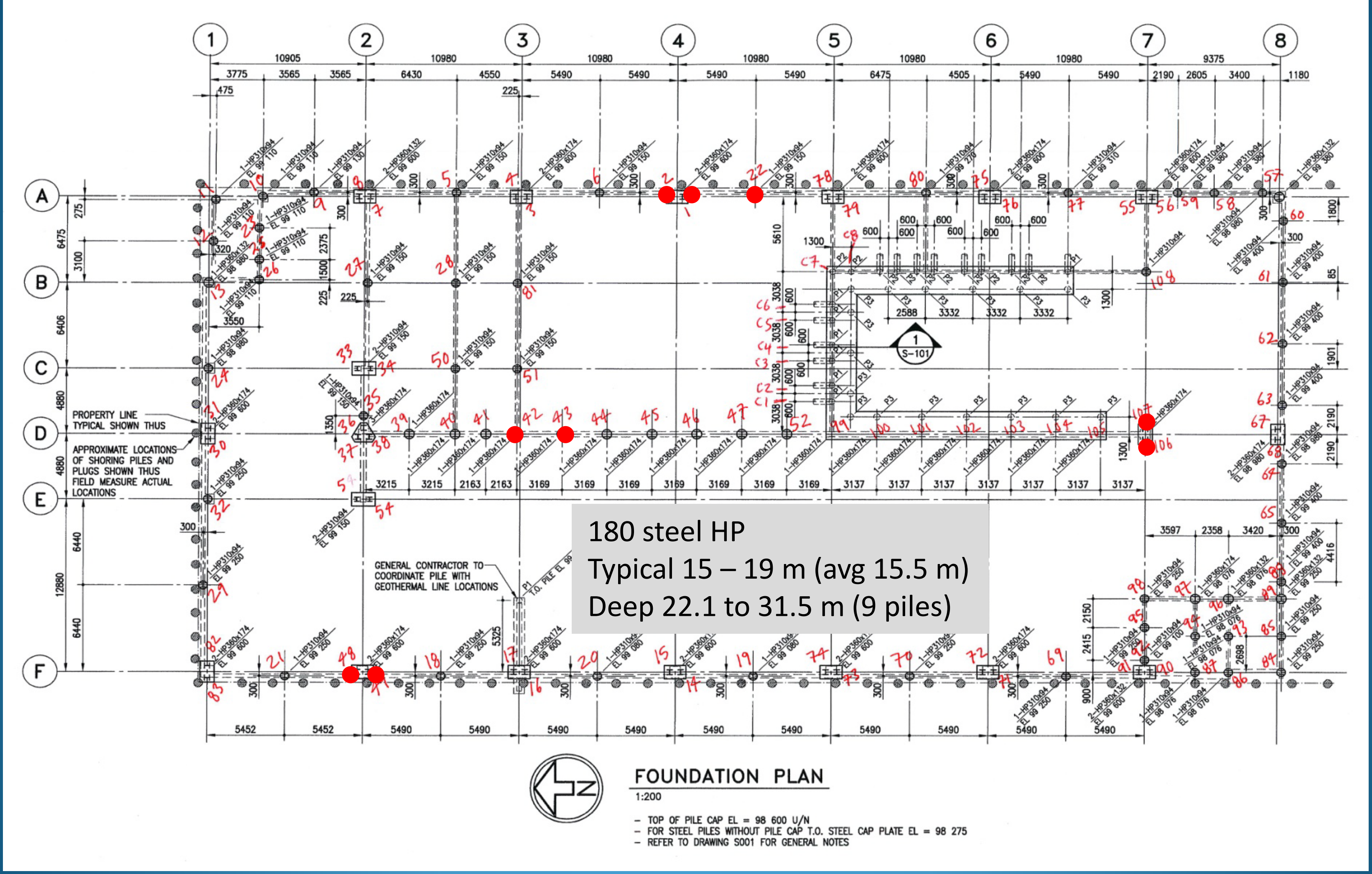
Foundation Inspection

- Footings:
  - Design depth, bearing pressure, soil type
  - clean undisturbed bearing surface,
  - unfrozen ground, free of water
  - Probe bearing surface
- Driven Piles:
  - Drive to length
  - Drive to refusal criteria, restrike, monitor heave
  - Record pile details, final sets, penetration
  - Dynamic testing and analysis

36” Diameter Boulder

Variable Bedrock Surface

Variable Pile Refusal Depth



180 steel HP
Typical 15 – 19 m (avg 15.5 m)
Deep 22.1 to 31.5 m (9 piles)

NBC 2010 – Section 4.2

4.2.2.3. Field Review

1) A field review shall be carried out by the *designer* or by another suitably qualified person to ascertain that the subsurface conditions are consistent with the design and that construction is carried out in accordance with the design and good engineering practice. (See Note A-4.2.2.3.(1).)

2) The review required by Sentence (1) shall be carried out

a) on a continuous basis
   i) during the construction of all *deep foundation units* with all pertinent information recorded for each *foundation unit*,
   ii) during the installation and removal of retaining structures and related backfilling operations, and
   iii) during the placement of engineered *fills* that are to be used to support the *foundation units*, and

b) as required, unless otherwise directed by the *authority having jurisdiction*,
   i) in the construction of all *shallow foundation units*, and
   ii) in excavating, dewatering and other related works.

4.2.2.4. Altered Subsurface Condition

1) If, during construction, the *soil*, *rock* or *groundwater* is found not to be of the type or in the condition used in design and as indicated on the drawings, the design shall be reassessed by the *designer*.

2) If, during construction, climatic or any other conditions change the properties of the *soil*, *rock* or *groundwater*, the design shall be reassessed by the *designer*.

Foundation Inspection

- Footings:
  - clean undisturbed bearing surface,
  - unfrozen ground, free of water
  - Probe bearing surface

- Driven Piles:
  - Drive to length
  - Drive to refusal criteria, restrike, monitor heave
  - Record pile details, final sets, penetration
  - Dynamic testing and analysis

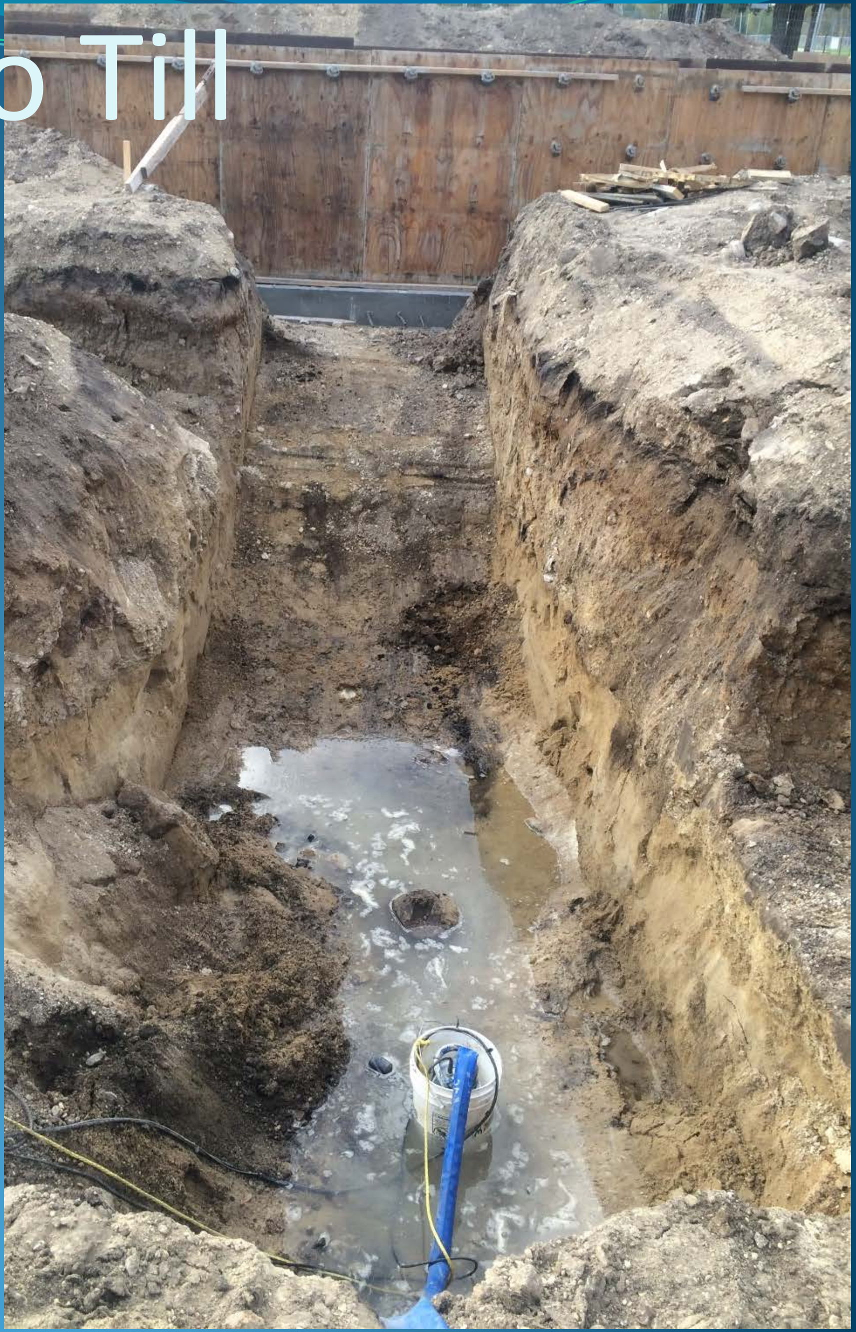
Footing On Silt Till

Foundation Frost Effects

Footing on Till

Variable Footing Depths

Change in Depth To Till



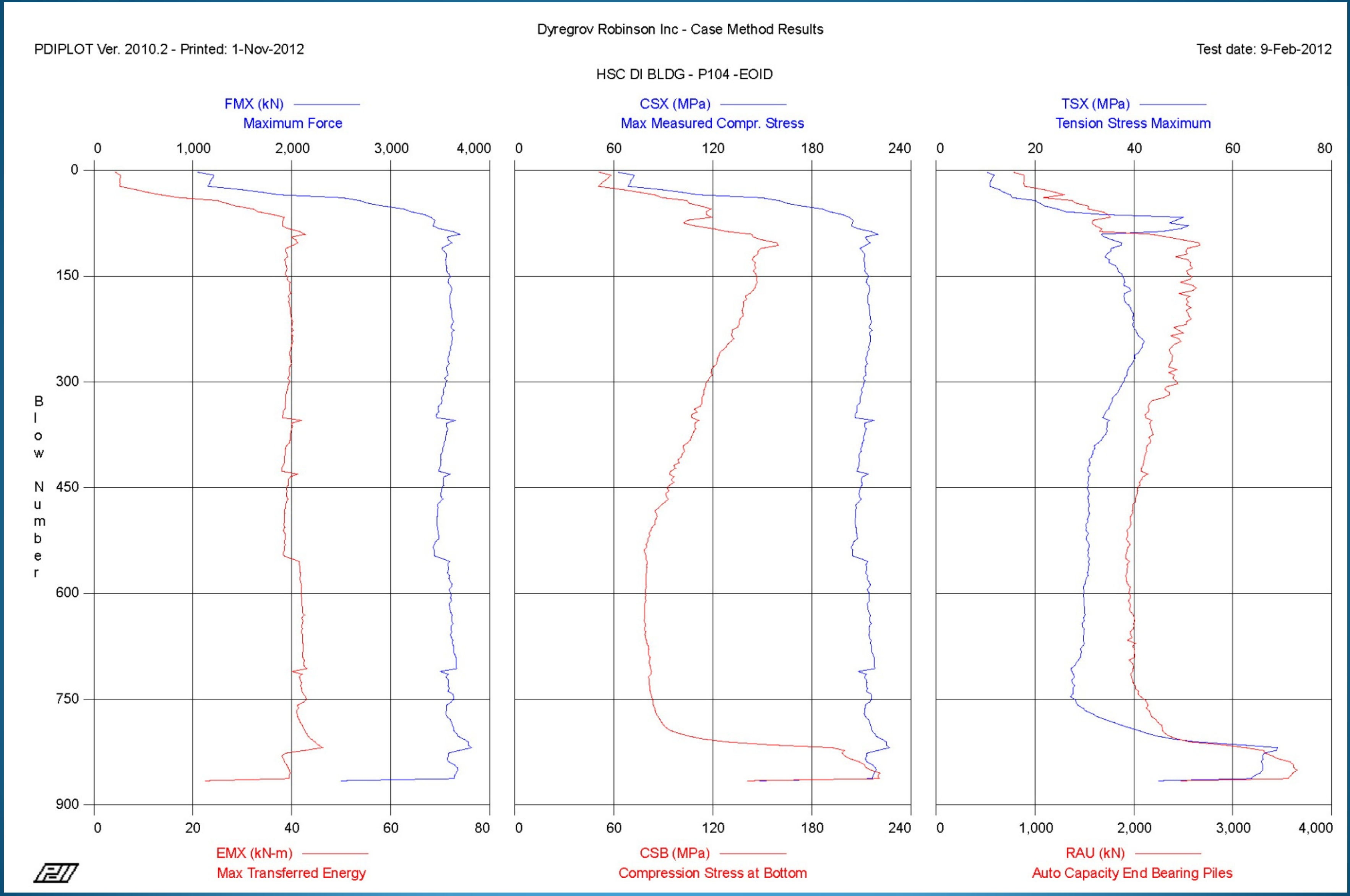
Dynamic Testing & Analysis

- Monitoring the effect of pile hammer impact on the pile in terms of stress (strain) and velocity (acceleration)

Dynamic Testing

- Data (strain / acceleration) collected for each blow of the hammer
- Monitor driving stresses, energy transferred, pile capacity
- CAPWAP analysis used to determine pile capacity
- Results used to confirm the driving energy and set criteria
- Several piles can be tested during construction

Dynamic Testing Results



Dynamic Testing Results

Table 2: Pile Testing Summary

Pile No.	Testing Condition	Hammer Drop Height	Rated Energy	Pile Set (per blow)	Transferred Energy (EMX) (kJ)			Compressive Stress (CSX) (MPa)		Compressive Stress (CSB) (MPa)		Tensile Stress (TSX) (MPa)		Mobilized Pile Capacity Estimates (Case-Goble Theory) (kN)			
		m	kJ	mm	max	avg	% of rated	max	avg	max	avg	max	avg	RAU	RA2	RX7	RX9
104	EOID	0.9	44.1	0.1	47	40	91%	230	213	151	49	71	34	3690	4111	3938	3763
	RSTRK	1.0	49.0	0.1	45	41	84%	234	225	197	174	68	66	3866	4372	4355	4140
	RSTRK	1.1	53.9	0.4	48	47	87%	247	243	234	217	73	71	*3991	*4376	*4571	*4318
	RSTRK	1.2	58.8	0.4	53	50	85%	259	251	254	237	74	72	4129	4685	4904	4640
	RSTRK	1.3	63.7	0.4	56	54	85%	271	266	267	261	76	74	4207	4861	5166	4885
														* for Blow #14 - analyzed with CAPWAP			

EOID End of initial drive
RSTRK Restrike

EMX transferred energy below gauges
CSX max compressive stress below gauges
CSB compressive stresses at pile base
TSX max tensile stress below gauges

RAU Case-Goble static resistance (no skin friction)
RA2 Case-Goble static resistance (moderate skin friction)
RX7 Case-Goble static resistance (damping factor 0.7)
RX9 Case-Goble static resistance (damping factor 0.9)

Foundation Inspection

- Drilled shafts
  - Correct shaft diameter and length
  - Evaluate soil / rock recovered from shaft
  - Base inspection
  - Proof drilling
  - Record final installation details

QUESTIONS ?