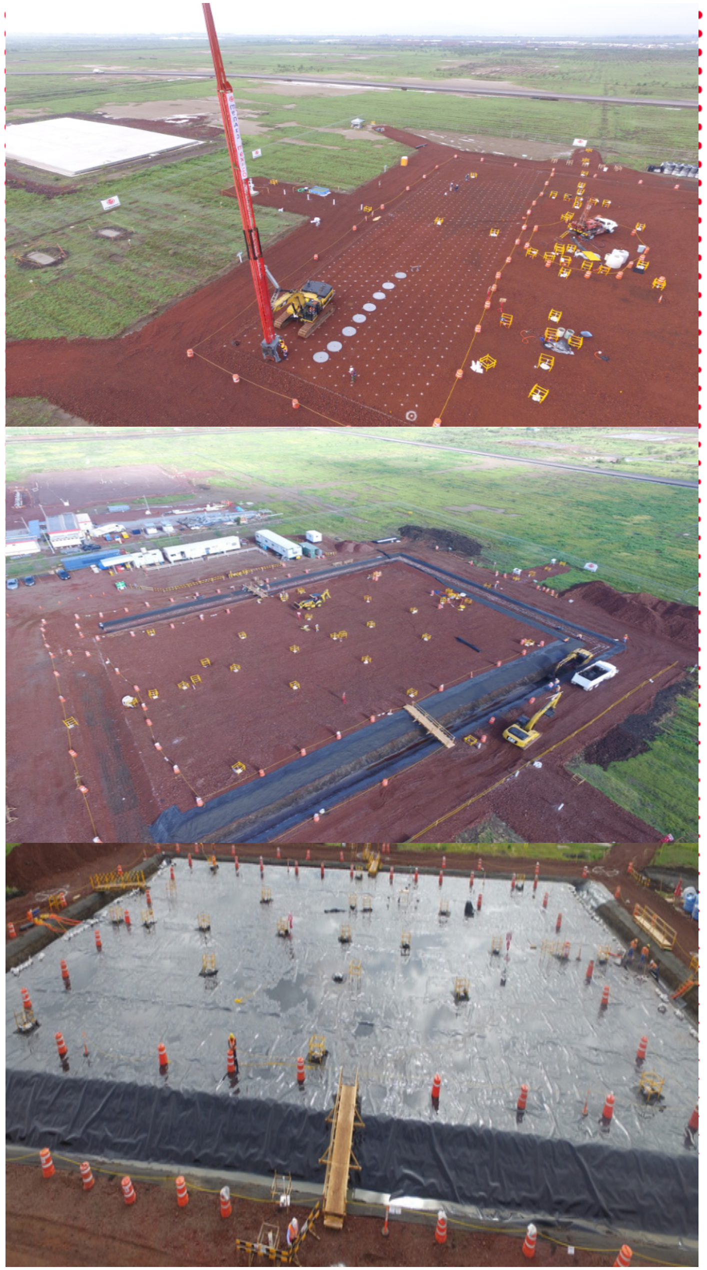
Amélioration et renforcement des sols

Consolidation atmosphérique – Aéroport de Mexico

Cyril Plomteux – Menard

26 AVRIL 2018

PRESENTATION GENERALE



PRESENTATION GENERALE

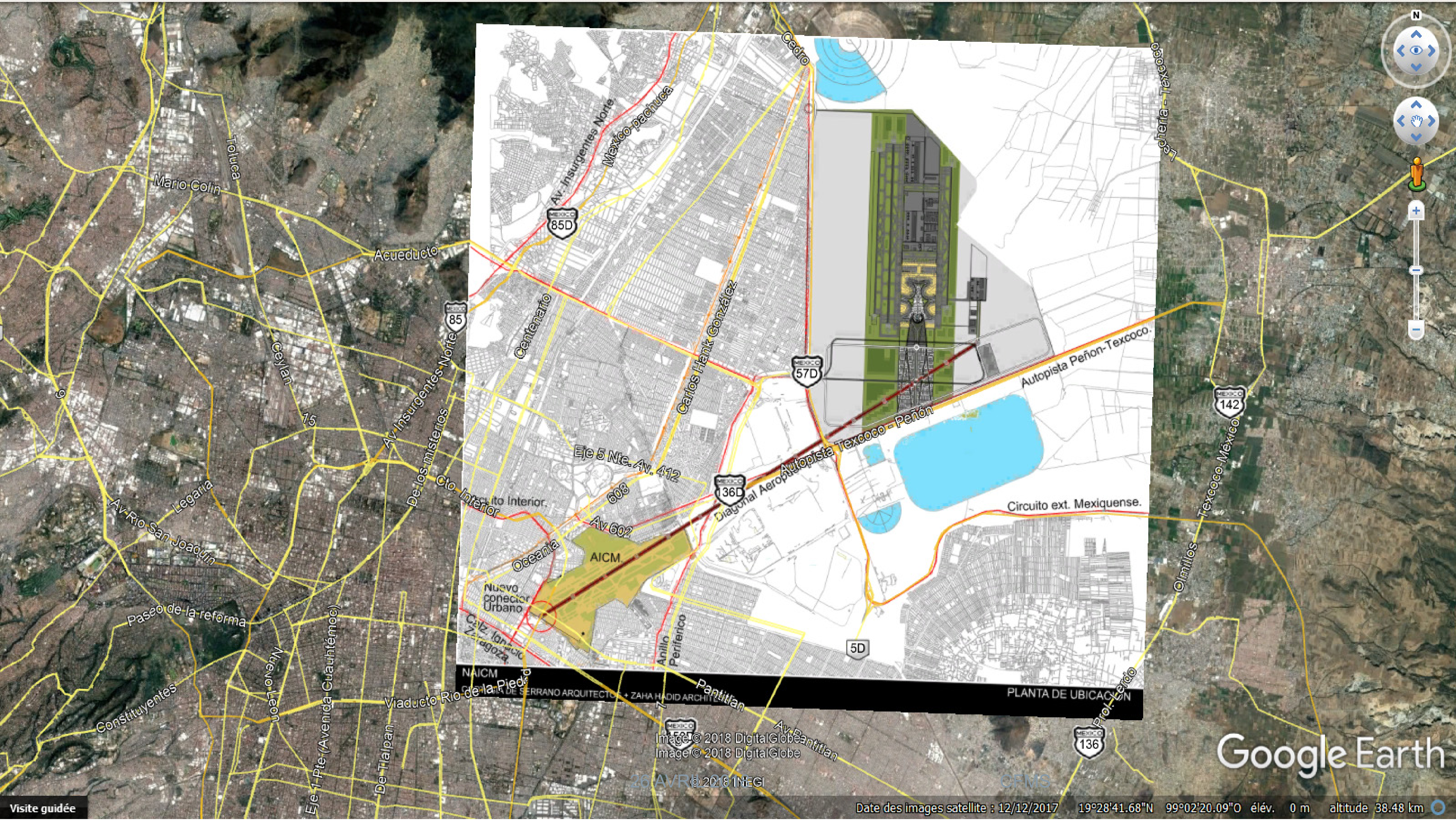
20 km de Mexico City sur l'ancient lac Texcoco

Client : Grupo Aeropuerto de la Ciudad de México

Designer : TADCO – SACMAG – NACO (Pistes) / ARUP (Terminal)

Projet :

- Surface totale: 4,430 ha
- 3 pistes
- 1 terminal (667 000 m2)
- 1 tour de controle

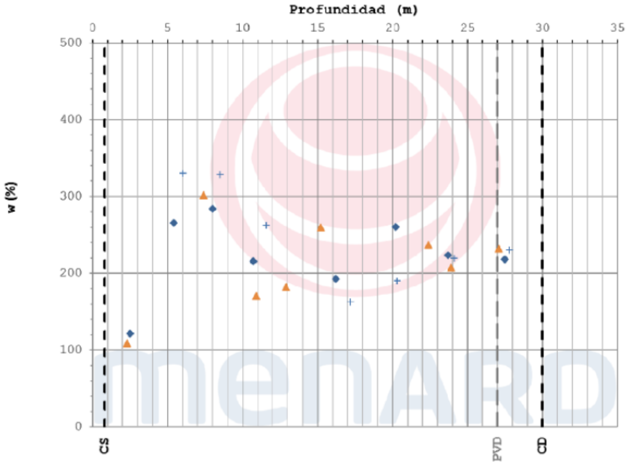

N
Cedro
Av. Insurgentes Norte
Mexico-pachuca
85D
Toluca
Mario Colín
Acueducto
85
Centenario
Carlos Hank González
57D
Lechería - Texcoco
Autopista Peñón-Texcoco.
Autopista Texcoco - Peñón
Diagonal Aeropuerto
136D
142
Ceylán
15
Av. Insurgentes Norte
De los misterios
Cto. Interior
Circuito Interior.
Eje 5 Nte. Av. 412
608
Av 602
Oceanía
AICM
Nuevo conector Urbano
Calz. Ignacio Zaragoza
Anillo Periférico
5D
Circuito ext. Mexiquense.
Texcoco-Mexico
Olmitos
Legaria
Av Río San Joaquín
Paseo de la reforma
Nuevo León
Eje 1 Pte (Avenida Cuauhtémoc)
De Tlalpan
Constituyentes
Viaducto Río de la Piedad
Pantitlán
Av. Pantitlán
Prol. Lerdo
136
NAICM
FERNANDO ROMERO ENTERPRISE + FOSTER + PARTNERS · TAPIA DE SERRANO ARQUITECTOS + ZAHA HADID ARCHITECTS
PLANTA DE UBICACION
Image © 2018 DigitalGlobe
Image © 2018 DigitalGlobe
© 2018 INEGI
26 AVRIL 2018
CFMS
Google Earth
Visite guidée

Date des images satellite : 12/12/2017 19°28'41.68"N 99°02'20.09"O élév. 0 m altitude 38.48 km

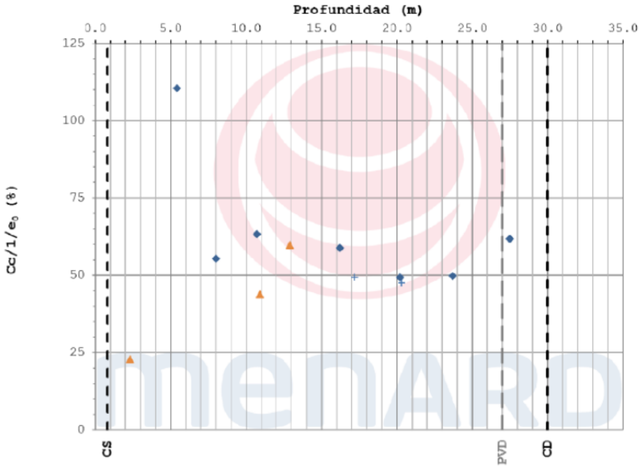
Conditions géotechniques

Designación	Unid.	Prof m		H	Prof. med	w	γ	Eoed	e_0	C_D	C_c	OCR	k	Cv	Ch= 3Cv
		de	a	m	m	%	kN/m³	MPa					máx m/year	máx m²/year	máx m²/year
Costra Superficial	CS	0	-1	1	0.5	-	14.50	4.50	-	-	-	-	-	-	-
Serie Arcillosa Superior	SAS1	-1	-5	4	3	165	13.66	0.94	3.28	0.106	0.983	1.6	1.3E-05	7.0E-01	2.09
	SAS2	-5	-8	3	6.5	300	12.66	0.15	10.54	1.027	12.76	1.2	3.6E-05	2.9E-01	0.87
	SAS3	-8	-11	3	9.5	250	11.20	0.44	12.84	0.54	7.668	1	2.7E-05	6.8E-01	2.03
	SAS4	-11	-16	5	13.5	230	12.16	0.41	6.22	0.122	4.575	1	1.1E-05	2.6E-01	0.77
	SAS5	-16	-20	4	18	200	12.25	1.54	8.65	0.981	5.686	1	4.3E-06	3.8E-01	1.13
	SAS6	-20	-27	7	23.5	225	12.17	1.44	7.74	0.549	4.357	1.3	1.0E-05	8.1E-01	2.44
	SAS7	-27	-30	3	28.5	230	12.00	1.23	8.45	0.437	5.841	1.3	6.1E-06	4.2E-01	1.26
Primera Capa Dura	C.D	-30	-32	2	31	-	19.00	30.00	-	-	-	-	-	-	-

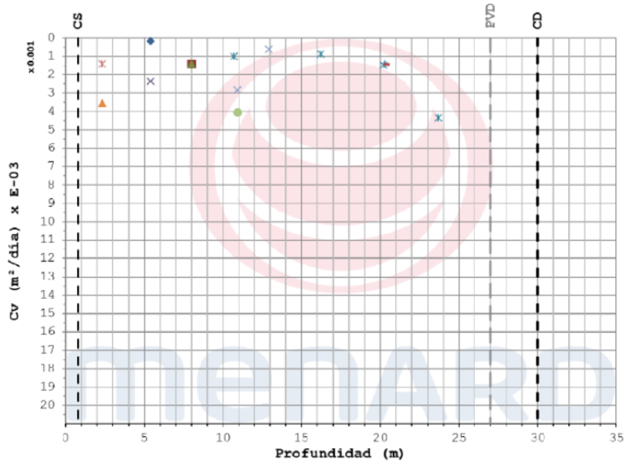
Contenido de agua, w(%)



Cc / 1+e_0



Coeficiente de consolidación vertical, Cv



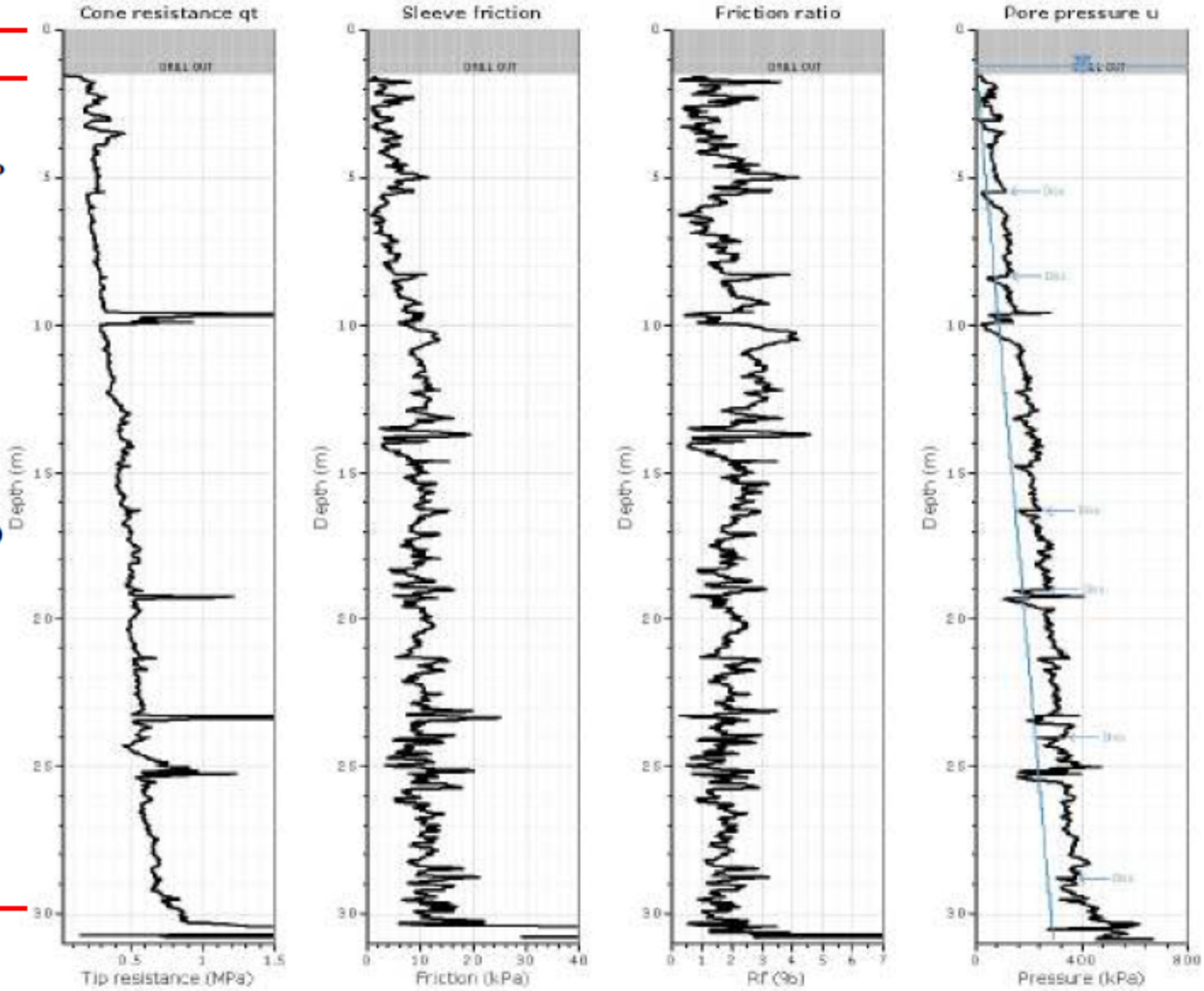
Plataforma de Tezontle

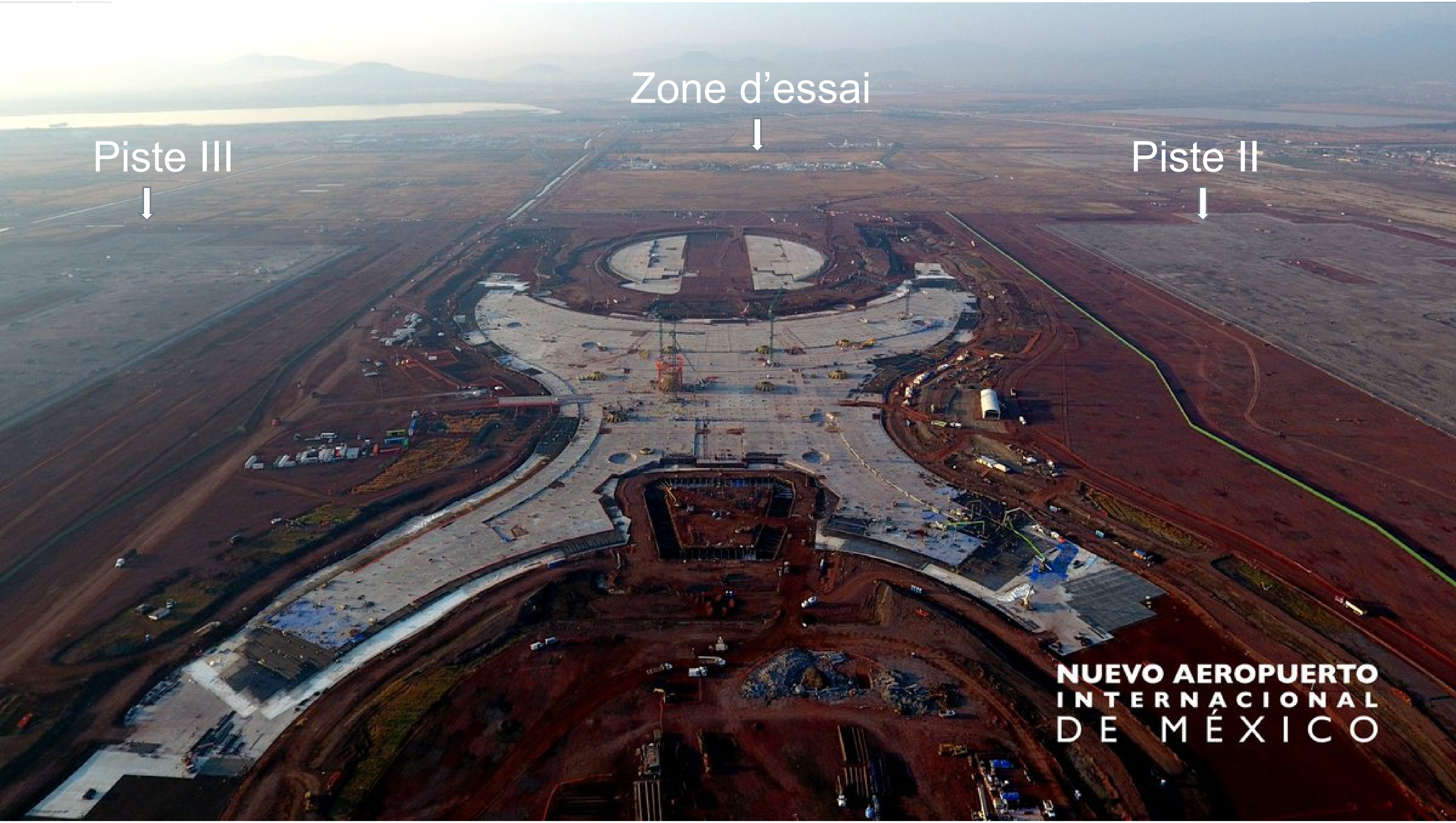
NAF ~ 1.10 m

Hundimiento reg prom ~ 24 a 32 cm/año

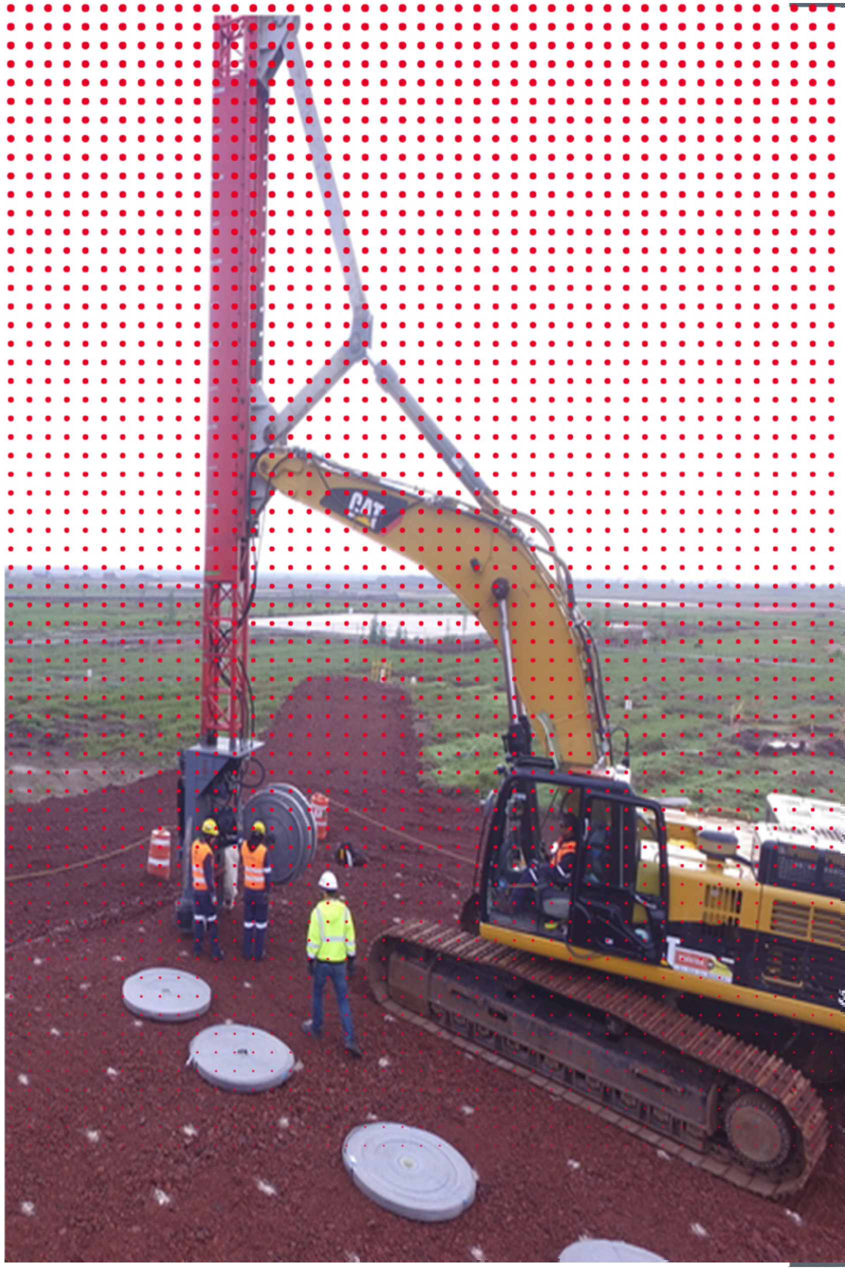
FAS (Formación arcillosa superior) con intercalaciones de arenas y cenizas volcánicas)
Arcillas CH

Capa dura (CD)

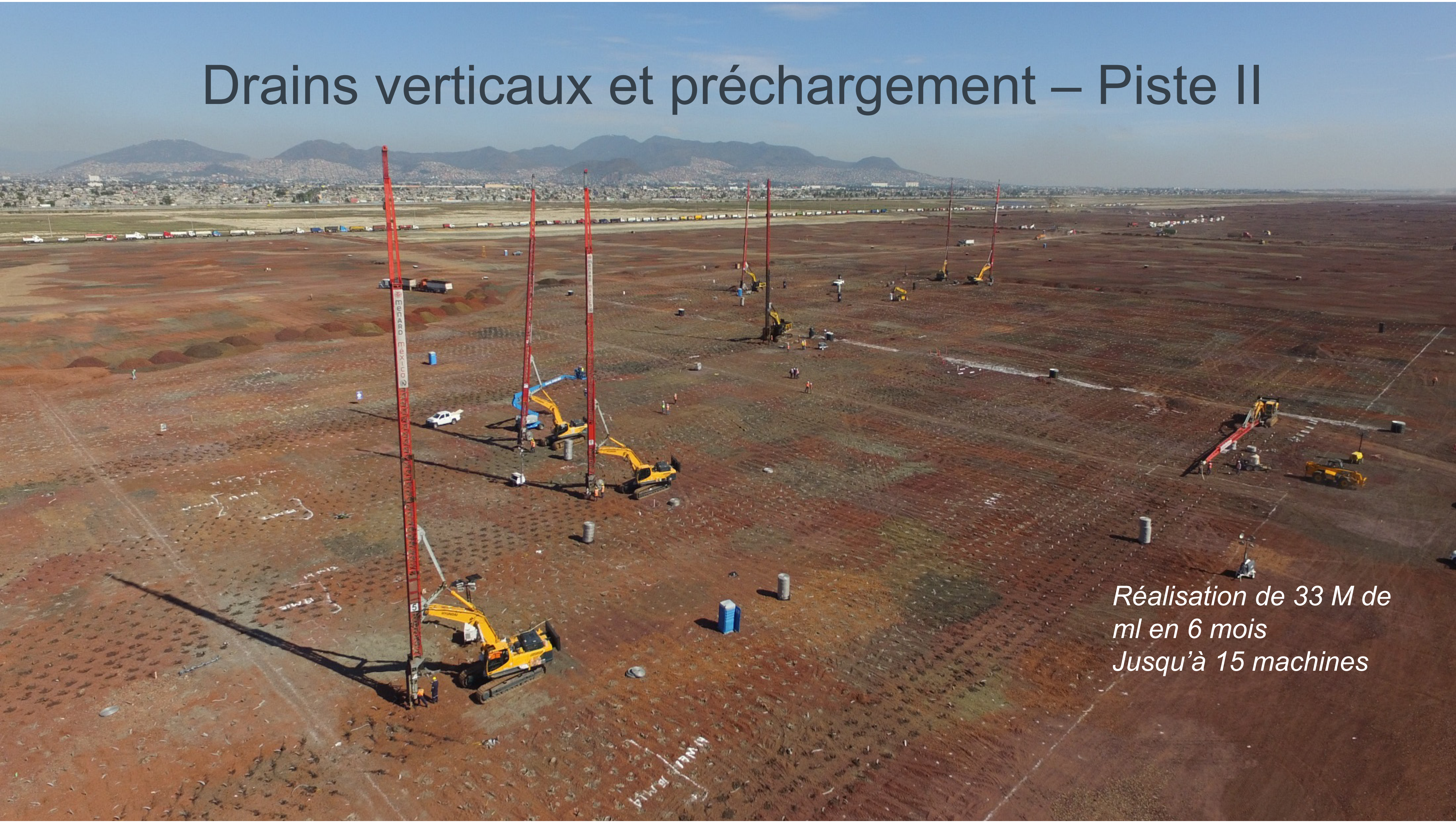



Zone d'essai
Piste III
Piste II
NUEVO AEROPUERTO
INTERNACIONAL
DE MÉXICO

LES TRAVAUX

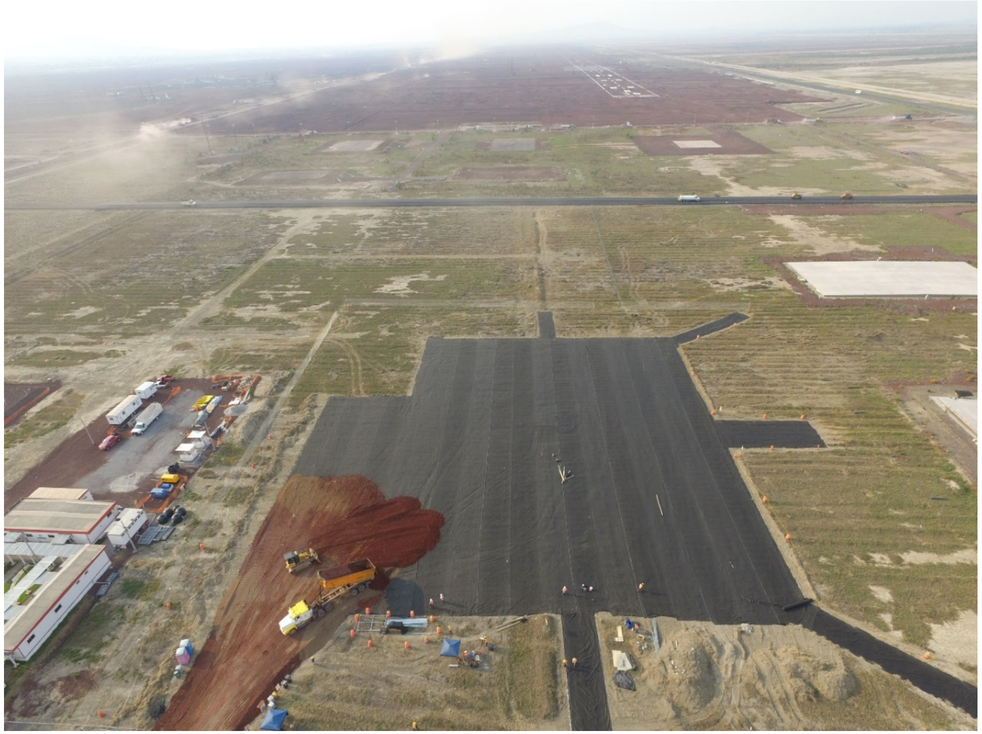


Drains verticaux et préchargement – Piste II

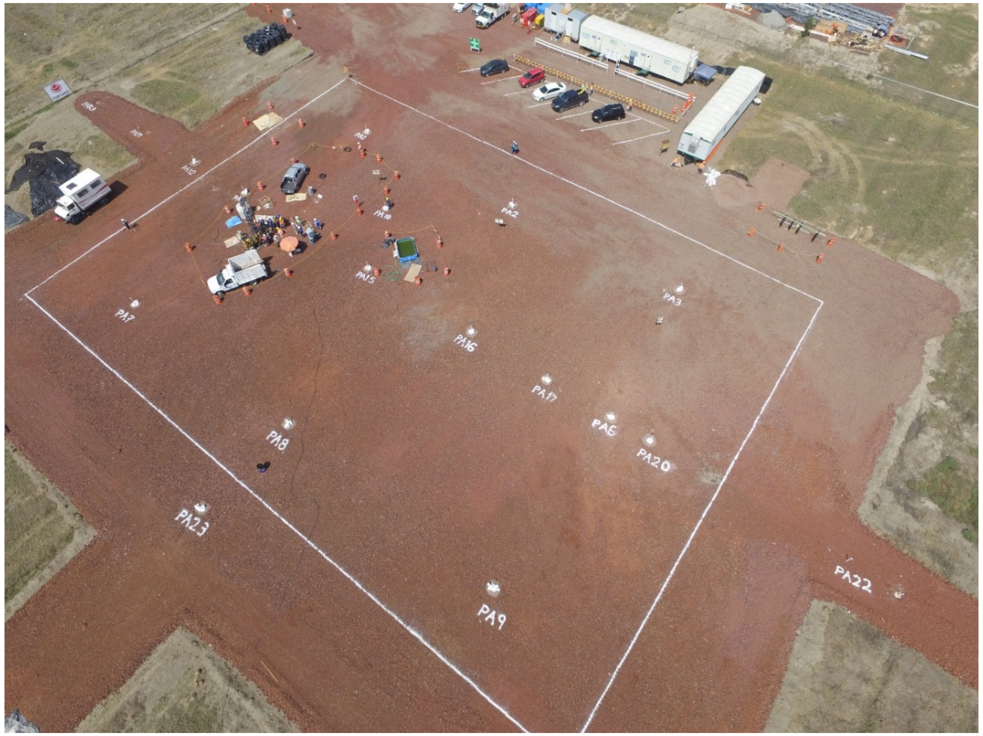

menARD méxico

Réalisation de 33 M de ml en 6 mois
Jusqu'à 15 machines

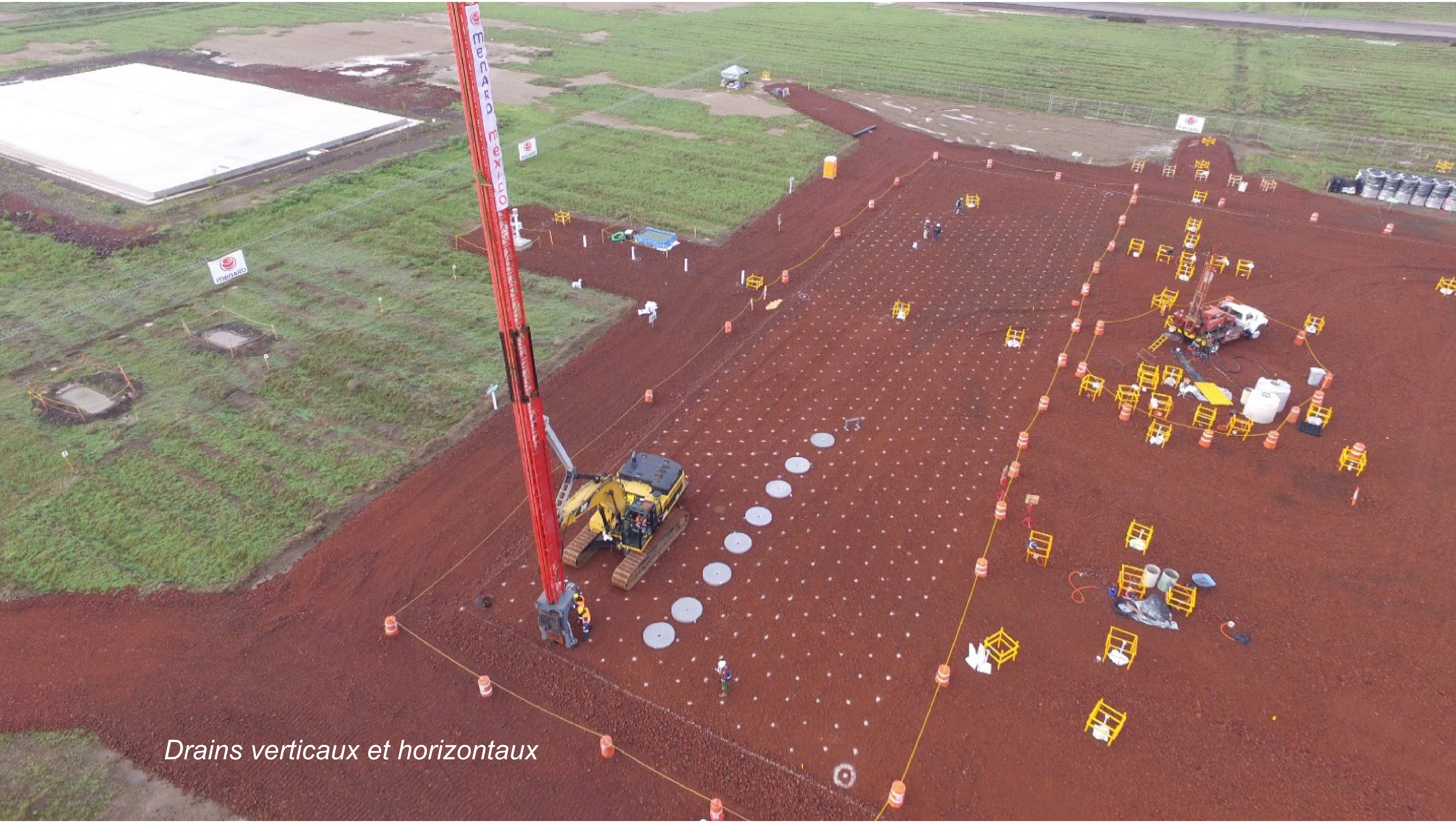
Consolidation par Menard Vacuum



Plateforme de travail
0,5 m + 0,5 m = 1 m de tezontle (13,7 kN/m3)

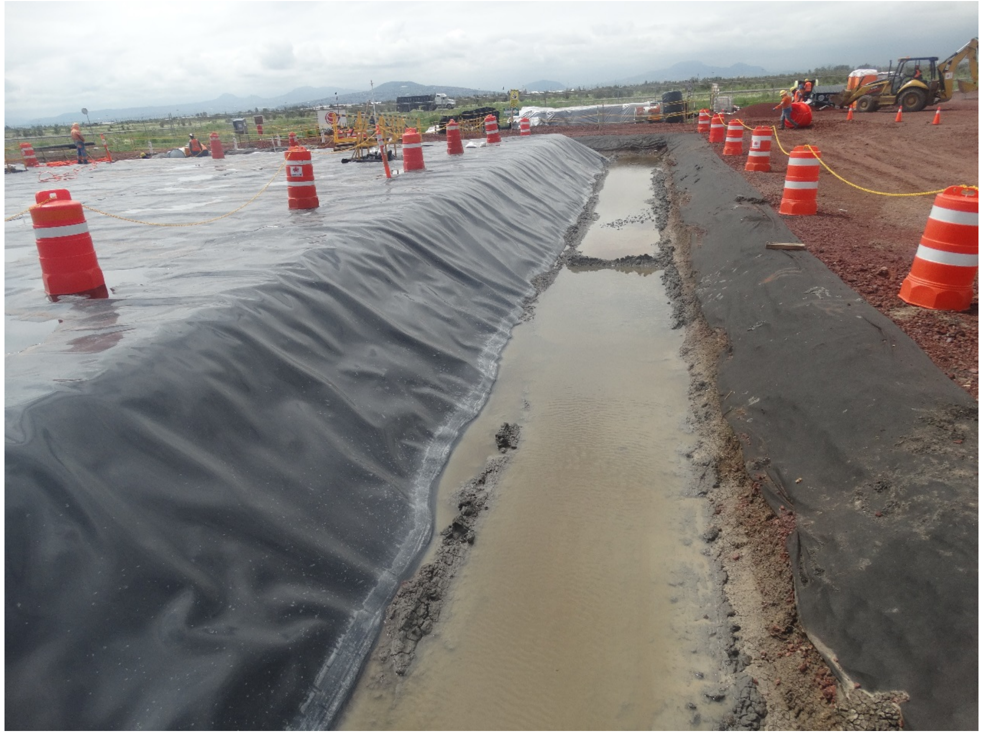

PA7
PA15
PA16
PA17
PA2
PA3
PA5
PA20
PA8
PA23
PA9
PA22

Mise en place de l'instrumentation

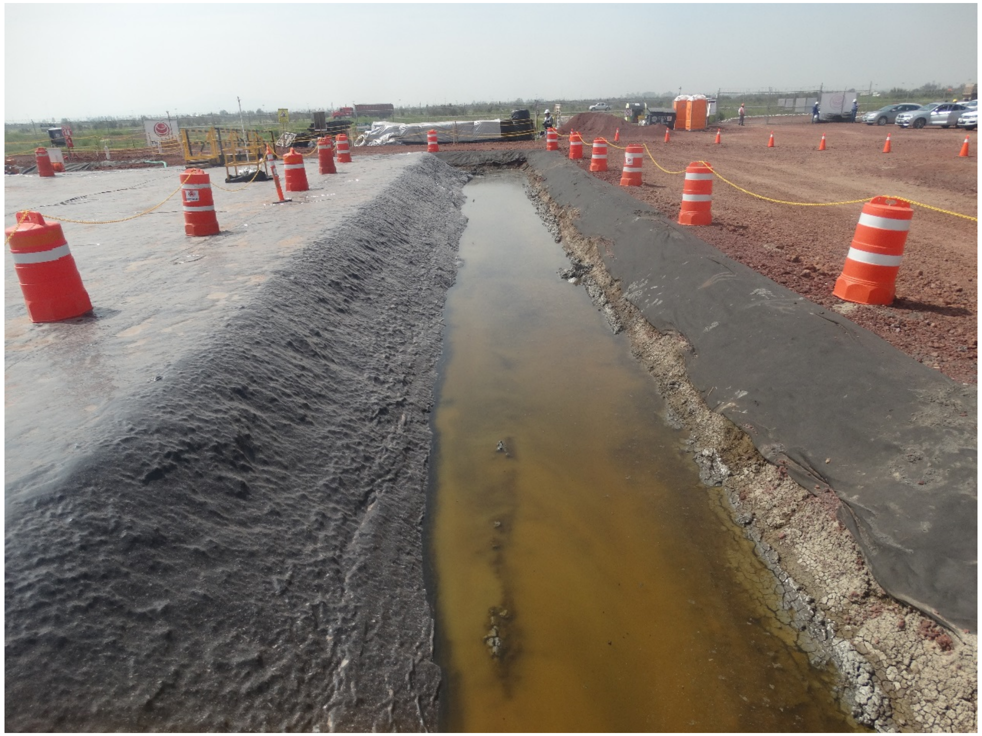

menard mexico
menard

Drains verticaux et horizontaux

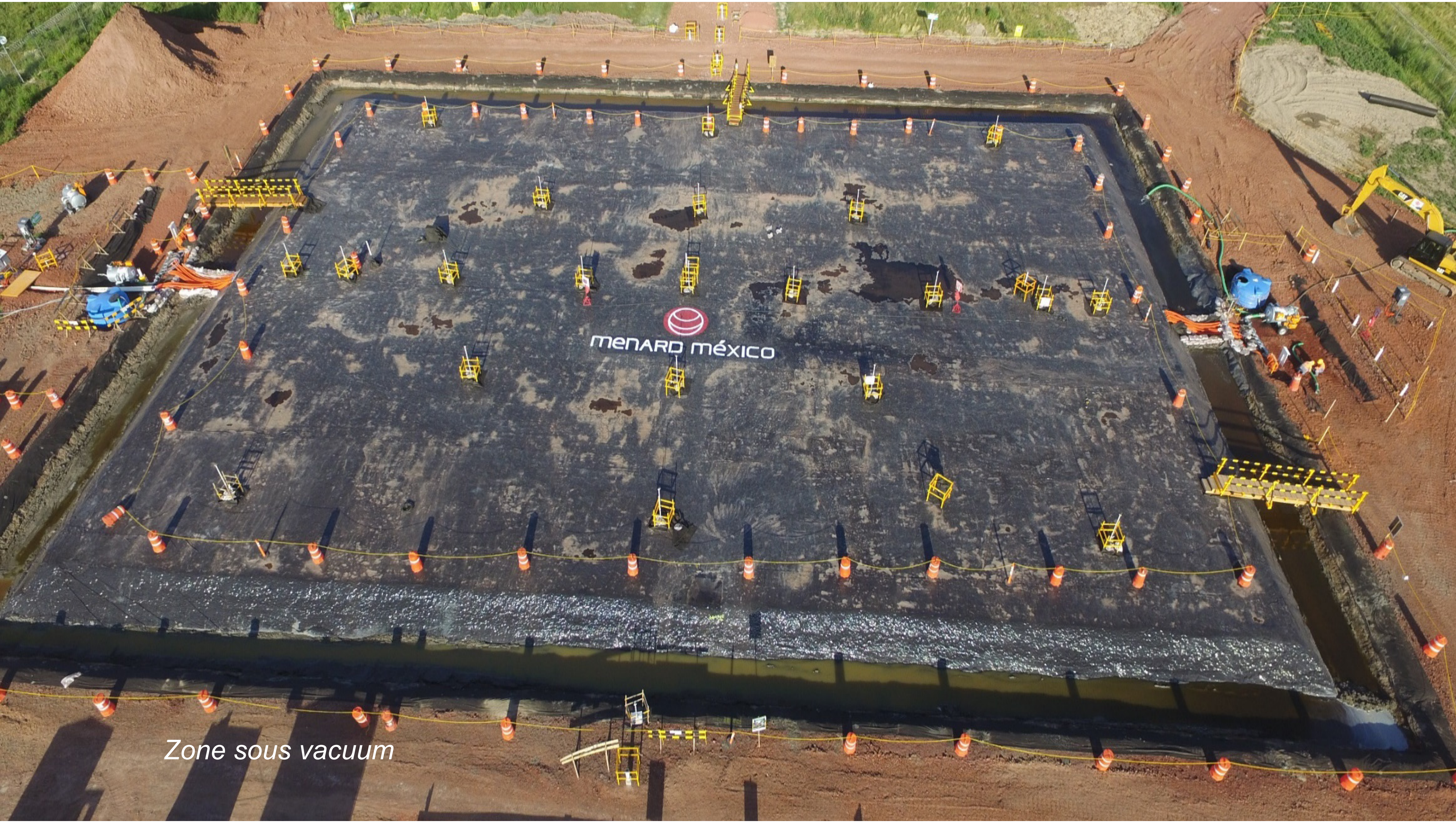
Consolidation par Menard Vacuum



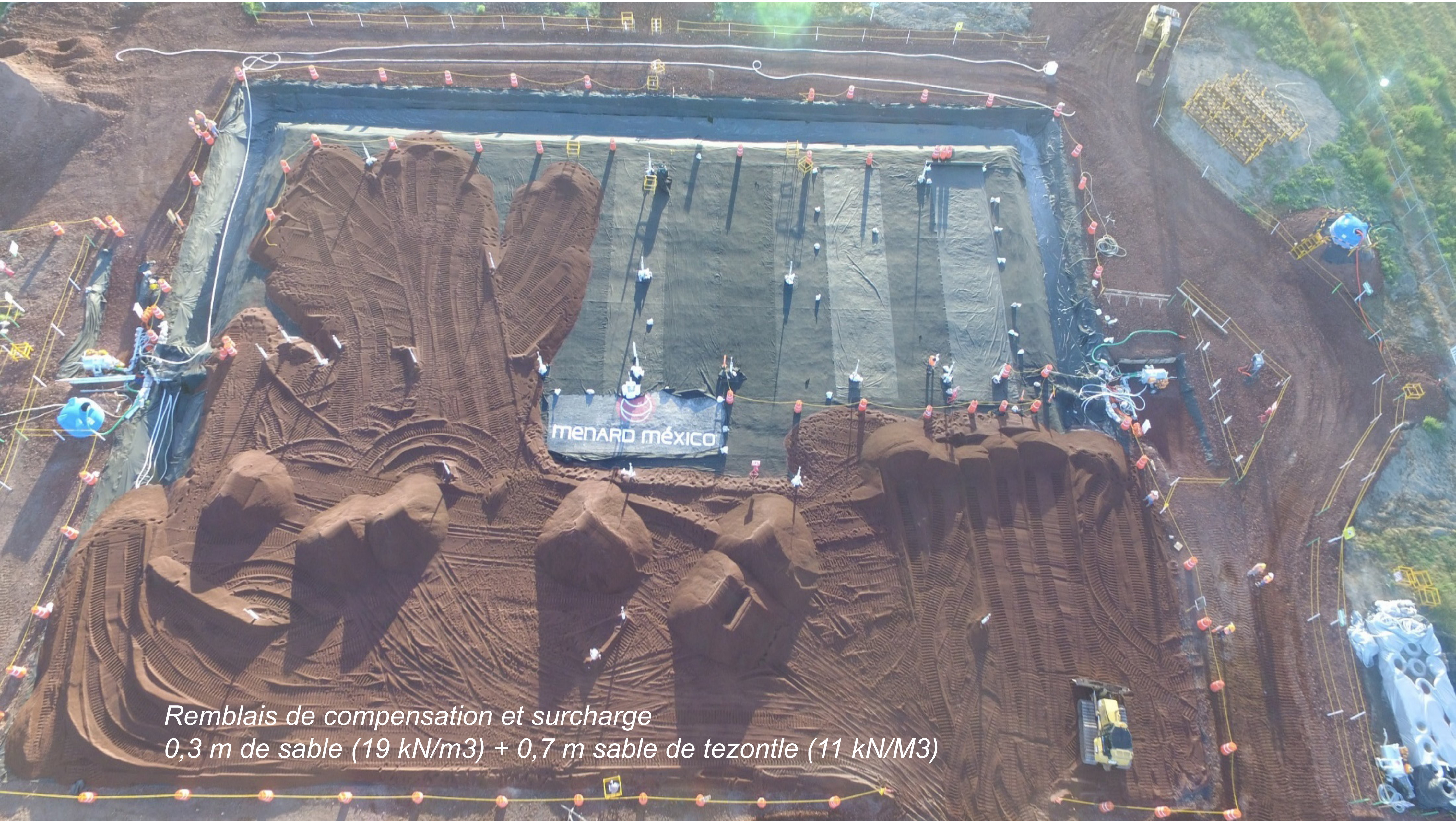
Avant mise en route du vacuum



Après mise en route du vacuum

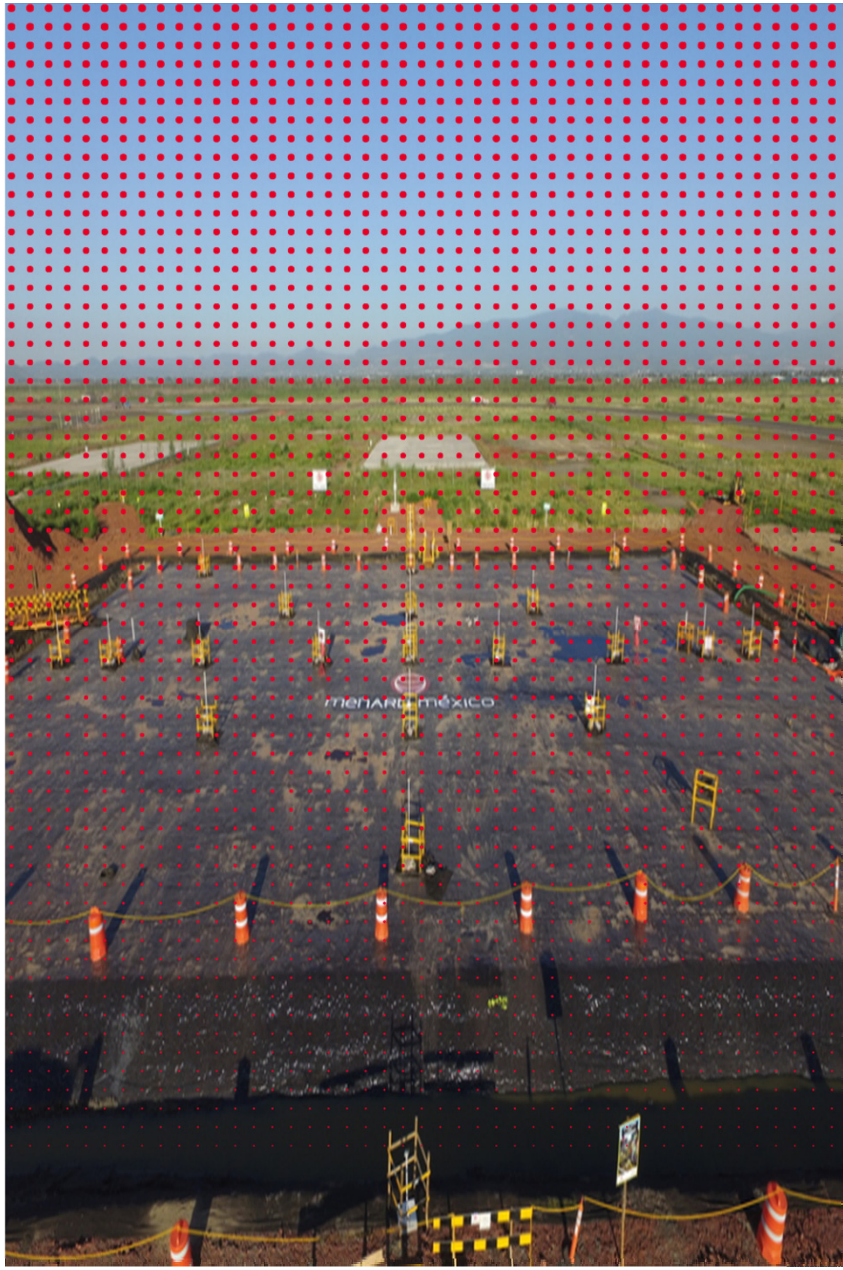

menard méxico

Zone sous vacuum


menard méxico

Remblais de compensation et surcharge
0,3 m de sable (19 kN/m3) + 0,7 m sable de tezontle (11 kN/M3)

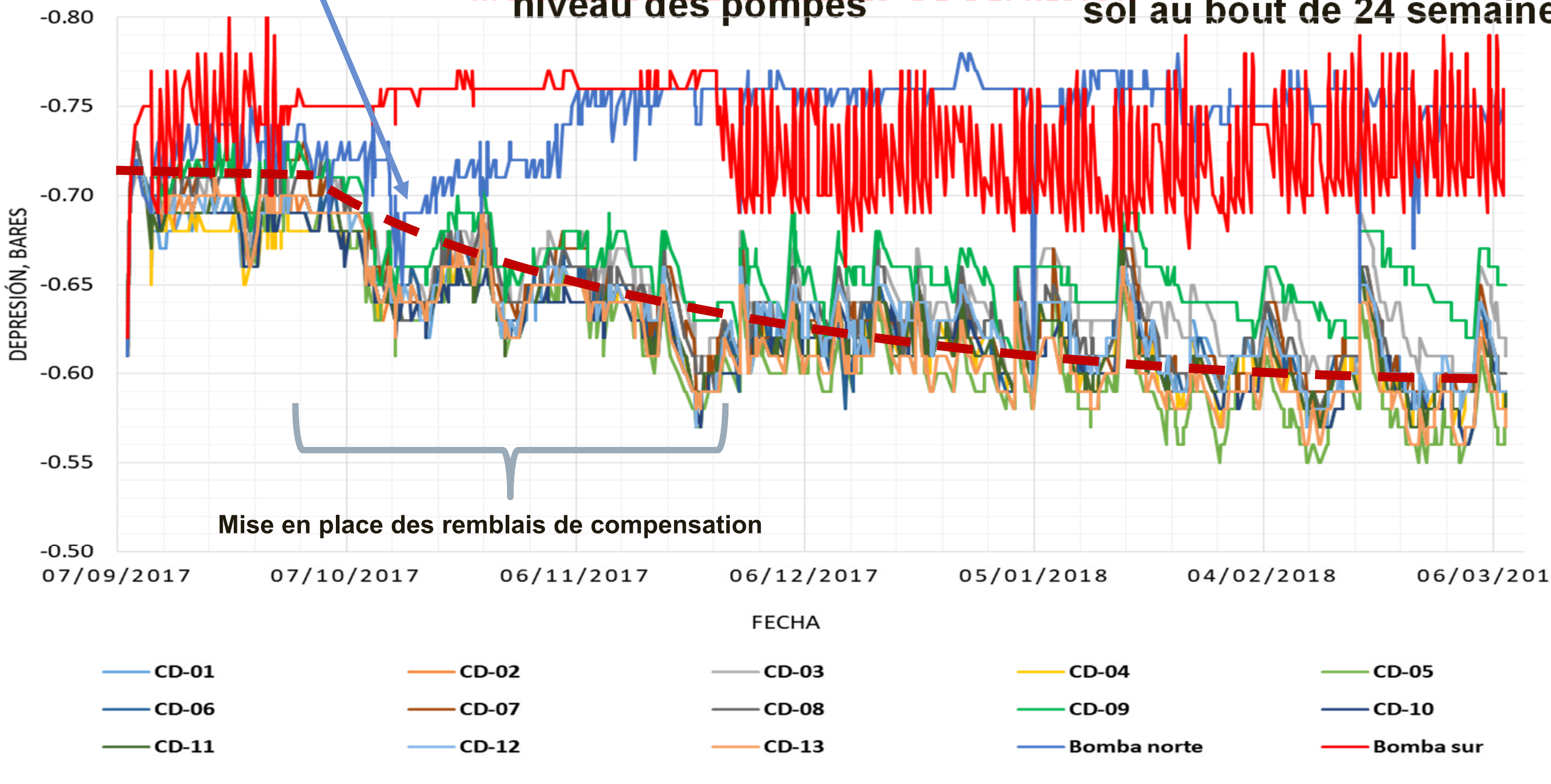
RESULTATS


menard méxico

Depression

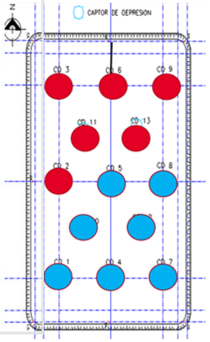
73 kPa de dépression au niveau des pompes

60 kPa de dépression dans le sol au bout de 24 semaines



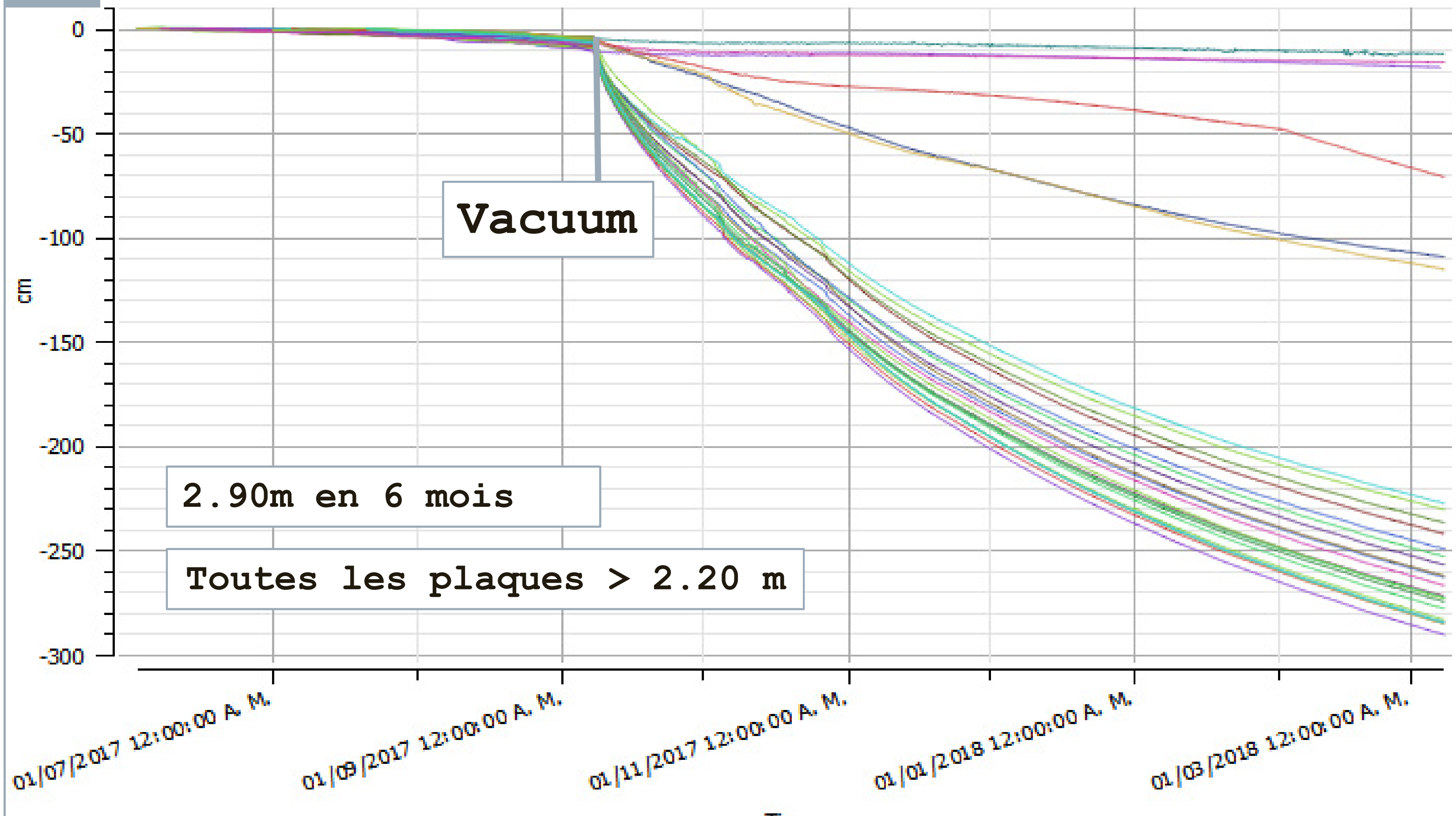
Mise en place des remblais de compensation

menard méxico
CD 13
bar


CAPTOR DE DEPRESION
CD 3
CD 6
CD 9
CD 11
CD 13
CD 2
CD 5
CD 8
CD 1
CD 4
CD 7

La pression atmosphérique à Mexico city (2250 m d'altitude) est de 78 kPa

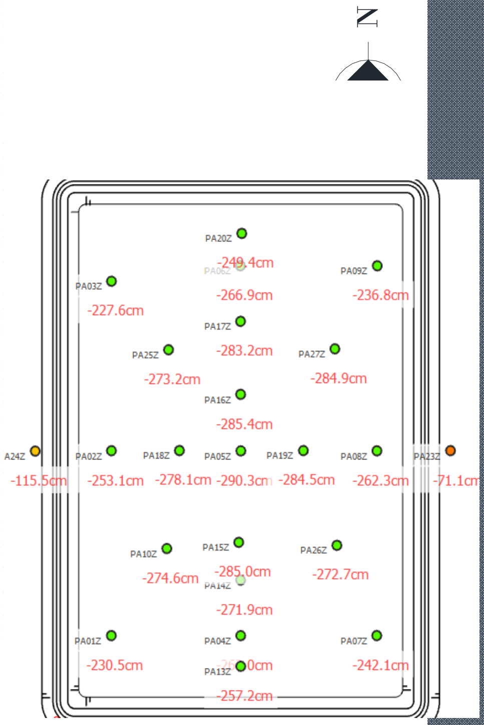
Plaques de tassement



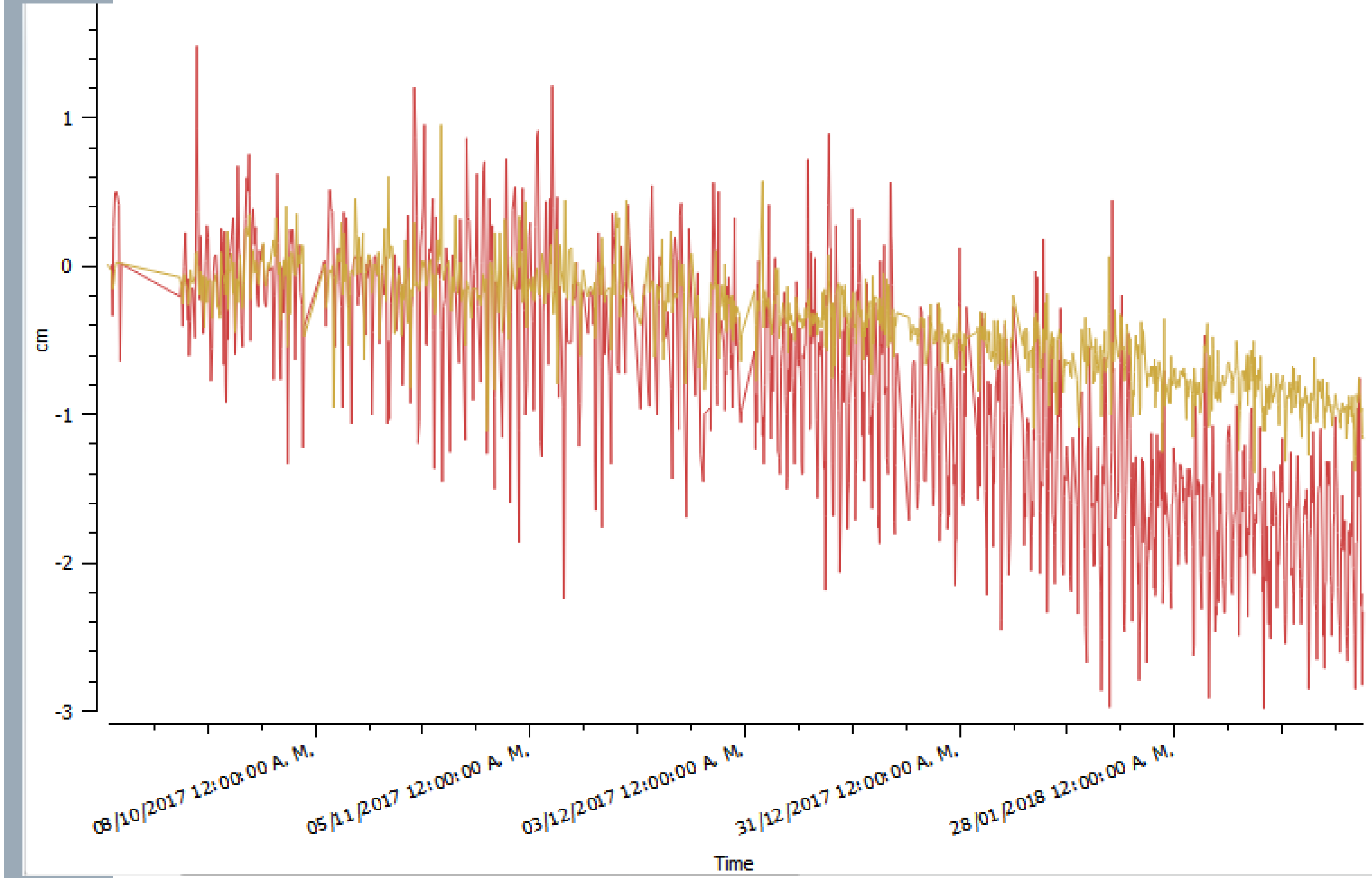
Vacuum

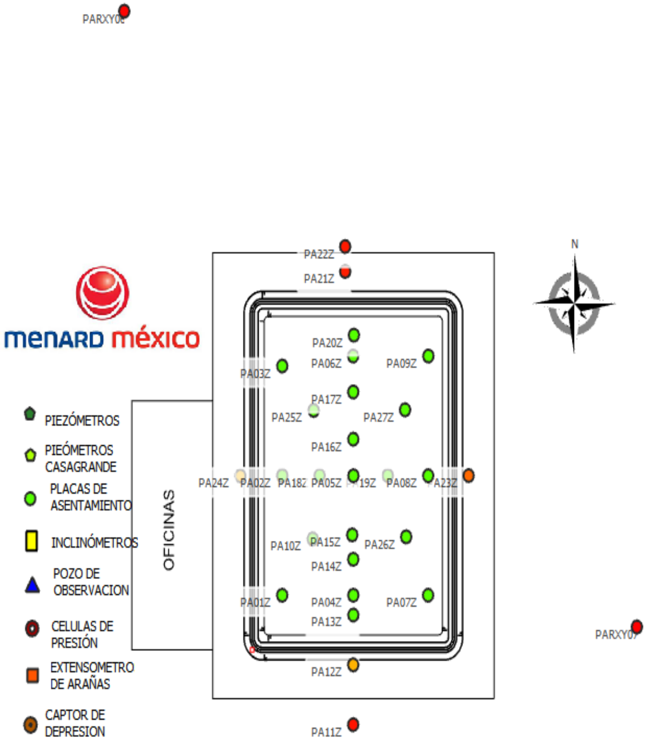
2.90m en 6 mois

Toutes les plaques > 2.20 m

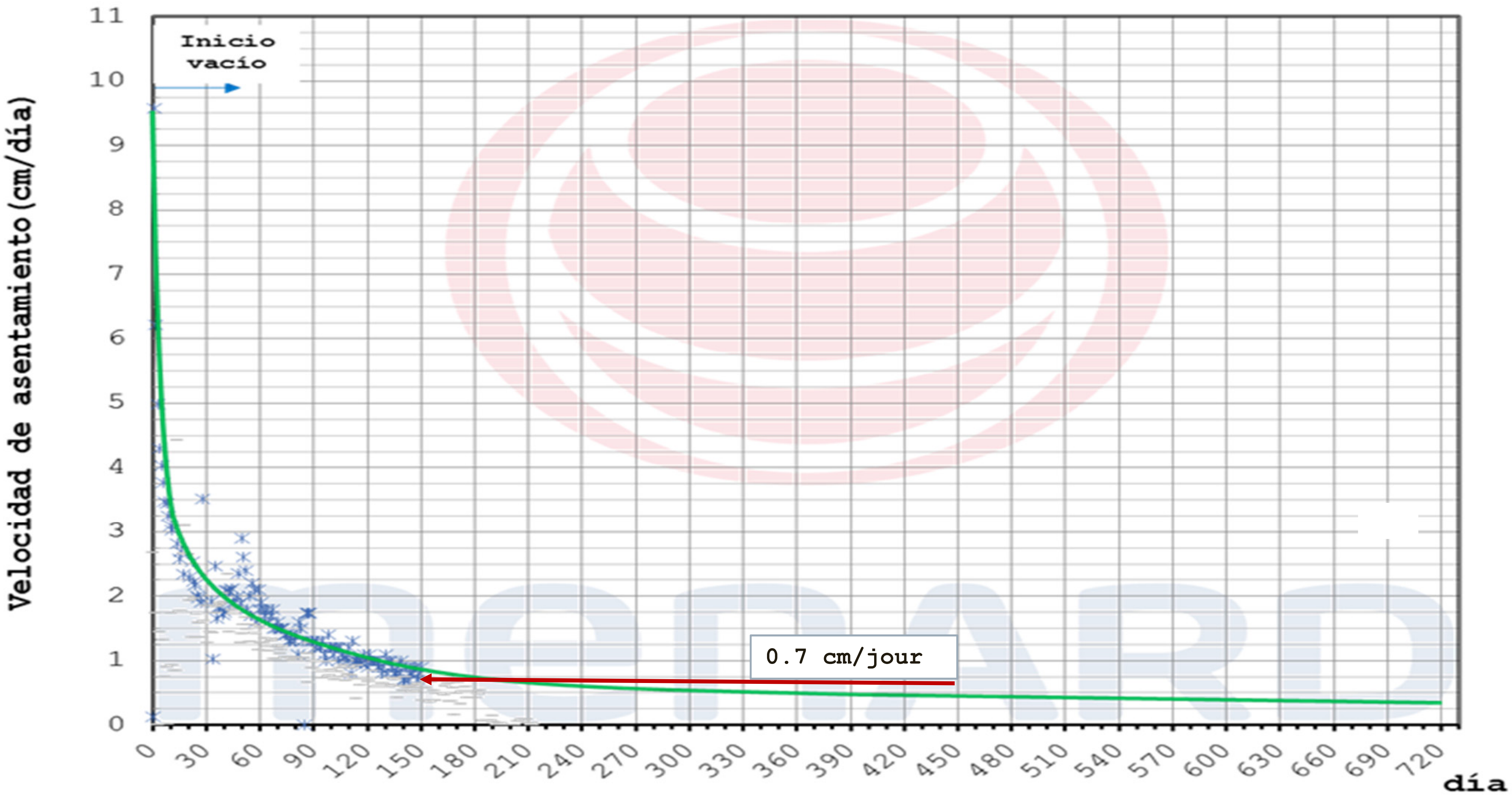

N
PA20Z
-249.4cm
PA06Z
-266.9cm
PA09Z
-236.8cm
PA03Z
-227.6cm
PA17Z
-283.2cm
PA25Z
-273.2cm
PA27Z
-284.9cm
PA16Z
-285.4cm
A24Z
-115.5cm
PA02Z
-253.1cm
PA18Z
-278.1cm
PA05Z
-290.3cm
PA19Z
-284.5cm
PA08Z
-262.3cm
PA23Z
-71.1c
PA10Z
-274.6cm
PA15Z
-285.0cm
PA14Z
-271.9cm
PA26Z
-272.7cm
PA01Z
-230.5cm
PA04Z
PA13Z
-257.2cm
PA07Z
-242.1cm

Plaques de tassement

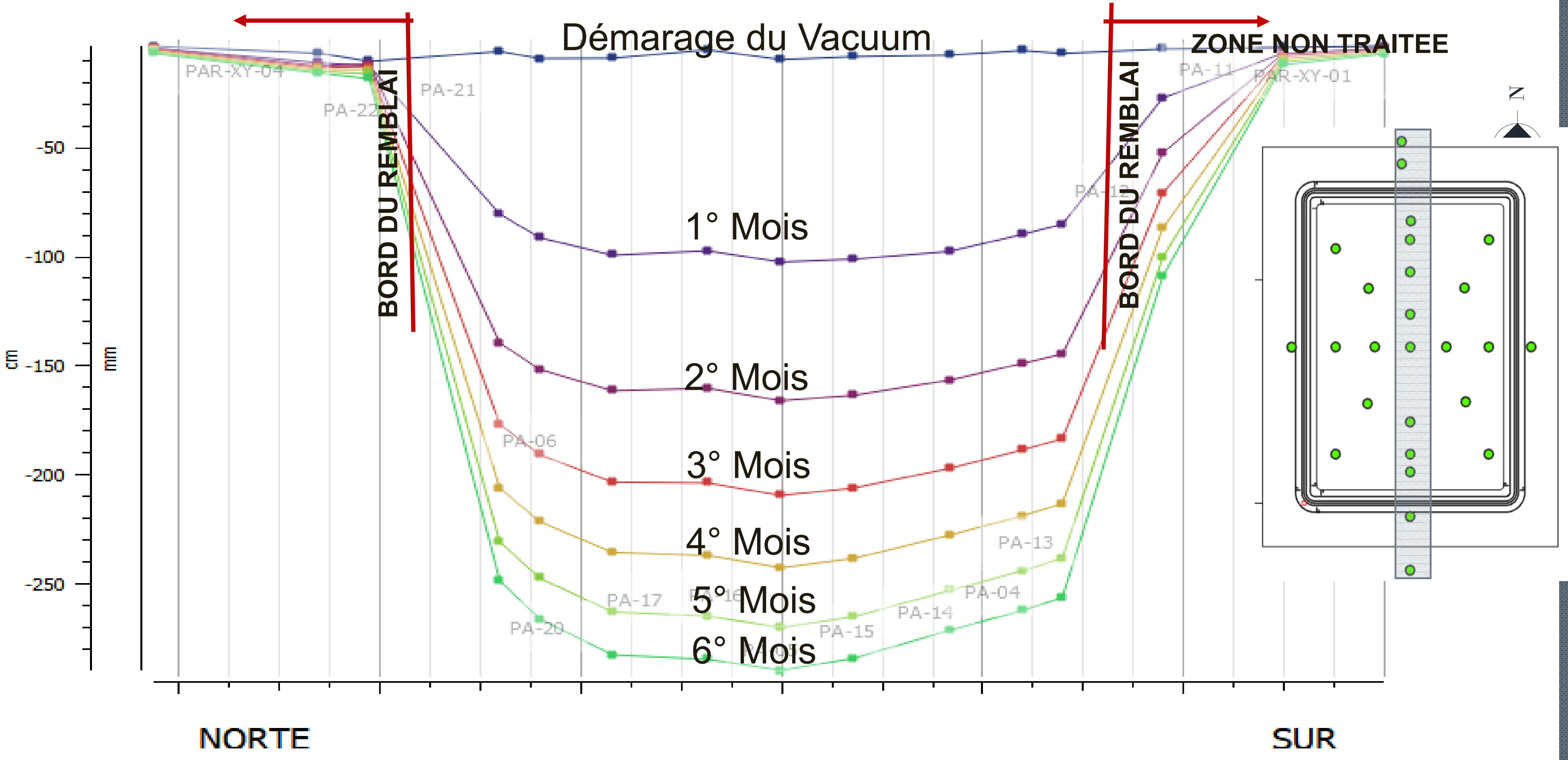



PARXY0
menard méxico
PIEZÓMETROS
PIEÓMETROS CASAGRANDE
PLACAS DE ASENTAMIENTO
INCLINÓMETROS
POZO DE OBSERVACION
CELULAS DE PRESIÓN
EXTENSOMETRO DE ARAÑAS
CAPTOR DE DEPRESION
OFICINAS
PA22Z
PA21Z
PA20Z
PA06Z
PA09Z
PA03Z
PA17Z
PA25Z
PA27Z
PA16Z
PA24Z
PA02Z
PA18Z
PA05Z
19Z
PA08Z
A23Z
PA10Z
PA15Z
PA26Z
PA14Z
PA01Z
PA04Z
PA07Z
PA13Z
PA12Z
PA11Z
N
PARXY07

Historique des vitesses de tassement

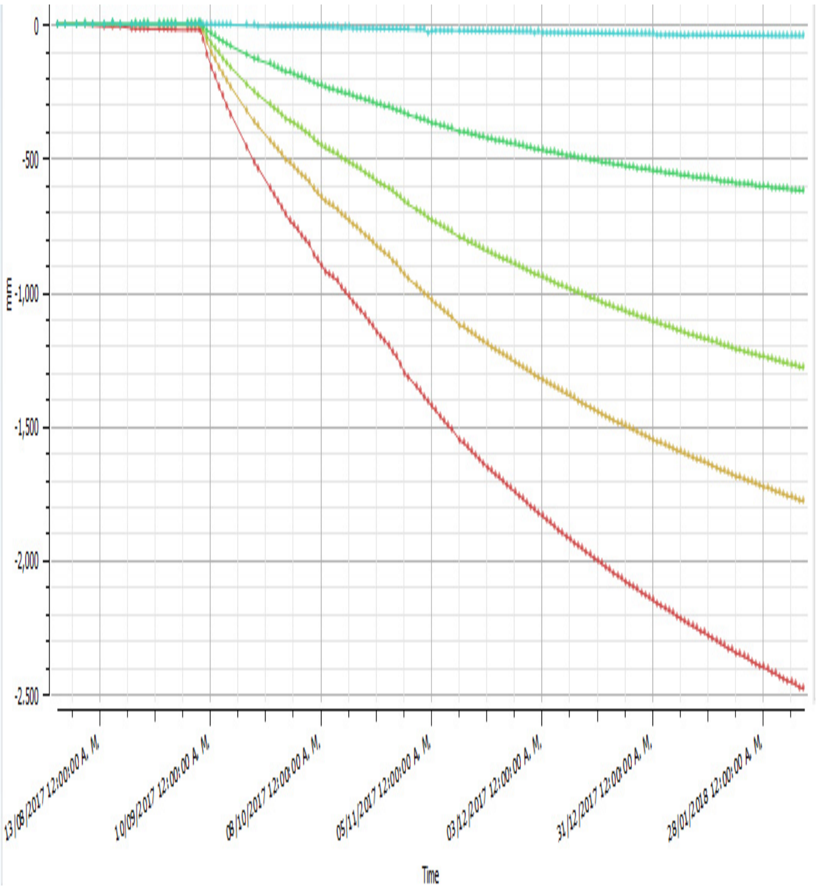


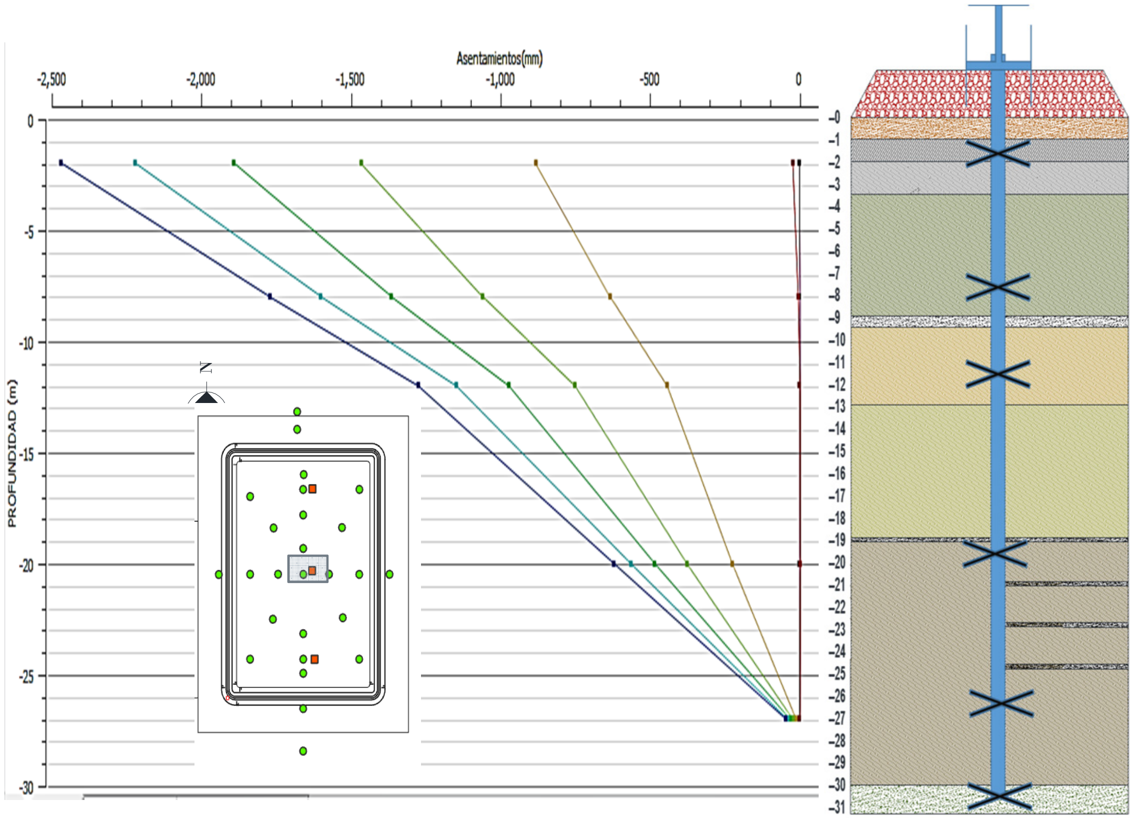
Profil de tassement Nord-Sud



Extensomètres multipoints

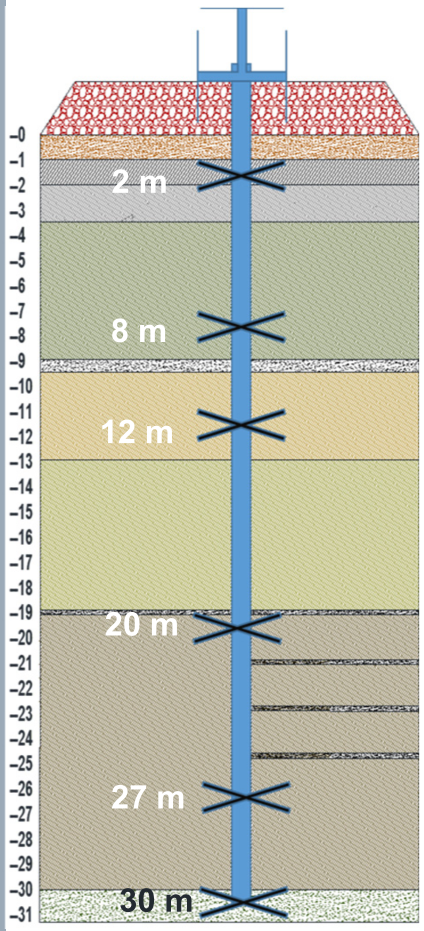
Tassement vs temps





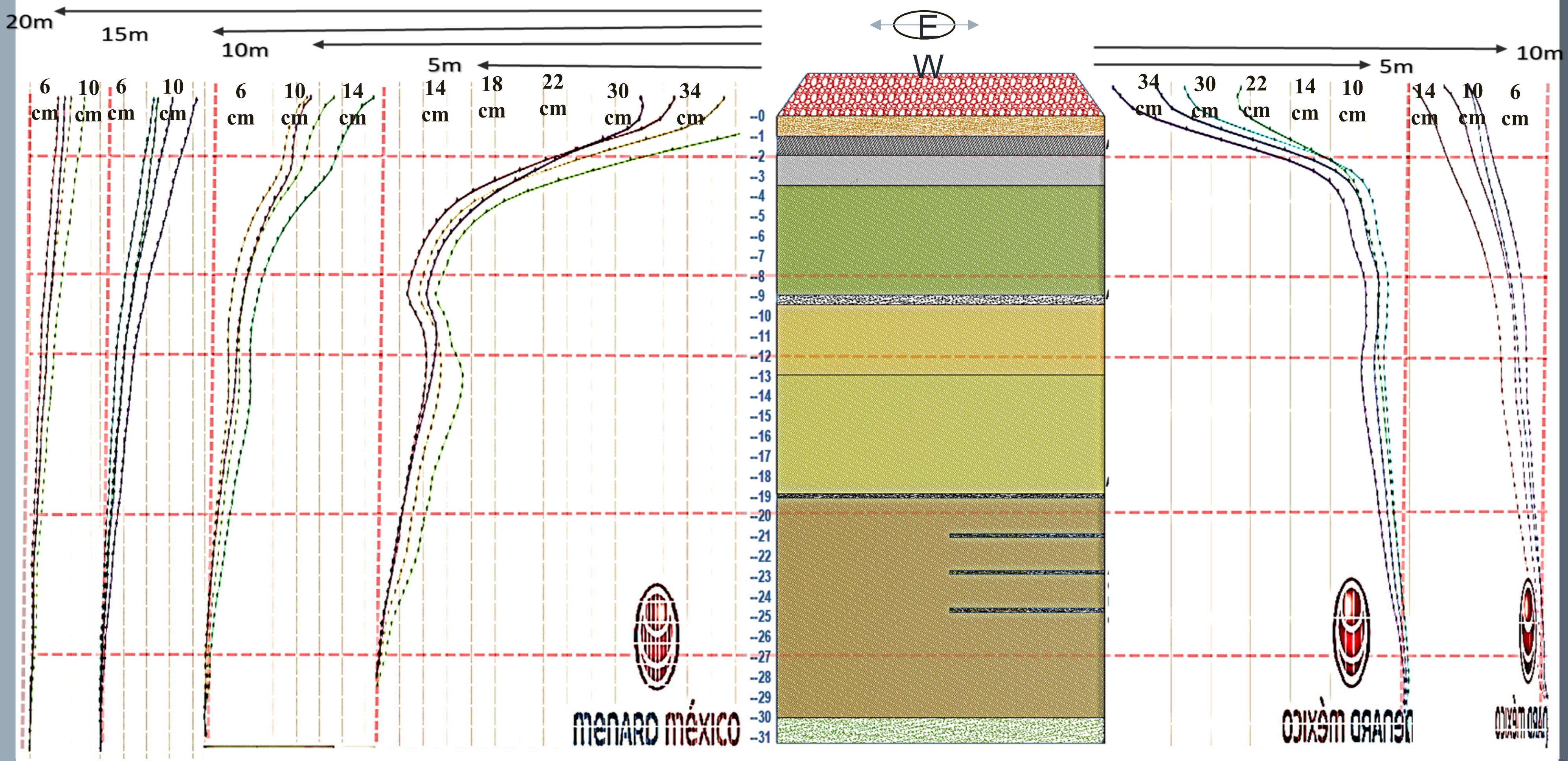
Tassement vs profondeur

Extensomètres multipoints

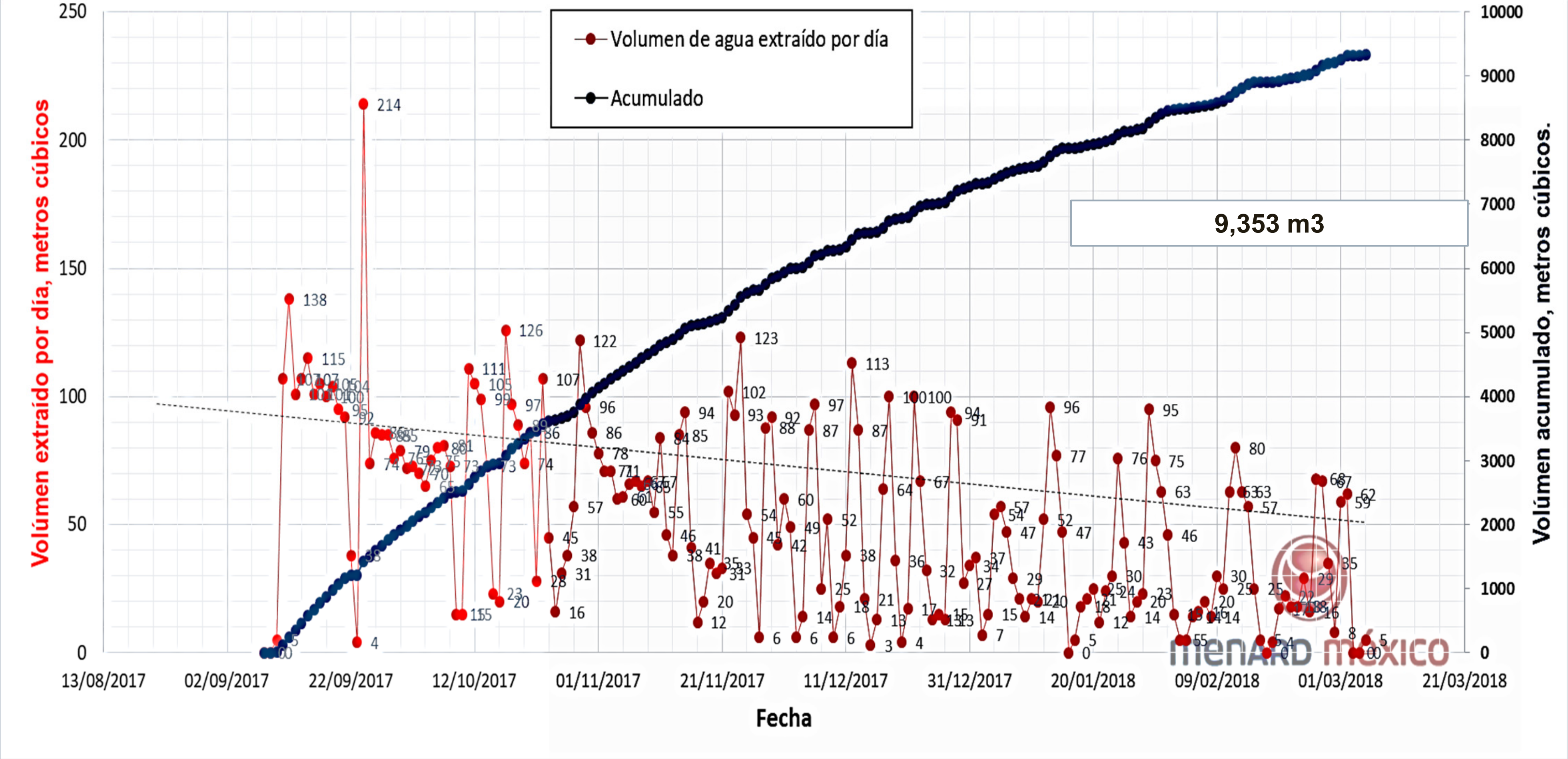

-0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
-16
-17
-18
-19
-20
-21
-22
-23
-24
-25
-26
-27
-28
-29
-30
-31
2 m
8 m
12 m
20 m
27 m
30 m

PROFUNDIDAD	ESTRATO	ESPESOR m	ASENTAMIENTO ACUMULADO M	ASENTAMIENTO APORTADO M	ASENTAMIENTO EN CM POR CADA METRO	% DE APORTACIÓN
Placa 2	CS y terraplen	2m y 1m tezontle	2.9	0.3	10.000	10.34%
2 8	FAS-01	6	2.6	0.7	11.667	24.14%
8 12	FAS-02	4	1.9	0.6	15.000	20.69%
12 20	FAS-03	8	1.3	0.64	8.000	22.07%
20 27	FAS-04	7	0.66	0.608	8.686	20.97%
27 30.7	FAS-05	3.7	0.052	0.05	1.351	1.72%
30.7 31	CD	0.3	0.002	0.002	0.667	0.07%

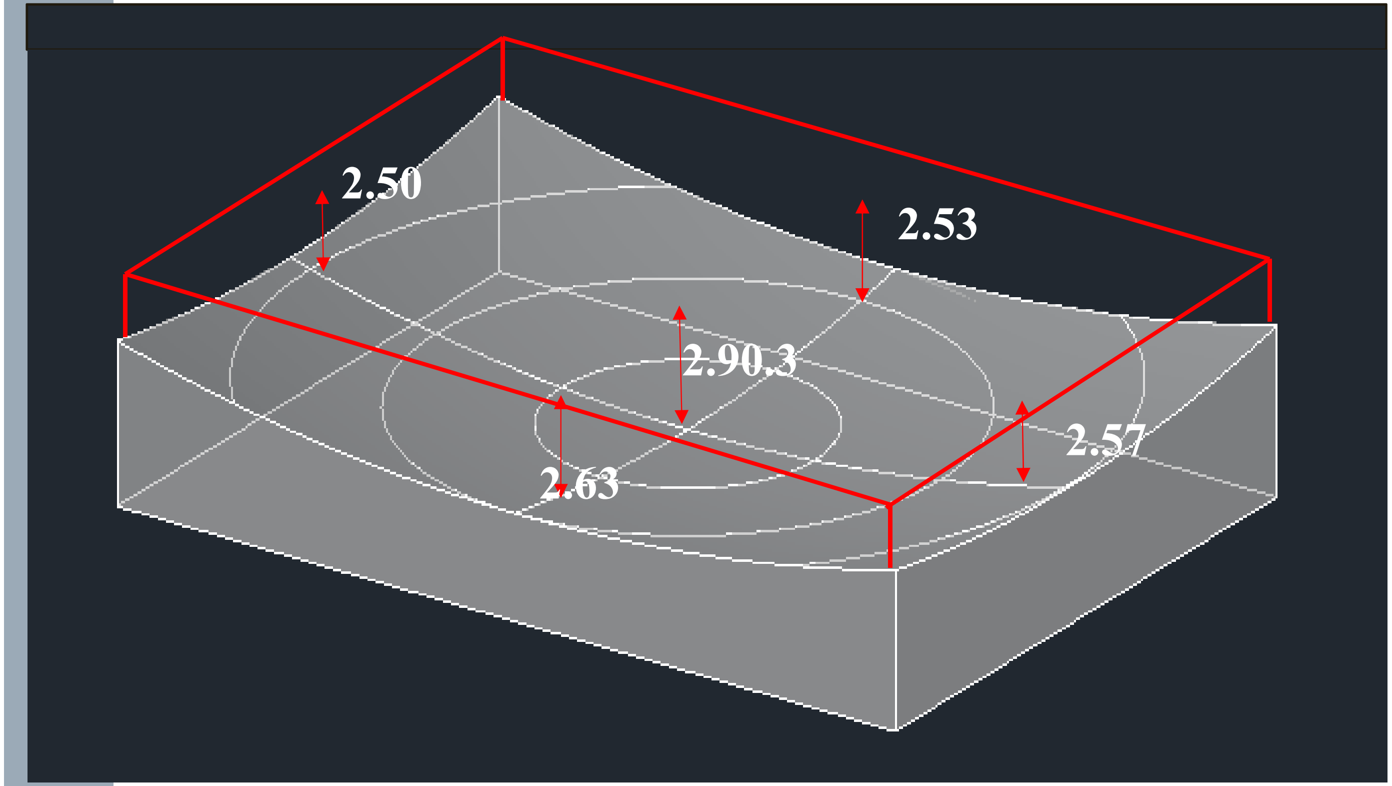
Inclinomètres

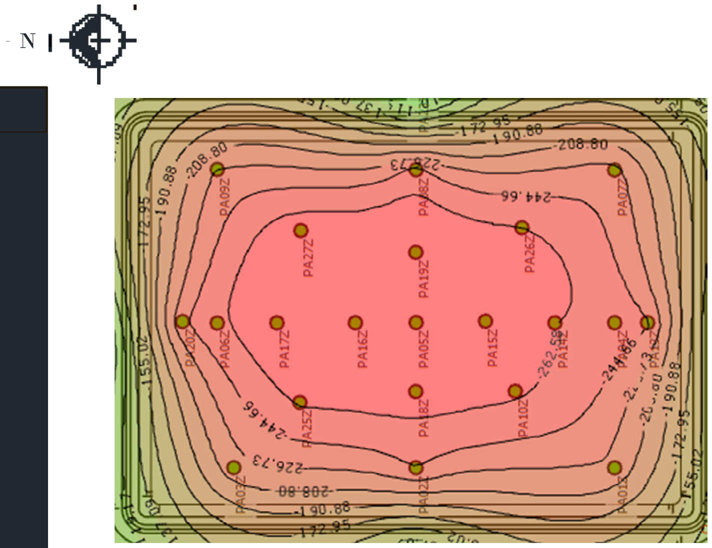


Volume d'eau extrait



Volume d'eau extrait – volume de tassement

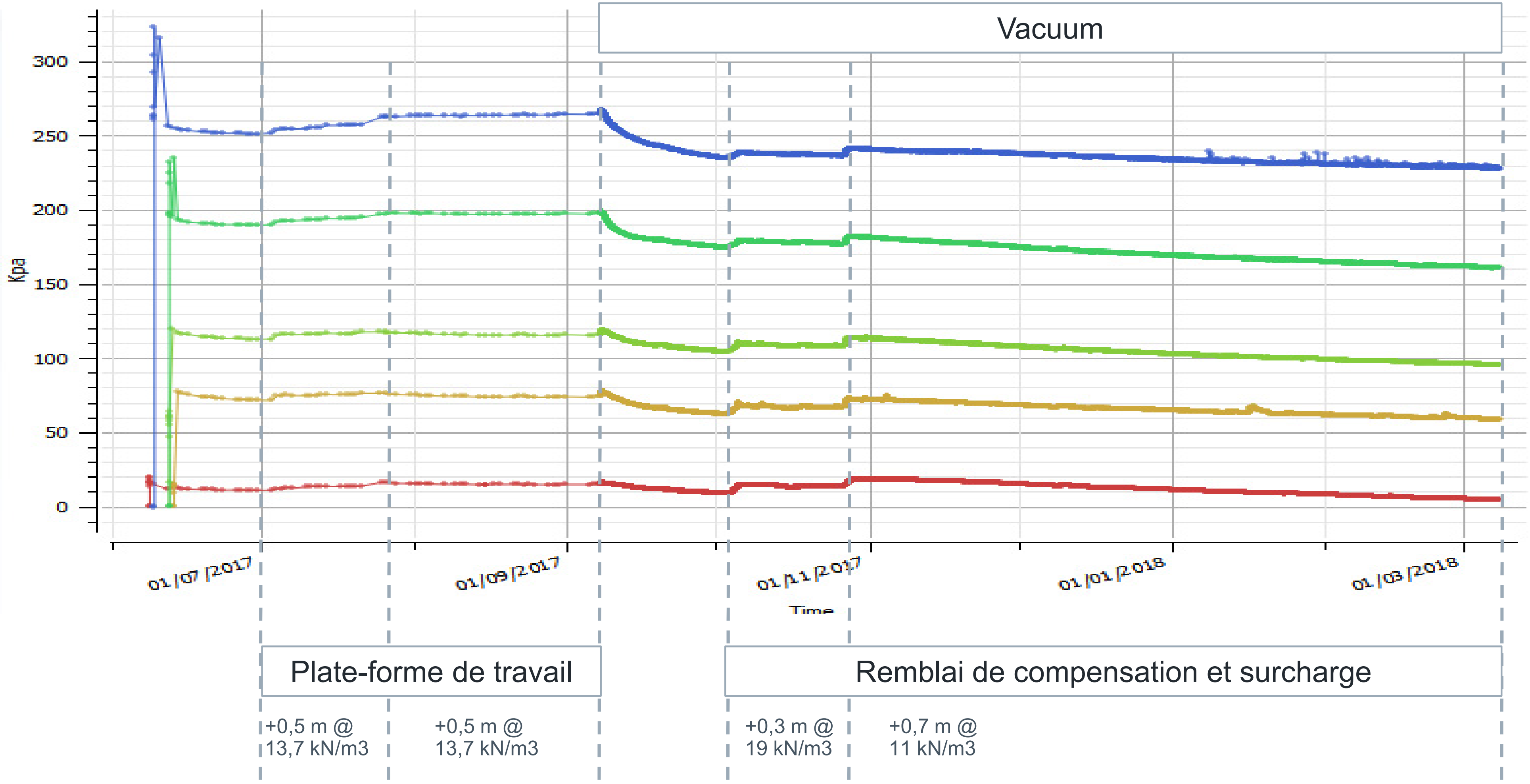

2.50
2.53
2.90.3
2.63
2.57


N
PA09Z
PA08Z
PA07Z
PA27Z
PA19Z
PA26Z
PA20Z
PA06Z
PA17Z
PA16Z
PA05Z
PA15Z
PA14Z
PA04Z
PA13Z
PA25Z
PA18Z
PA10Z
PA03Z
PA02Z
PA01Z
-155.02
-172.95
-190.88
-208.80
-226.73
-244.66
-262.58

Vol. tassement = 9,628 m3

Vol. eau extrait = 9,353 m3

Piezomètres électriques



Vacuum

Plate-forme de travail

+0,5 m @
13,7 kN/m3

+0,5 m @
13,7 kN/m3

Remblai de compensation et surcharge

+0,3 m @
19 kN/m3

+0,7 m @
11 kN/m3

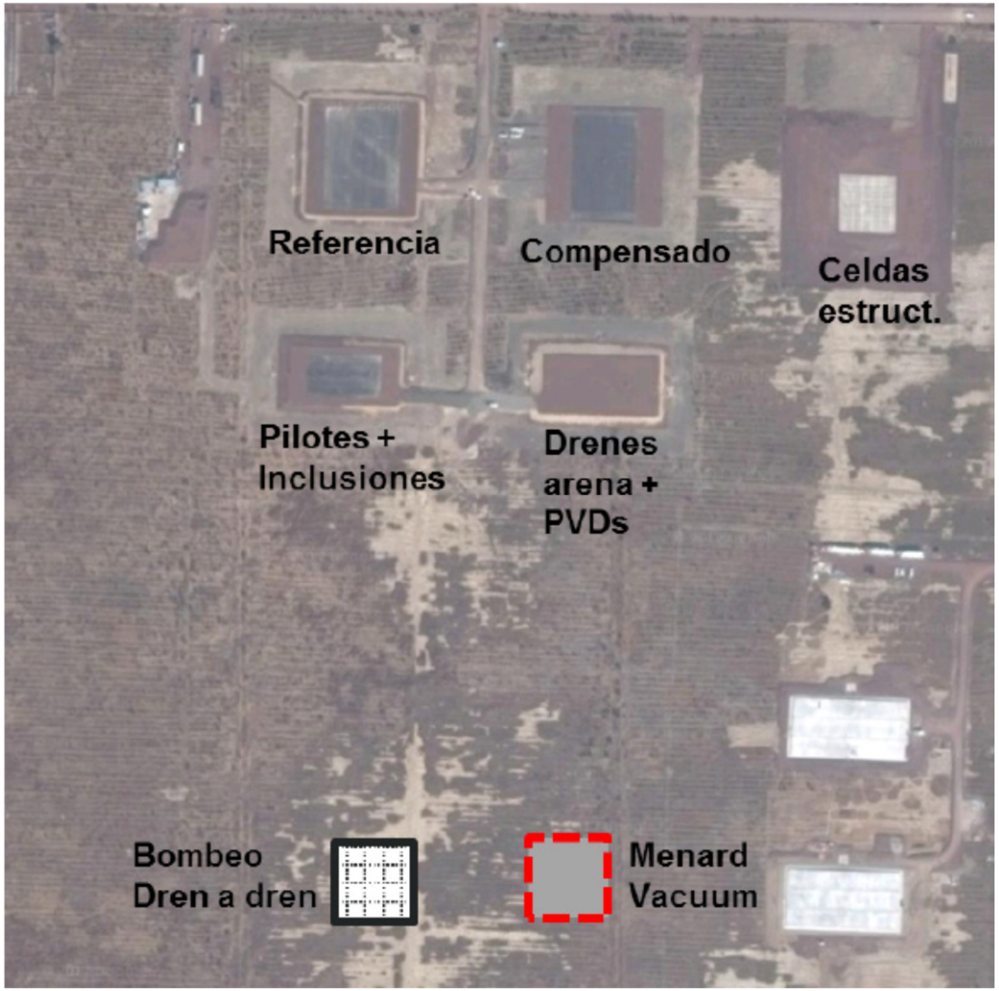
Degré de consolidation

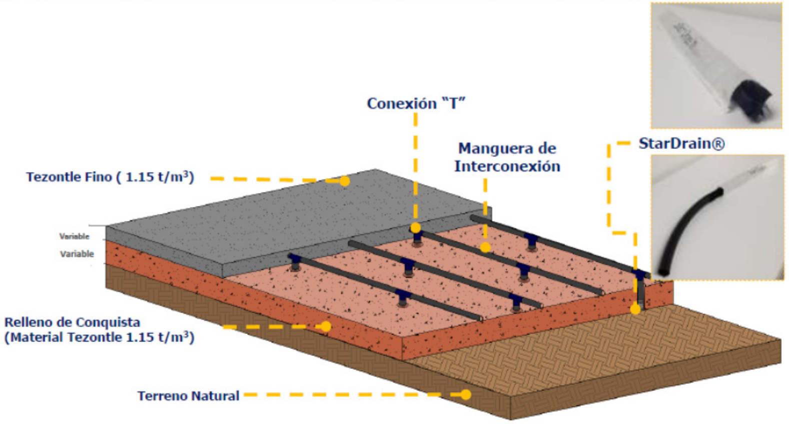
Instrument	Dissipation kPa	Total kPa	U%	Charge de remblai	Contrainte de consolidation kPa
PzE	**27**	**60**	**46**	**27.4**	**40,2**

Instrument	tassement m	Total m	U%	Contrainte de consolidation kPa
PA-05	**290**	**630**	**46**	**40.2**

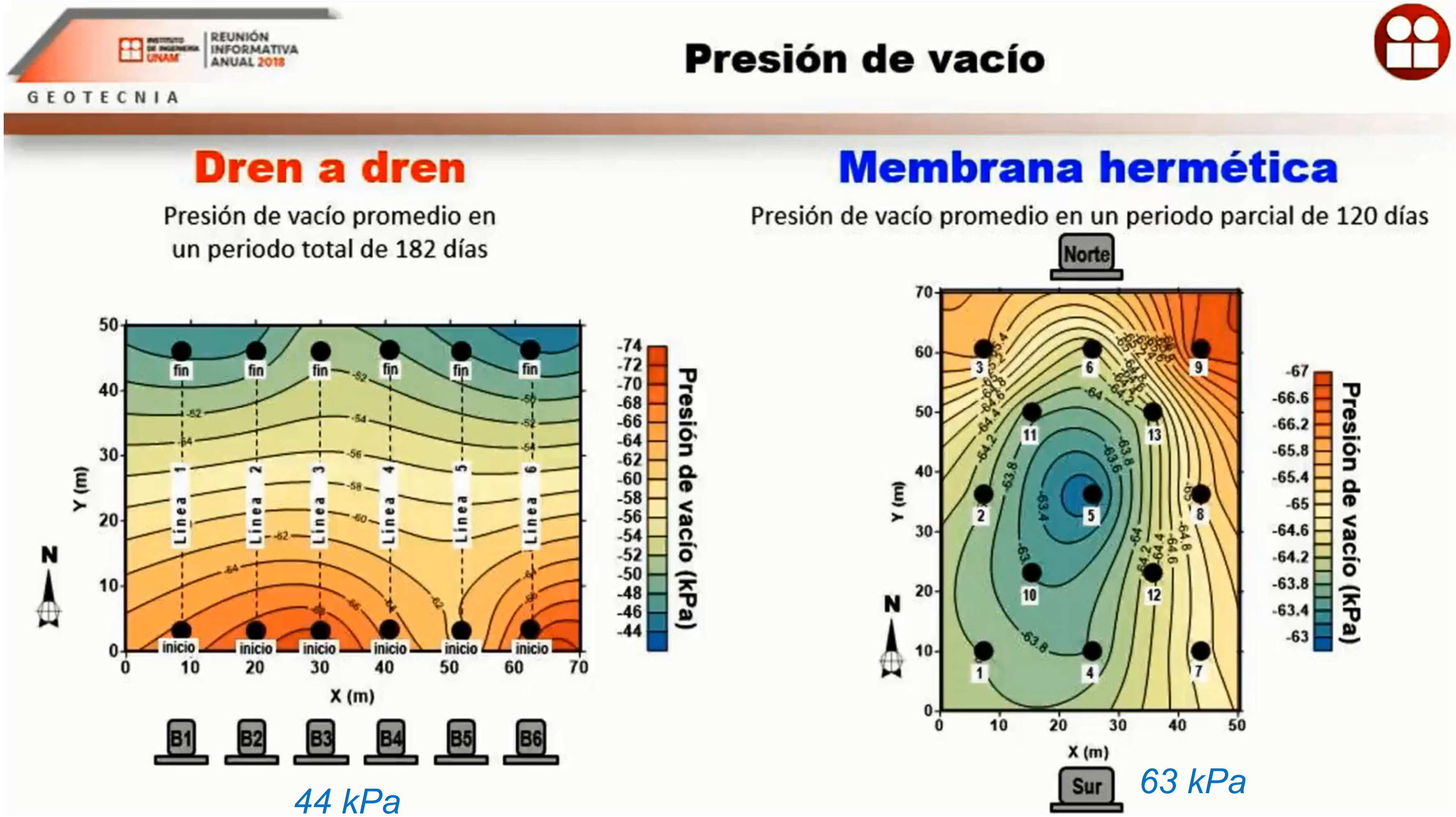
COMPARAISON MENARD VACUUM Vs DRAIN A DRAIN

Comparaison Drain à drain Vs Menard Vacuum


Referencia
Compensado
Celdas estruct.
Pilotes + Inclusiones
Drenes arena + PVDs
Bombeo Dren a dren
Menard Vacuum


Conexión "T"
Manguera de Interconexión
StarDrain®
Tezontle Fino (1.15 t/m^3)
Variable
Variable
Relleno de Conquista (Material Tezontle 1.15 t/m^3)
Terreno Natural

Comparaison Drain à drain Vs Menard Vacuum



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GEOTECNIA

Presión de vacío

Dren a dren

Presión de vacío promedio en un periodo total de 182 días

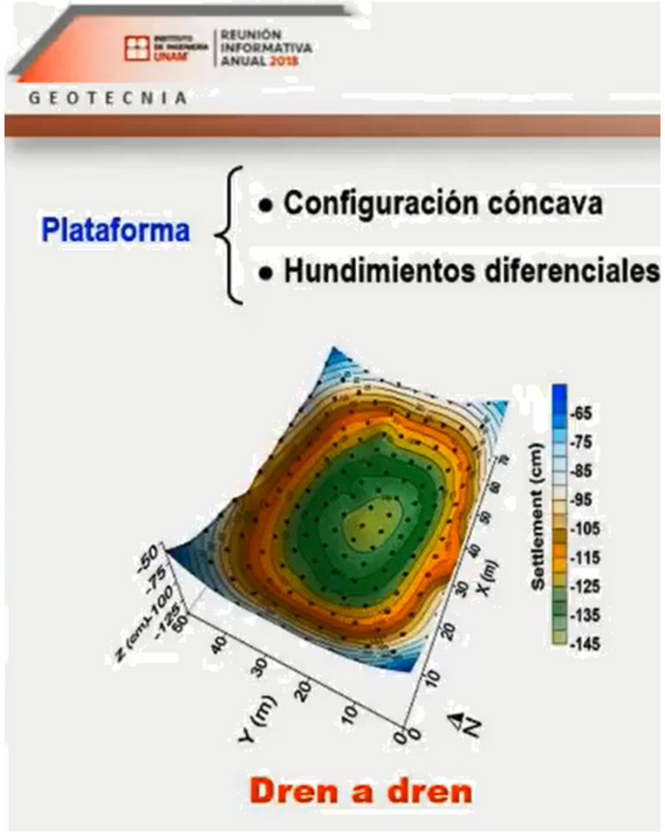
Membrana hermética

Presión de vacío promedio en un periodo parcial de 120 días

44 kPa

63 kPa

Drain à drains: Tassements différentiels



REUNIÓN INFORMATIVA ANUAL 2018

GEOTECNIA

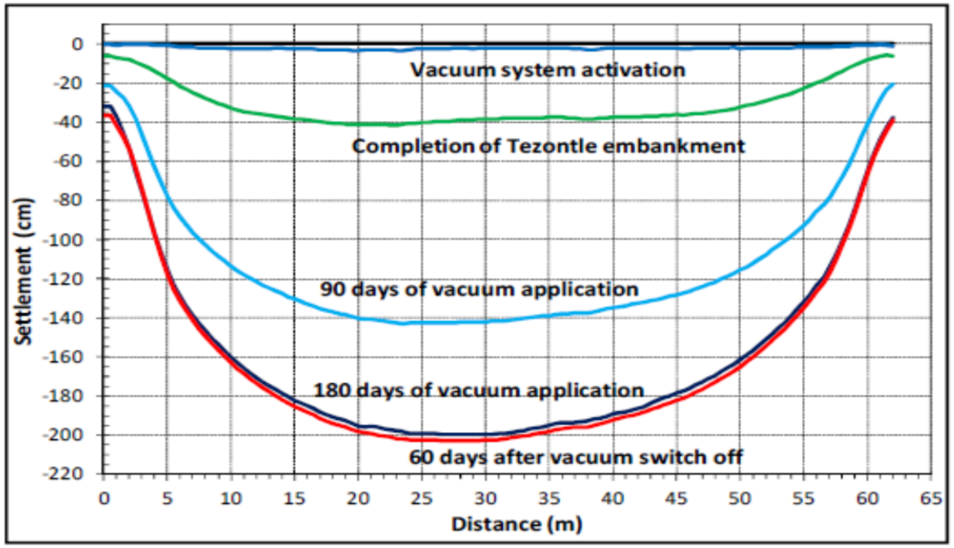
Plataforma
- Configuración cóncava
- Hundimientos diferenciales

Settlement (cm)
-65
-75
-85
-95
-105
-115
-125
-135
-145
Z (cm)
-50
-75
-100
-125
X (m)
Y (m)
N

Dren a dren

Differential settlements along the transverse centerline

Fig.10 summarizes data obtained from the horizontal inclinometer. Curves evidence isochronic settlement profiles that have almost symmetrical shapes and trends similar to that exhibited by traditional embankments. The differential settlements between the center and the boundaries of the embankment are influenced by the inward movements of the lateral boundaries caused by vacuum. Boundary settlements vary linearly with the corresponding ones detected at the centre. Along the transverse centerline a ratio equal to 0.6 between lateral and central settlements was observed: this value is practically coincident with that predicted by the elastic theory for traditional embankments.

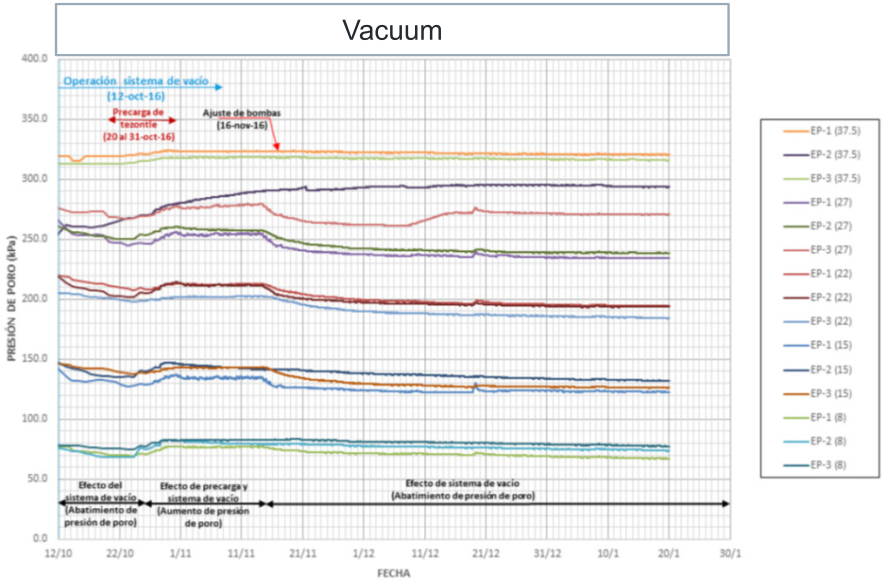


Bords: 1.20 m
Centre: 2.00 m

Fig 10 – Time history of settlements measured by horizontal inclinometer

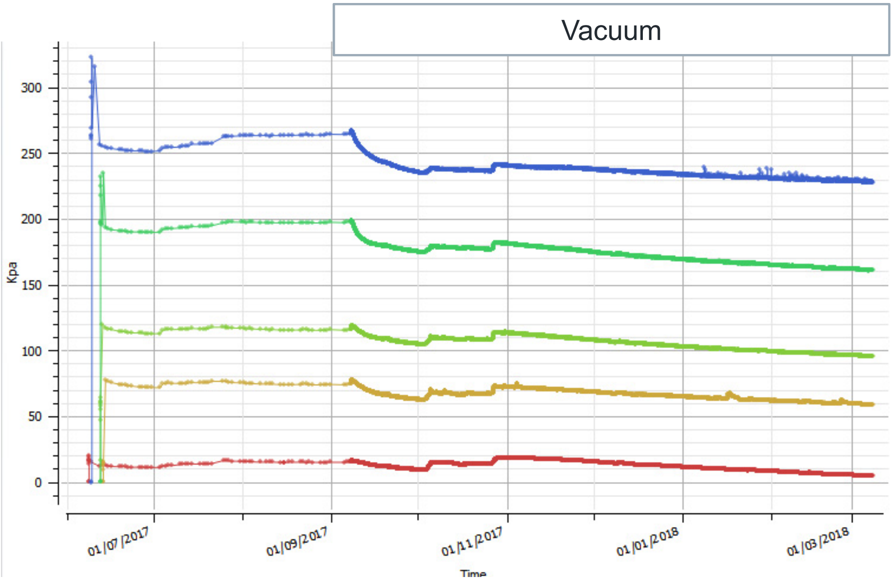
Comparaison Drain à drain Vs Menard Vacuum

DRAIN À DRAIN



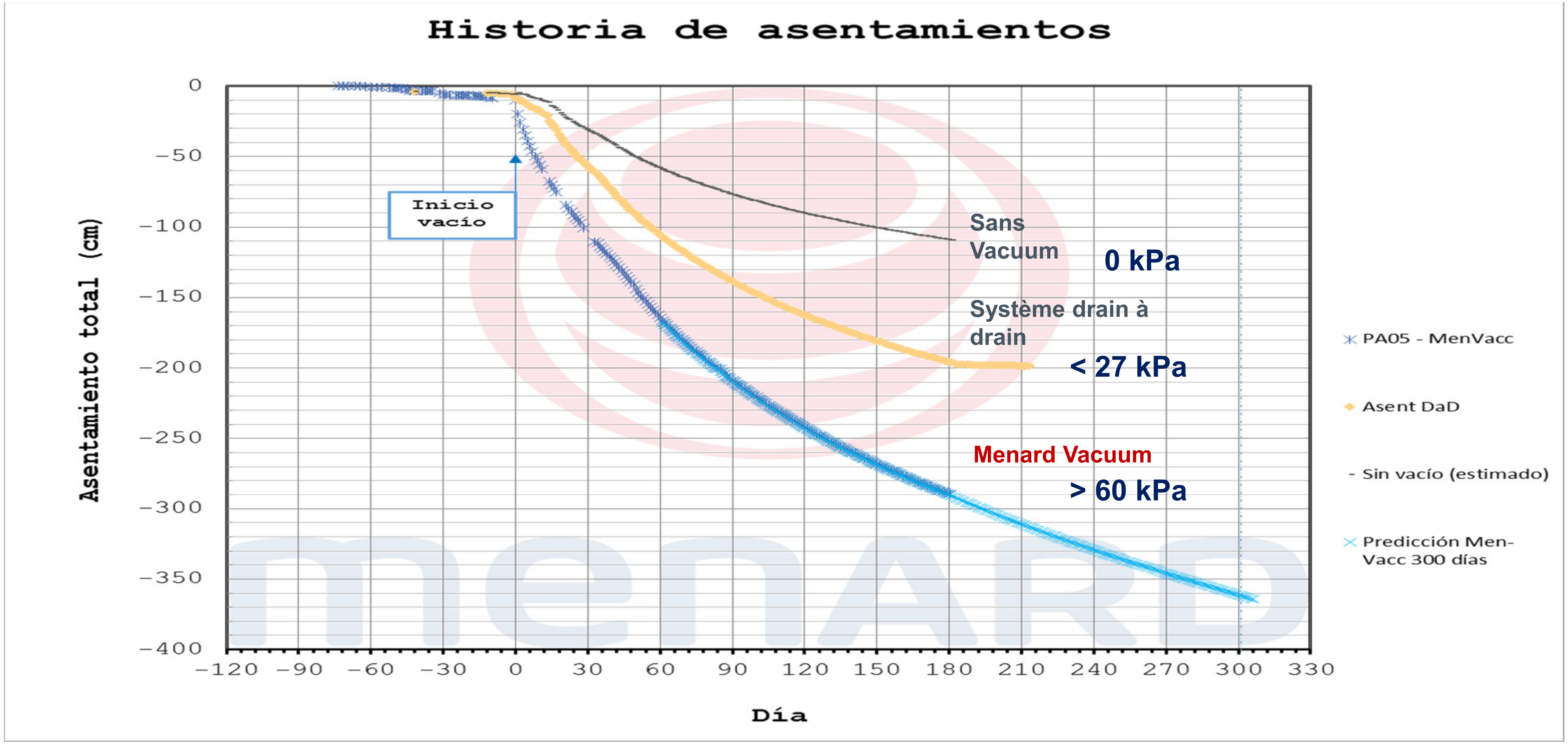
Consolidation sur 6 mois = **12,5 Kpa**
Soit Dv = 27 kPa avec U = 46%

MENARD VACUUM

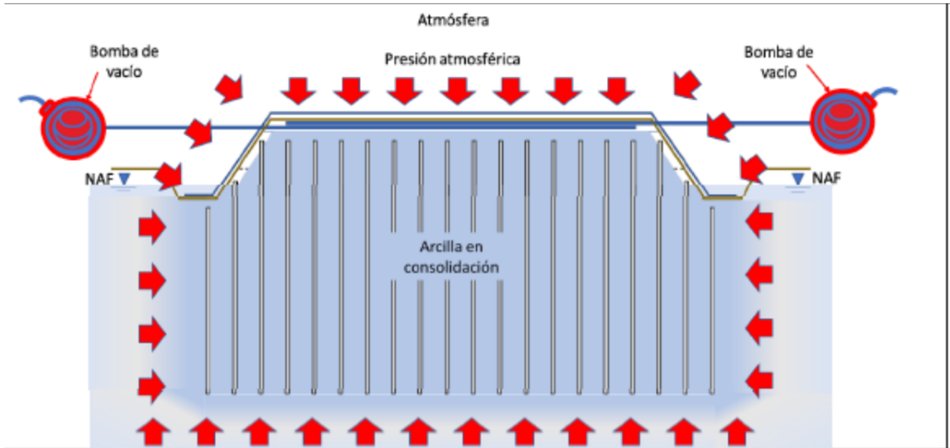


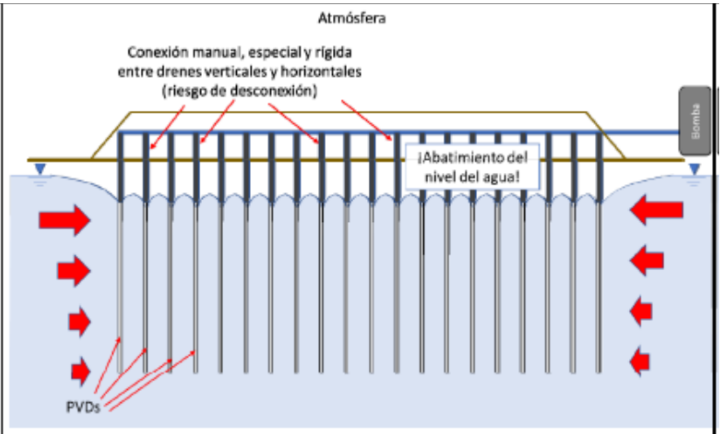
Consolidation sur 6 mois = **40,5 Kpa**
Soit Dv = 60 kPa avec U = 46%

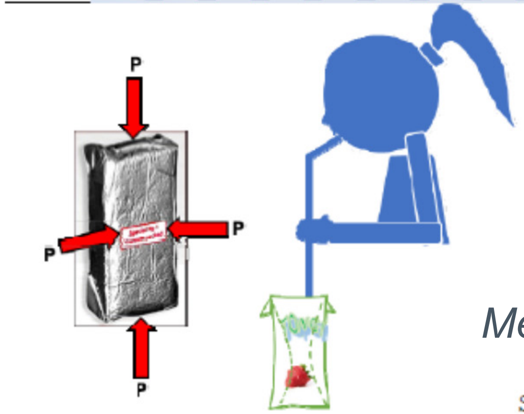
Comparaison Drain à drain Vs Menard Vacuum



Comparaison Drain à drain Vs Menard Vacuum

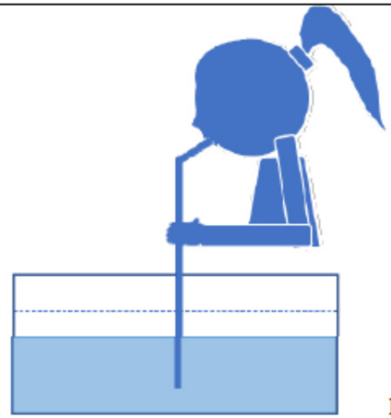

Atmósfera
Bomba de vacío
Presión atmosférica
Bomba de vacío
NAF
NAF
Arcilla en consolidación


Atmósfera
Conexión manual, especial y rígida entre drenes verticales y horizontales (riesgo de desconexión)
Bomba
¡Abatimiento del nivel del agua!
PVDs



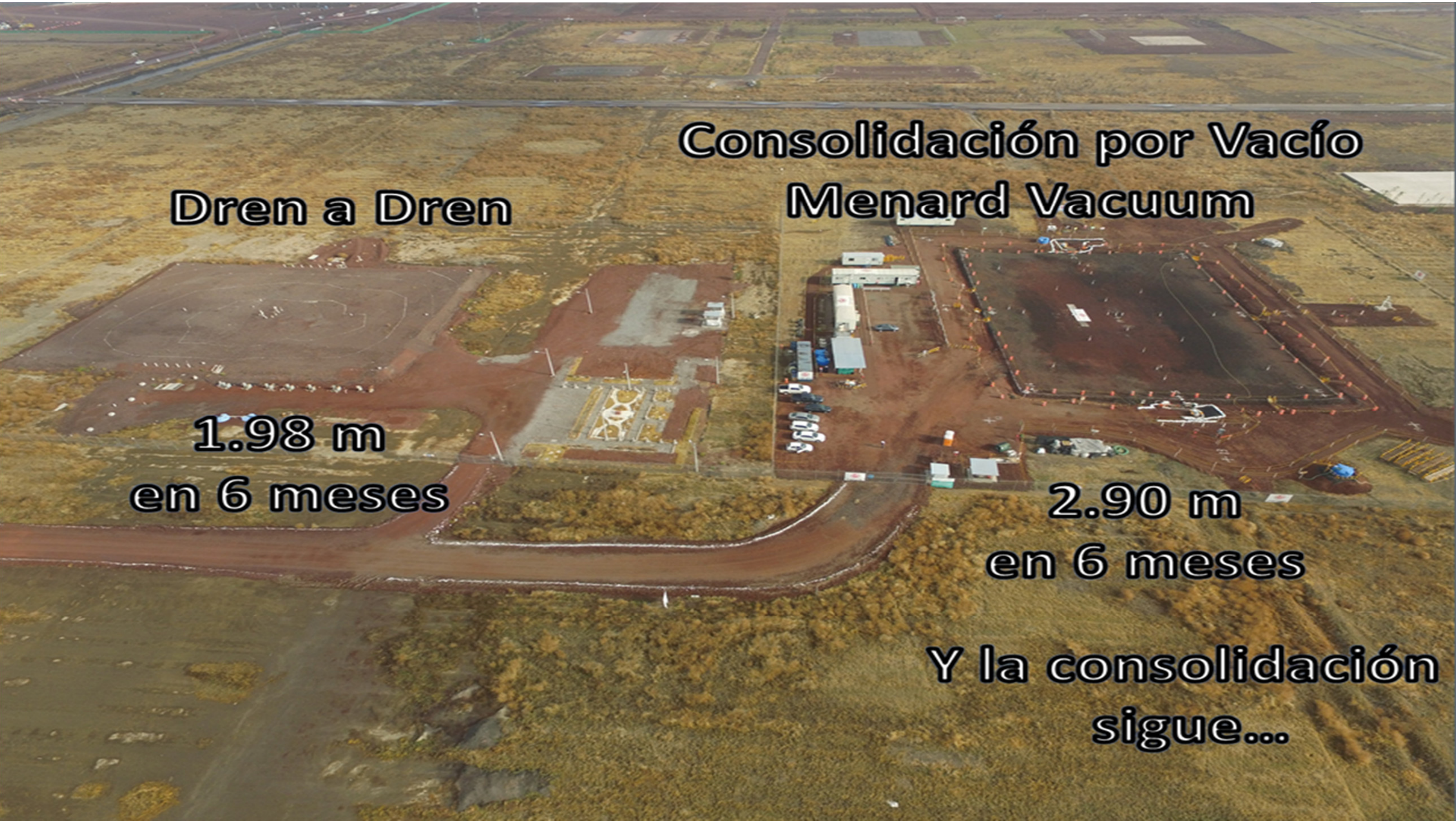
Menard Vacuum

Saco de café / Tetrapack



Otros

Bombeo



Consolidación por Vacío
Menard Vacuum

Dren a Dren

1.98 m
en 6 meses

2.90 m
en 6 meses

Y la consolidación
sigue…