RemTech 2015

Jet Grouting – an alternate for environmental cut-off

Stephen Custeau P. Eng., Matcon Environmental
Paolo Gazzarrini P. Eng., Sea to Sky Geotech

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Summary

- History of Jet Grouting
- How the technology is working
-Applications
- Case Histories for environmental applications
  - Recochem Port Coquitlam
  - New Westminster Pier
  - John Hart Dam (cut off)

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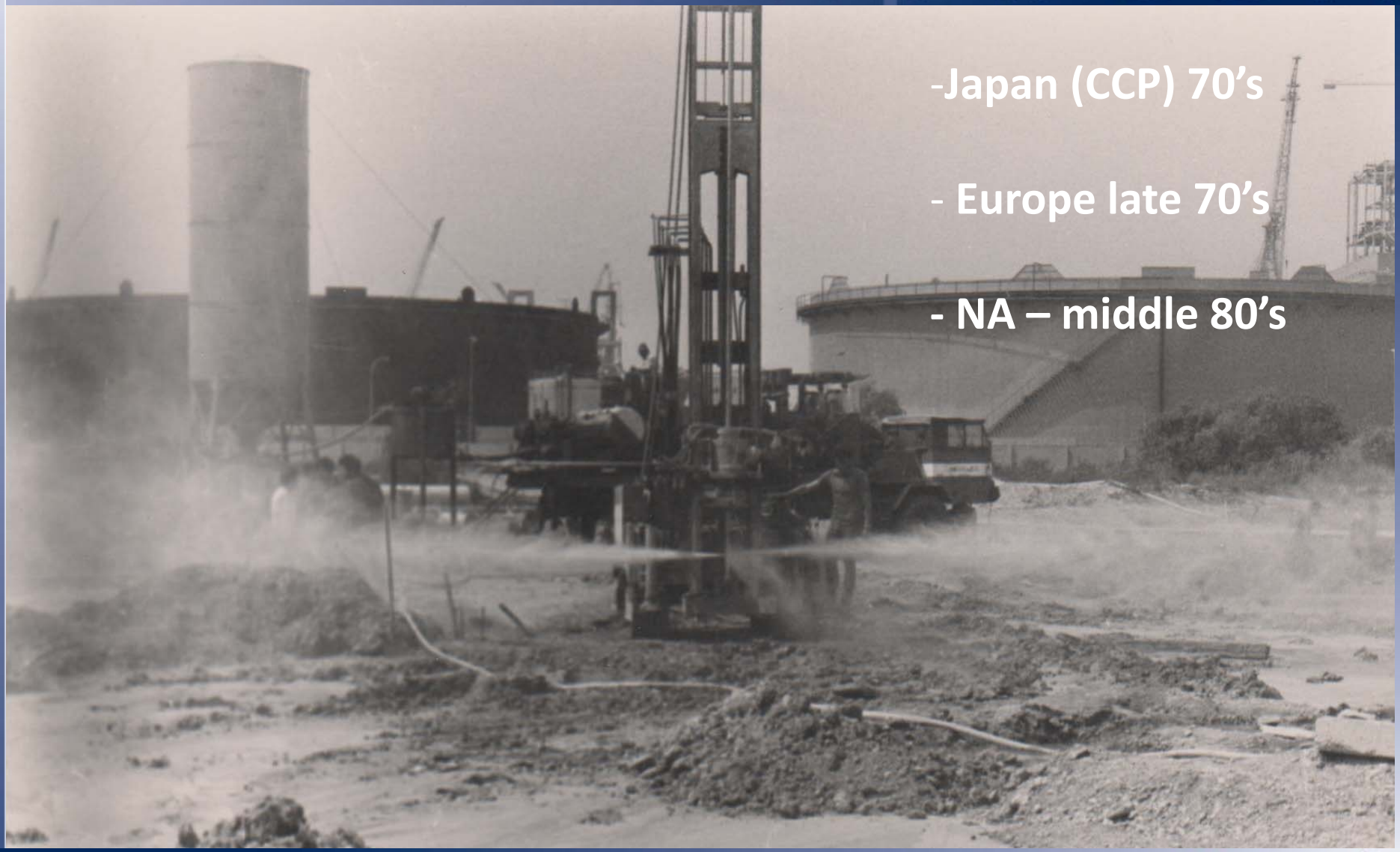
History



-Japan (CCP) 70's

- Europe late 70's

- NA – middle 80's

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Standards

GEO-INSTITUTE OF ASCE
GROUTING COMMITTEE
JET GROUTING TASK FORCE

JET GROUTING GUIDELINE

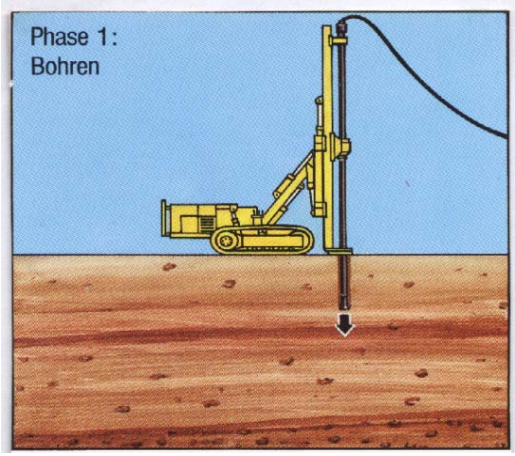
June 2009

http://content.geoinstitute.org/files/pdf/G-I-ASCEJetGroutingGuideline-final.doc

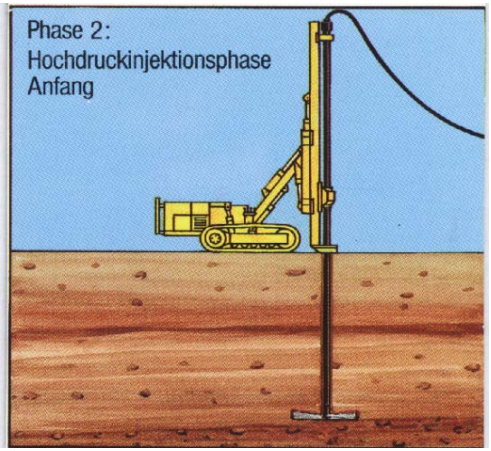
Page 1 of 30

How is working

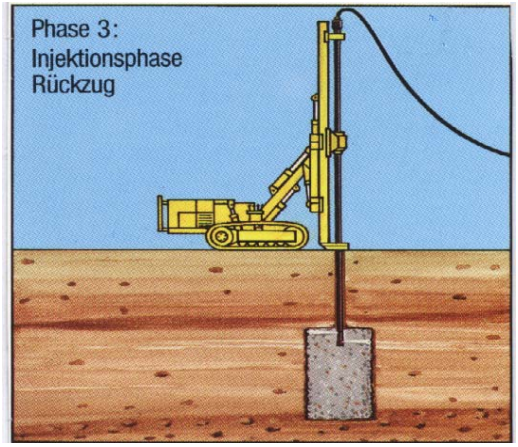
STEP 1 : DRILLING



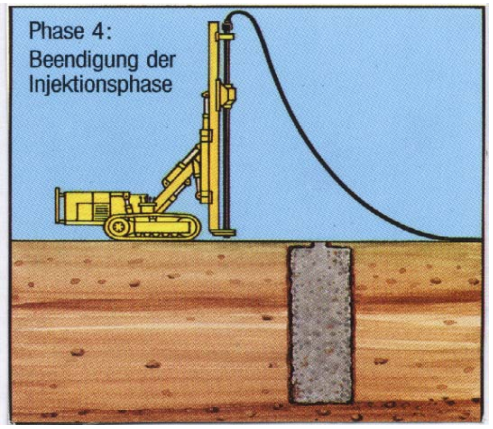
STEP 2 START JETTING WITH W/C GROUT MIX FROM THE BOTTOM



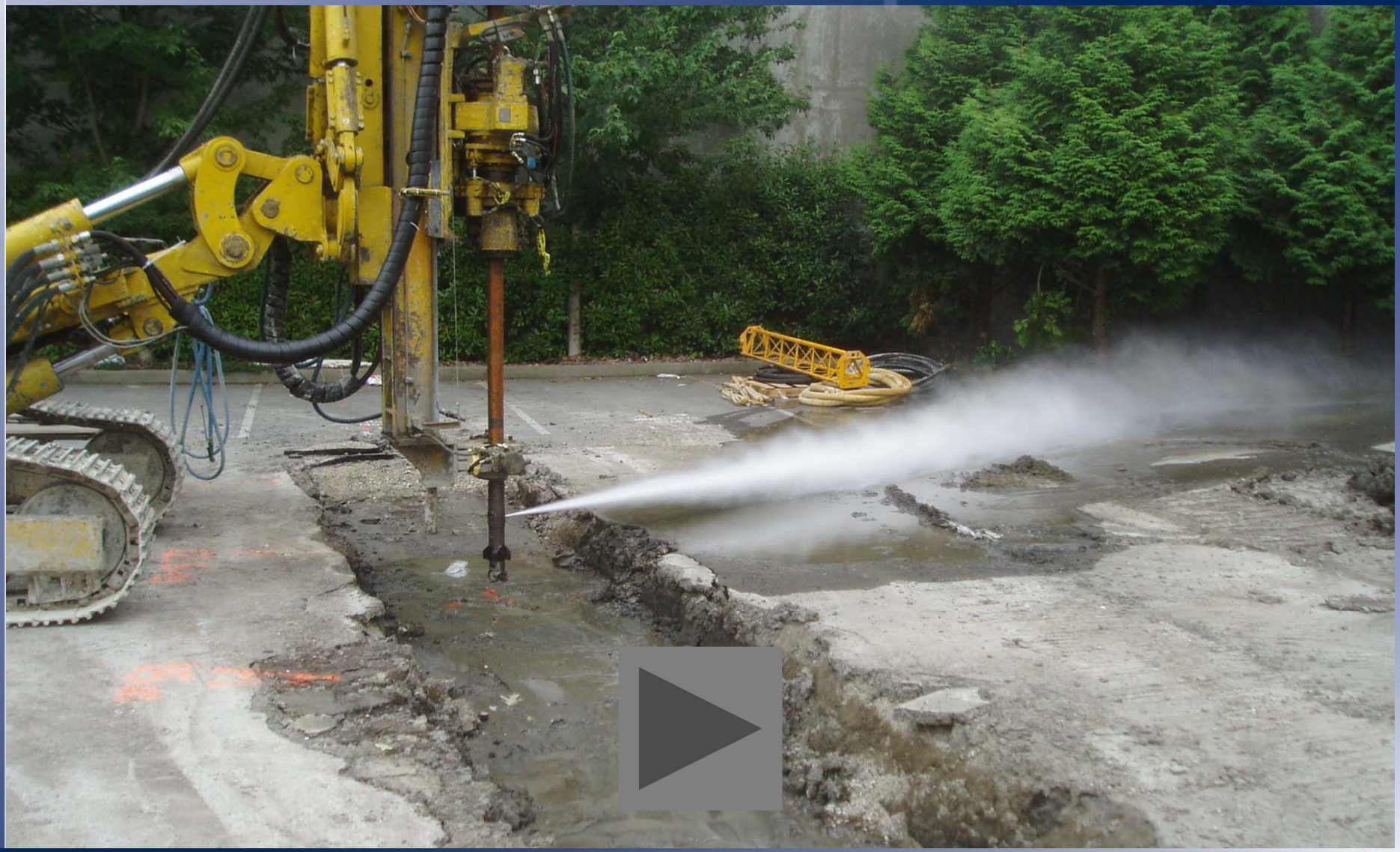
STEP 3: PULL UP THE ROTATING JET



RESULT: ROUND COLUMN CONSISTING OF WATER/CEMENT MIX AND INSITU SOIL



How is working



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Result

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Result

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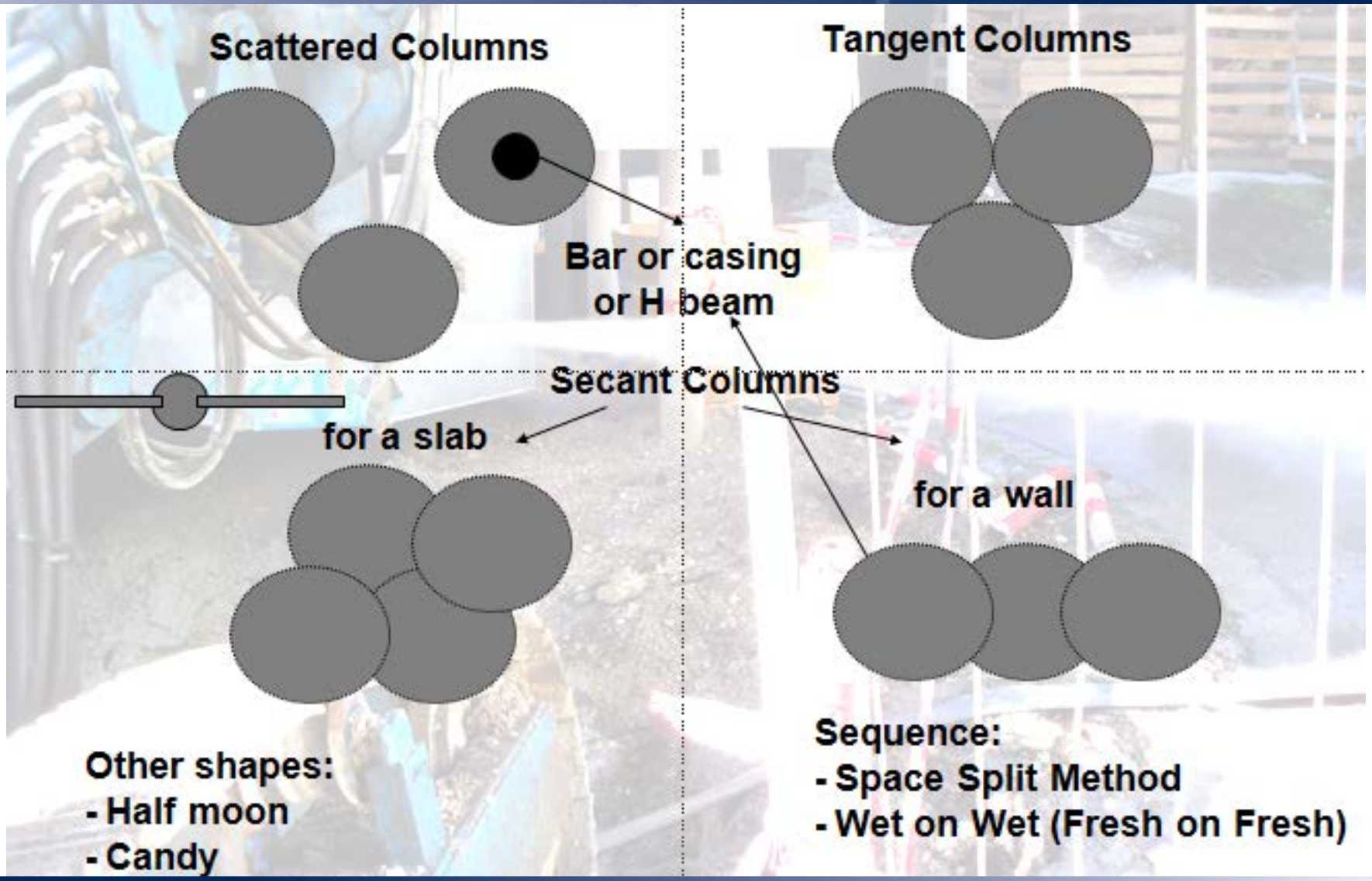
Geometry


Scattered Columns
Tangent Columns
Bar or casing
or H beam
Secant Columns
for a slab
for a wall
Other shapes:
- Half moon
- Candy
Sequence:
- Space Split Method
- Wet on Wet (Fresh on Fresh)

Environmental

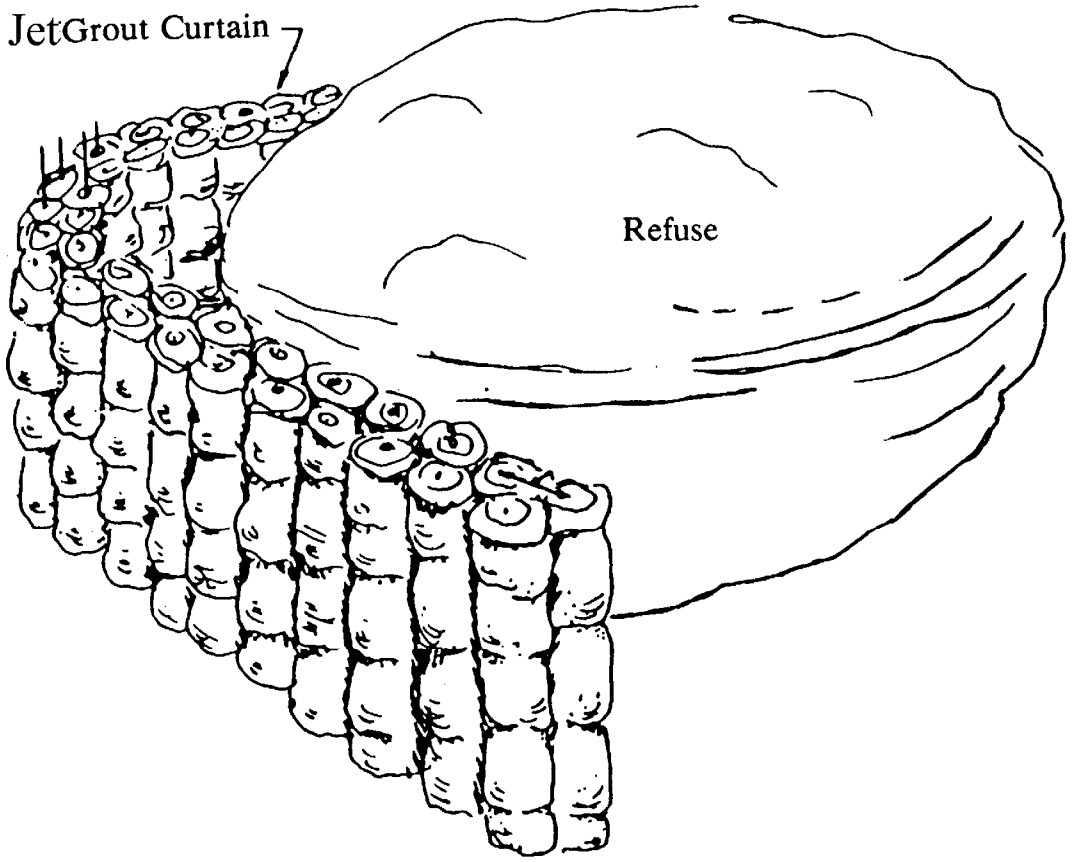
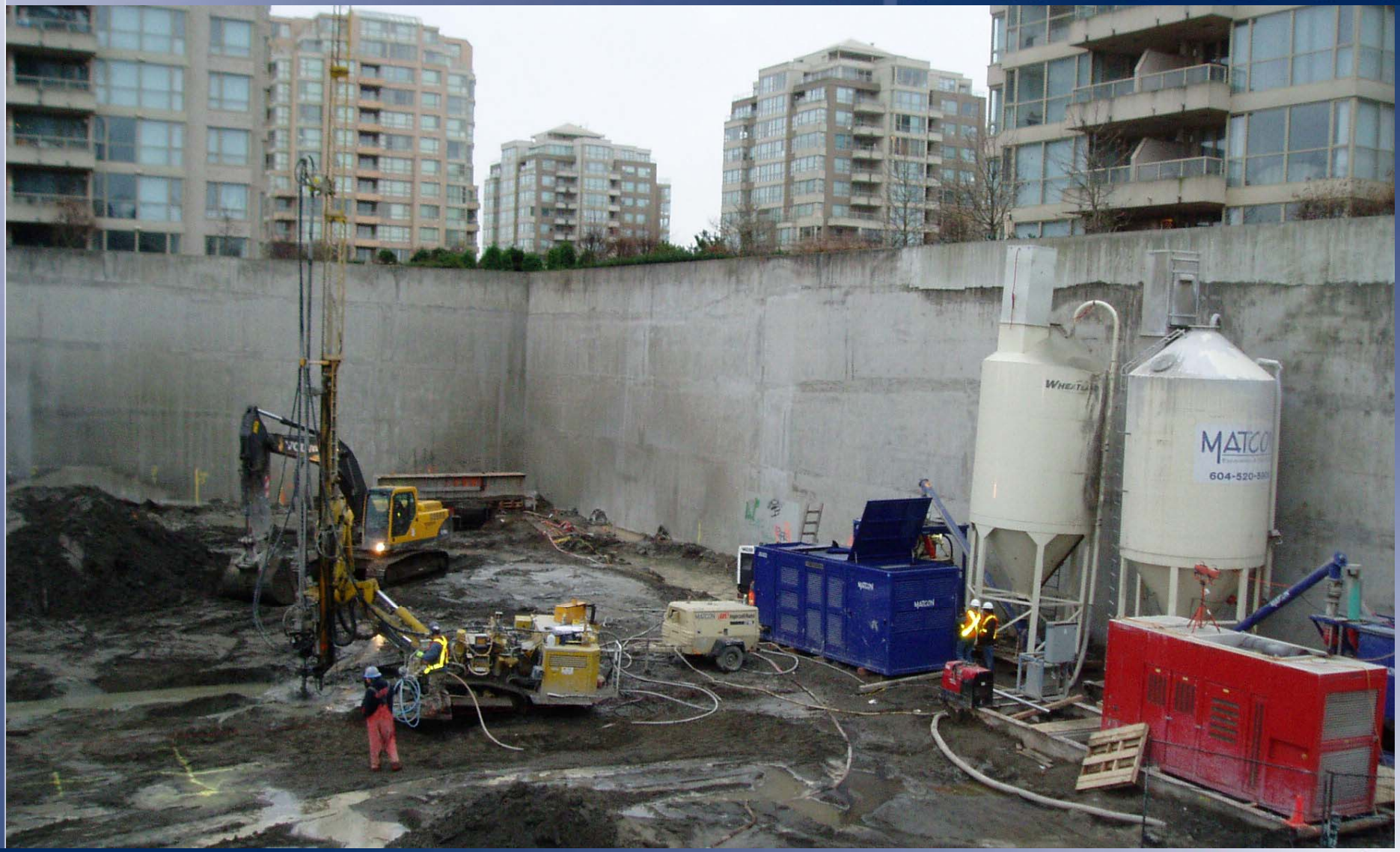


Fig. 9 - Grout curtain used to isolate waste from flowing groundwater. (from USEPA, 1978)

Typical Site Installation



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JG parameters

- Pressure p (MPa) - Grout Mix and/or Air water in case of D&T

-Flow Q (m^3/hr) - Grout Mix and/or Air water in case of D&T

-Diameter d_n (mm) and number (N) of nozzles. These give the total area of the nozzle A_n (mm^2)

-Velocity of withdraw of the rods or Treatment Velocity v_t (m/hrs or cm/sec)

-Specific Volume of Fluid jet-grouted V (m^3/m) and consequently volume of cement (Kg/m)

-Rotation speed of the rods v_r (rpm)

-Composition of grout mix in terms of W/C ratio.

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Flexibility

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Range of Results

Type of Soil	Diameter (m)			UCS (Mpa)	E (Mpa)
	Single fluid	Double Fluid	Triple Fluid		
Gravel	0.6-1.2	1.0-1.6	2.0-3.0	10-30	2,500-15,000
Sandy Gravel	0.5-1.0	0.9-1.8	1.5-3.0	8-20	2,500-10,000
Silty Clay	0.5-1.0	0.8-1.5	1.2-2.8	5-15	2,500-7,500
Clayly Silt	0.4-0.6	0.7-1.0	1.0-1.5	2-8	1,000-5,000
Clay	0.4-0.8	0.6-1.2	0.8-1.2	1-6	500-5,000

Permeability= 10^{-6} to 10^{-8} m/s
Depending on soil conditions and grout Mix (with or w/o bentonite).

Field Test

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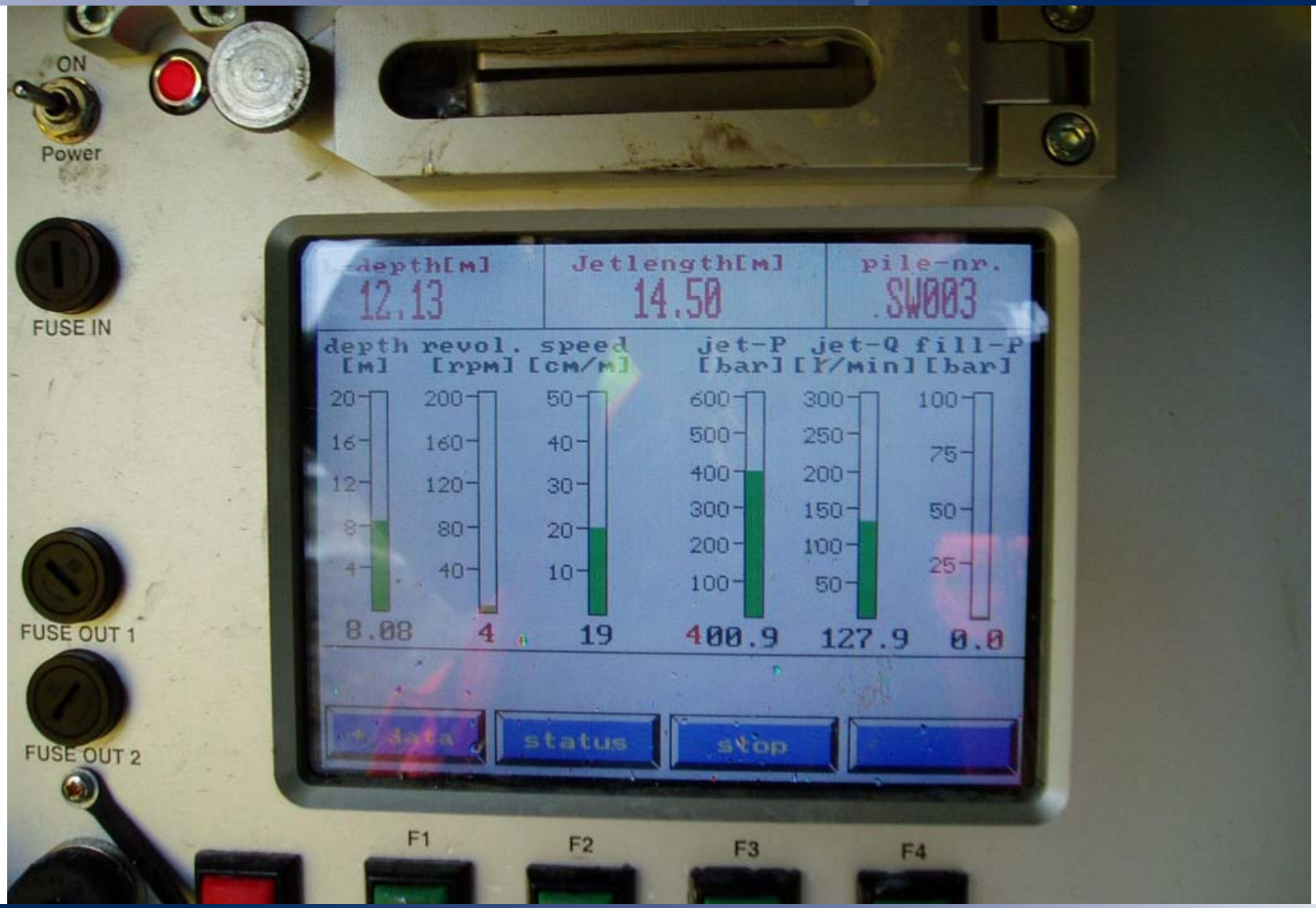
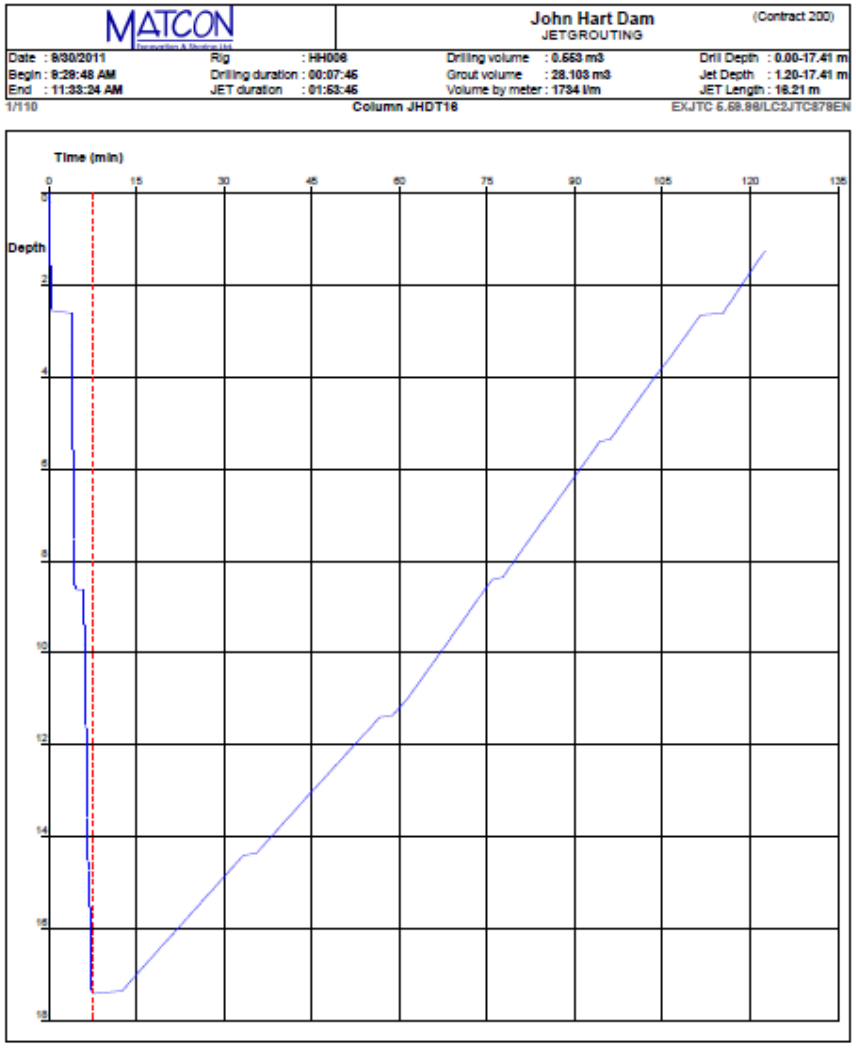
QC at the Grout Plant

QC- Monitoring and recording jetting



QC- Monitoring and recording jetting



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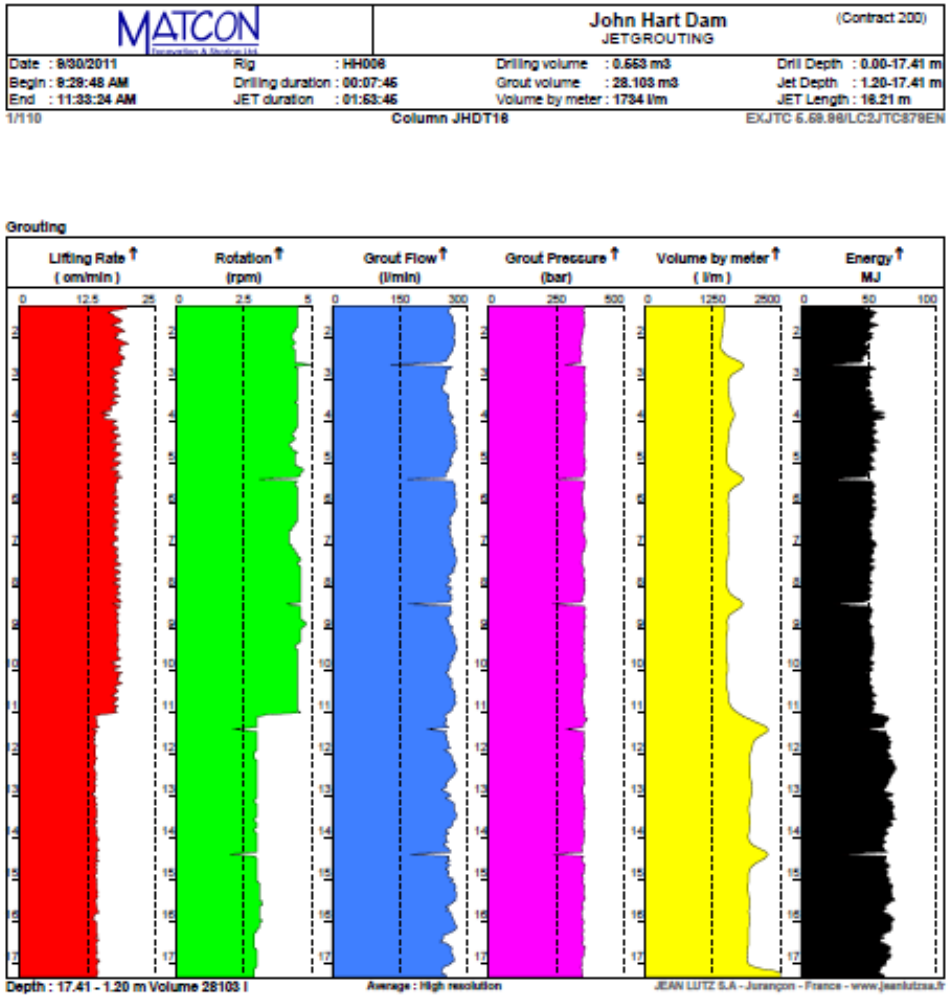
QC- Monitoring and recording jetting



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Verticality

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Verticality

MATCON Excavation & Shoring Ltd.

John Hart Dam (Contract : 200)

TIGOR H -Borehole deviation (measured toward magnetic north)

Drilling length : 16.65 m

Date : 9/28/2011
Hours : 8:04:37 AM - 8:14:55 AM

Terminal Inclination : 179.56 ° Inclination Instruction : 0 °
Terminal Orientation : 209.92 ° Orientation Instruction : 0 °

Column : TIG06

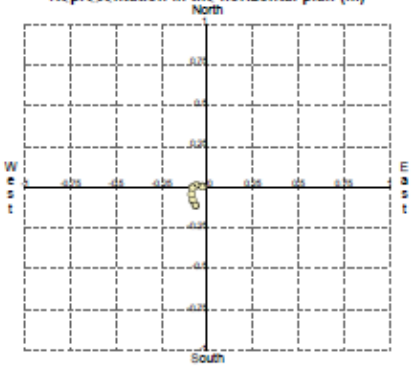
EXJTC 6.69.98/LC2/TC679EN

Z +
North
West

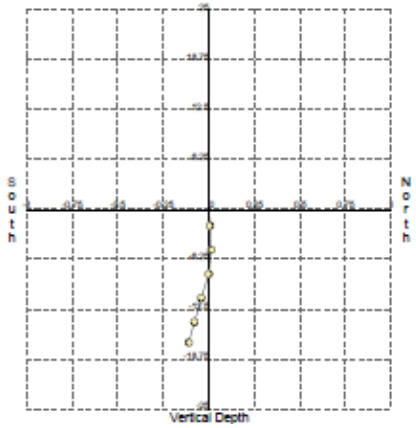
Borehole deviation data

Drilling length (m)	Vertical Depth (m)	South-North (m)	West-East (m)	Difference with instructions (m)	Difference with instructions (%)
0.00	0.00	0.00	0.00	0.00	0.00
2.03	-2.03	0.01	-0.03	0.03	1.41
5.05	-5.05	0.01	-0.06	0.06	1.20
8.07	-8.07	-0.00	-0.08	0.08	1.00
11.09	-11.09	-0.04	-0.09	0.09	0.86
14.09	-14.09	-0.08	-0.08	0.11	0.80
16.65	-16.65	-0.11	-0.06	0.13	0.76

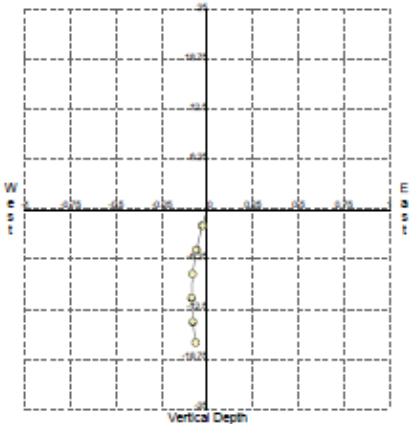
Representation in the horizontal plan (m)



Deviation under South-North axis (m)



Deviation under West-Easth axis (m)



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Verticality

Columns	Distance between columns at rock elevation (mm)	Geometrical wall thickness (mm)
P1 – T2	736.66	1071.55
P1 – T33	758.14	1092.04
P1 – T34	807.45	1019.07
T2 – S3	385.62	1240.24
S3 – T4	667.85	1115.82
T4 – P5	818.82	1016.81
P5 – T6	782.93	1037.80
T6 – S7	714.63	1086.14
S7 – T8	633.14	1136.43
T8 – P9	735.86	1073.06
P9 – T10	729.54	1088.29
T10 – S11	598.82	1153.77
S11 – T12	771.82	1046.09
T12 – P13	772.93	1045.27
P13 – T14	811.24	1013.82
T14 – S15	609.68	1148.24
S15 – T16	613.81	1146.29
T16 – P17	847.5	985.65
P17 – T18	635.26	1122.78
T18 – S19	744.53	1065.68
S19 – T20	630.86	1136.61
T20 – P21	685.26	1104.63
P21 – GP22P	586.04	1162.43
GP22P – T22	582.84	1162.43
T22 – S23	431.80	1226.33
S23 – T24	765.62	1047.70
T24 – P25	753.57	1059.42
P25 – T26	712.27	1087.64
T26 – S27	862.84	978.40
S27 – T28	767.75	1048.06
T28 – P29	688.00	1103.12
P29 – T30	605.52	1150.37
T30 – T31	328.42	630.44
T30 – T32	548.53	1178.61

LEGEND:

- As built centre of column (Top) – Surveyor data
- Theoretical centre of column (As per drawing MESL-211026-010)
- As built centre of column at rock elevation

NOTES:
Columns are indicated at 1.3m in diameter at rock elevation, centered over as-built points

N

SCALE 1:50 METERS

MATCON Excavation & Shoring Ltd.	DATE: SEPT. 29, 2011	JOHN HART DAM	FILE NO.:	REVISIONS:
	DRN. BY: AD APP'D.	HT NORTH EARTHFILL DAM		REV.A SEPT. 30, 2011
	SCALE: 1:50	Bottom of TIGOR location	DWG. NO.: MESL-211026-013	REV.B OCT. 3, 2011
				REV.C

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Verification

- Coring
- Permeability tests (direct-indirect)
- Cross/holes, tomography
- Calipers
- Load test in case of piles

Case History in BC

19) Lynn Sewage Pumping Station, North Vancouver. Shoring and cutoff wall. 20) 21) 22) 23)
18)Edgemont Village, North Vancouver.
17) Trapp & Holbrook – 660 Columbia Street, New Westminster.
16) The Mandarin. Richmond - Jet Grouting for shoring, underpinning and cutoff wall.
15) Multi-Use Facility centre - City of New Westminster - Shoring and cutoff wall.
14) Zeballos (Vancouver Island) -Design and execution of a 75 diameters p cut off using Jet Grouting technology.
13) John Hart Dam – Flexible Jet Grouting cutoff.
12) Science World- Soil improvement against seismic liquefaction. Jet Grouting/ Compaction Grouting.
11) New Westminster Pier – Impervious environmental cutoff wall.
10) Iona treatment plant (GVRD- Vancouver) . Shaft for manhole sewer excavation. Siphon 1, 2 and 3, in 3 years.
9) BC Hydro Walter Substation North Vancouver- Jet grouting for concrete slab soil improvement against liquefaction.
8) Port Coquitlam. Cutoff for contaminated soils.
7) Pemberton Ave.- North Vancouver- Cutoff for contaminated soils
6) Olympic Village – False Creek – Vancouver- Jet Grouted cut off and shoring wall.
5) Richmond – Paloma Parkade- Jet-Grouted piles.
4) Clarkson & Sixth- New Westminster - Jet Grouting for soil improvement (building foundation) in proximity of Sky train tunnel for settlement control.
3) 102 st./King George Highway –Surrey - INFINITY- Shoring.
2)Esplanade & St. George North Vancouver - Shaft for Sewer installation.
1)Esplanade & Londsdale North Vancouver - Underpinning of CN tunnel in North Vancouver BC for shoring.

Major JG works

- **Shoring/CutOff/Underpinning:**
  - North Vancouver - Parcel 5
  - Richmond – The Mandarin
- **Shoring/CutOff:**
  - False Creek- Olympic Village
  - New Westminster- Multiuse Facility Centre
- **CutOff (environmental and not)**
  - Recochem Port Coquitlam
  - New Westminster Pier
  - John Hart Dam
  - Zeballos Lake
- **Soil Improvement for Settlement Control**
  - New Westminster- Clarkson & Sixth
- **Piling**
  - Richmond – Paloma Parkade
- **Shafts**
  - North Vancouver- Esplanade & St. George
  - IONA Treatment Plant (3 phases)

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Recochem Port Coquitlam

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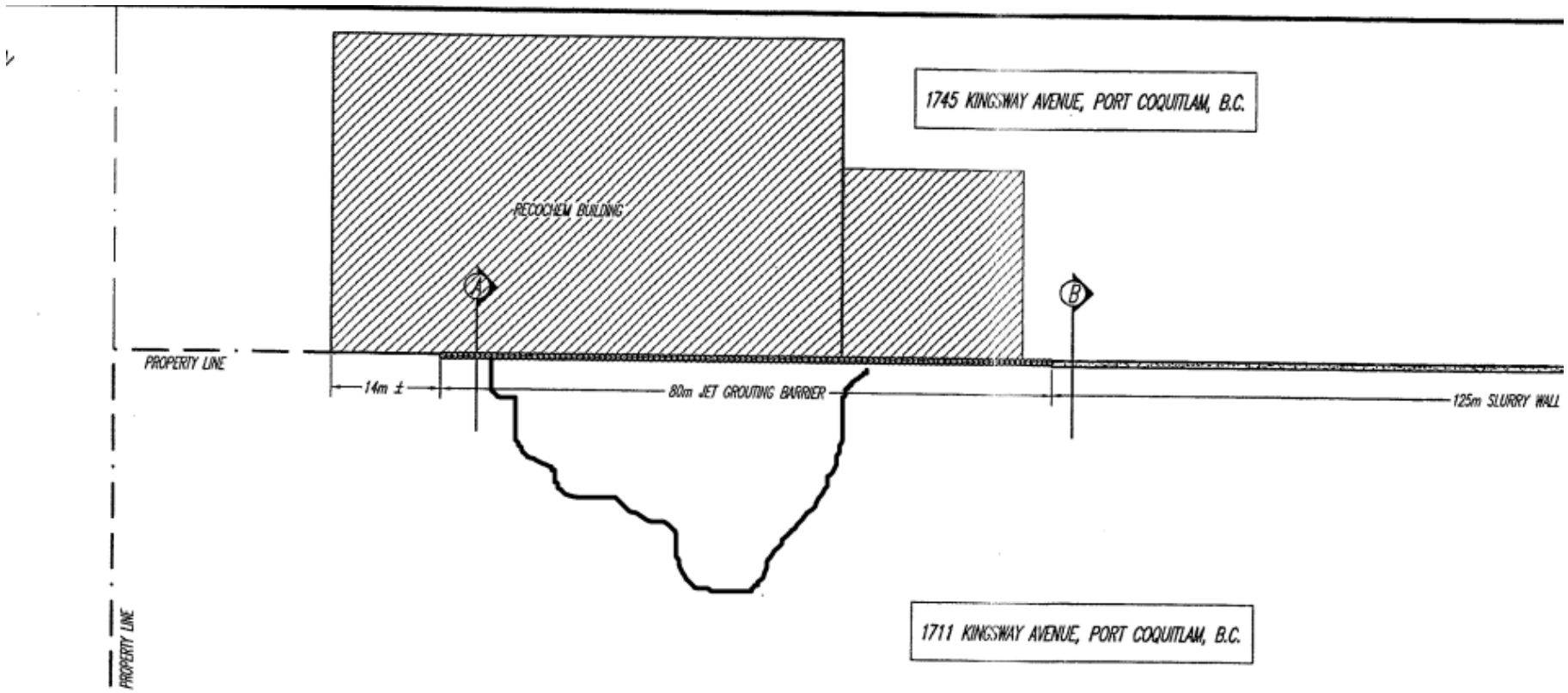
Port Coquitlam



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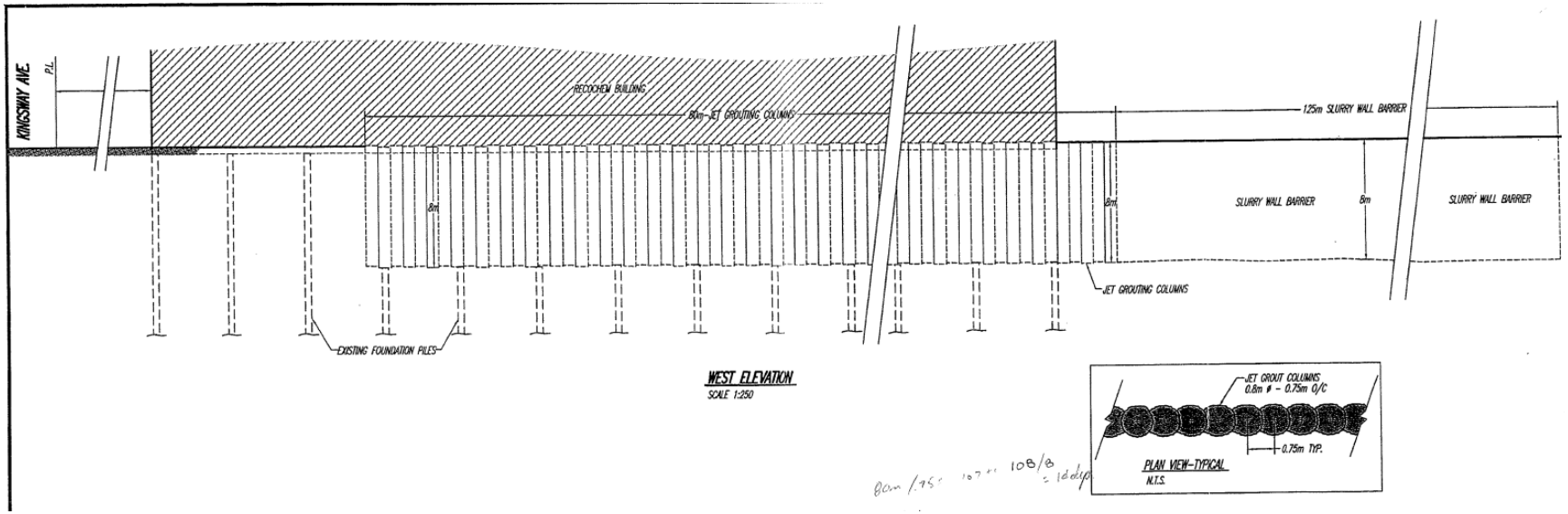
Port Coquitlam



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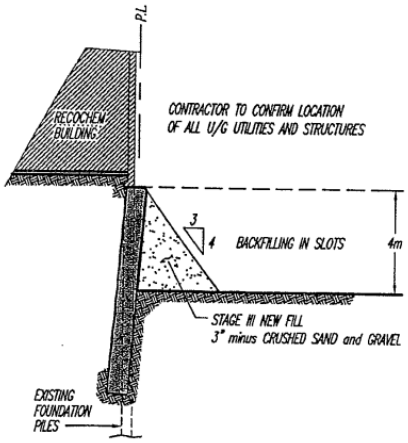
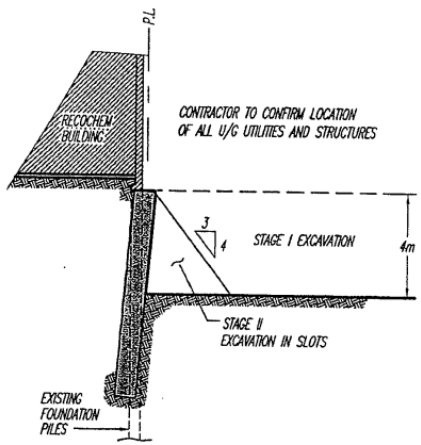
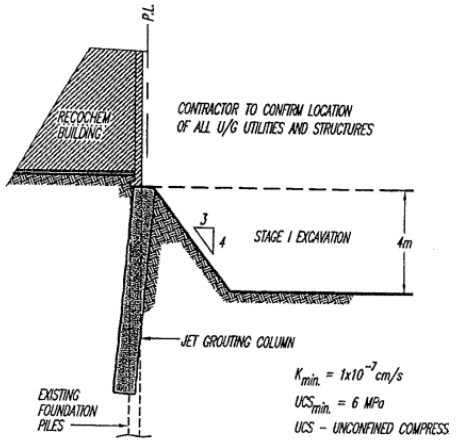
Port Coquitlam



SECTION A2
SCALE 1:200



SECTION A1
SCALE 1:200



SECTION A
SCALE 1:200

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Port Coquitlam

New Westminster Pier

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Location

Location

AERIAL PERSPECTIVE OVER LYTTON SQUARE
AND FESTIVAL LAWN

The Problem

Solvent Plume Area

A8 || WESTCOAST NEWS

BREAKING NEWS: VANCOUVERISUN.COM | THURSDAY, NOVEMBER 15, 2007

NEW WESTMINSTER

Toxic soil fouls plan for riverfront park

City and environment ministry look for ways to clean up contaminants 10-15 metres deep at Pier Park site

BY THERESA MCNAMUS

A small portion of the Westminster Pier Park site is home to a toxic blob of unknown origin.

A Nov. 8 report to New Westminster council states that remediation of contaminated soils at the park has been completed, but recent groundwater testing in the area around Fourth Street has identified a higher concentration of contaminants than was previously known. The contaminant, called tetrachloroethylene, is a common dry-cleaning chemical, which has been found at depths of 10 to 15 metres.

According to the report, the highest concentrations are located a short distance north of the park boundary, within the railway corridor.

"The contamination we found in the area around Fourth Street is a high risk," said Jim Lowrie, the city's director of engineering services. "It's a high-chlorinated solvent."

Lowrie said there are a few options available to address the contaminants because they are so far underground. He said they could be excavated, but that may not be the best option. "We can contain it and pump and treat it," he said. "If it's not mobile, we can leave it."

"The concern is the potential to migrate toward the river," Lowrie said. "The highest concentration is just off-site in the railway corridor. We are doing additional testing."

The Ministry of Environment has prioritized this site "because it's close to the river with political sensitivities around it," said Doug Walton, the manager of the ministry's risk assessment and remediation department. But, he added, tetrachloroethylene is "nothing unusual for us."

Lowrie said the toxic "blob" is about 750 square metres, which is about five per cent of the park property.

A previous laundry facility in the area has been ruled out as the source of the contaminants, but the source has yet to be identified.

"As part of the remediation process, a human health and ecological risk assessment study will be undertaken to assess the degree of exposure to humans and environment in order that appropriate mitigation measures may be implemented," said the report to council.

"Additional groundwater sampling is currently underway to determine if the contaminants are mobile, and to identify the potential source of the contamination."

JENELLE SCHNEIDERMAN FILES

The City of New Westminster is planning a waterfront park for a 3.2-hectare site along Front Street the city purchased last year.

New Westminster resident Christopher Bell has raised concerns about contamination since the city purchased the 3.2-hectare riverfront site last year. Last week, he met with representatives of the Ministry of Environment and the city for two hours to discuss the park site. "We are not even finished the testing," he said. "They haven't figured out the nature of the problem."

Bell said the area is now considered a high-risk area, rather than a low-risk area, as had been previously thought.

"We bought this real mess for $8 million without knowing the true toxic nature of this blob," he said.

Bell said a 2005 report done by an environmental consultant noted the presence of off-site contaminants.

Monday's staff report indicated that $400,200 had been spent on soil remediation at the site as of Sept. 30.

Lowrie said the method used to treat the contaminated area will dictate the cost of remediation.

New Westminster Record
With a file by Kim Pemberton

VANCOUVER SUN

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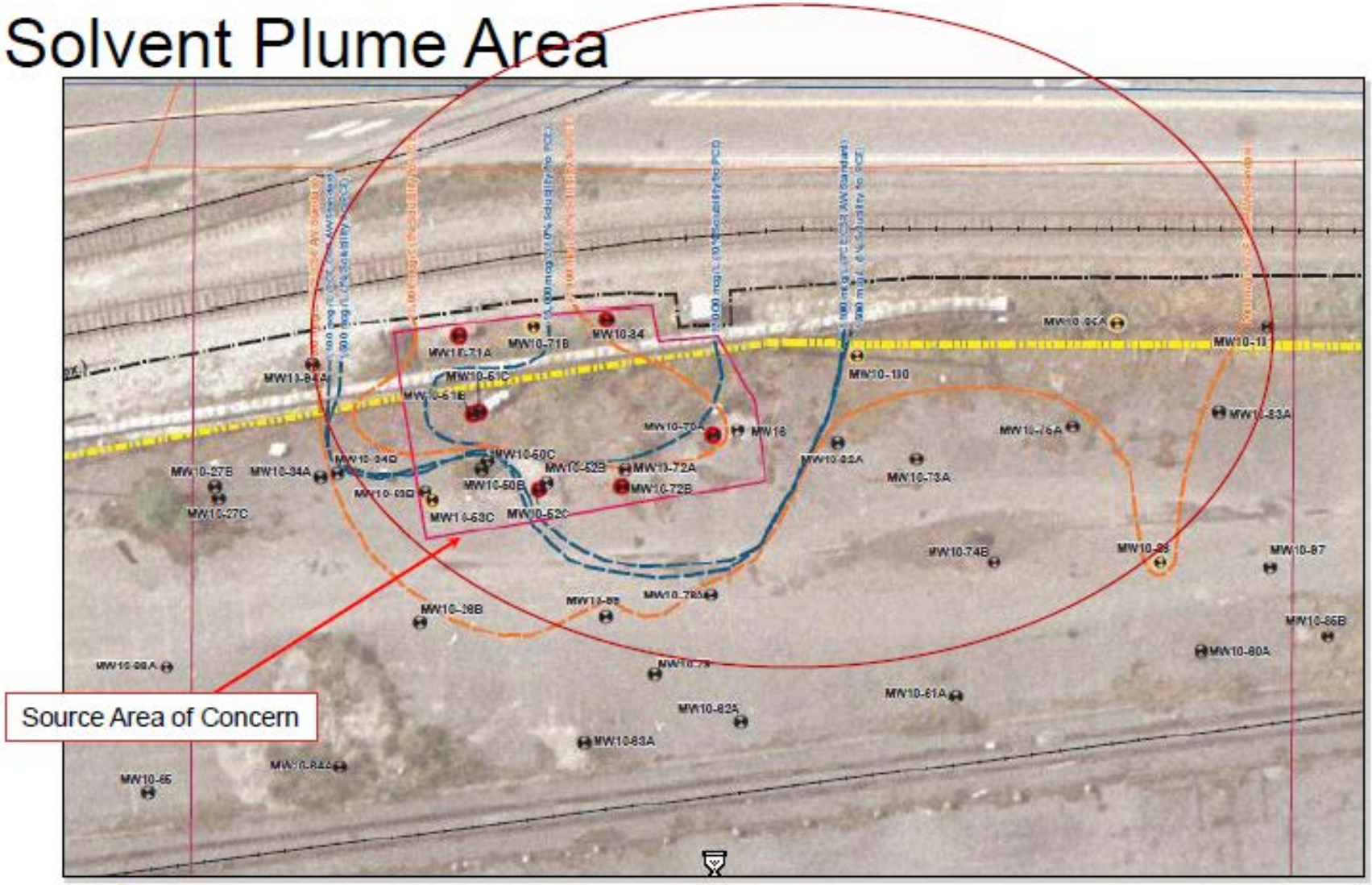
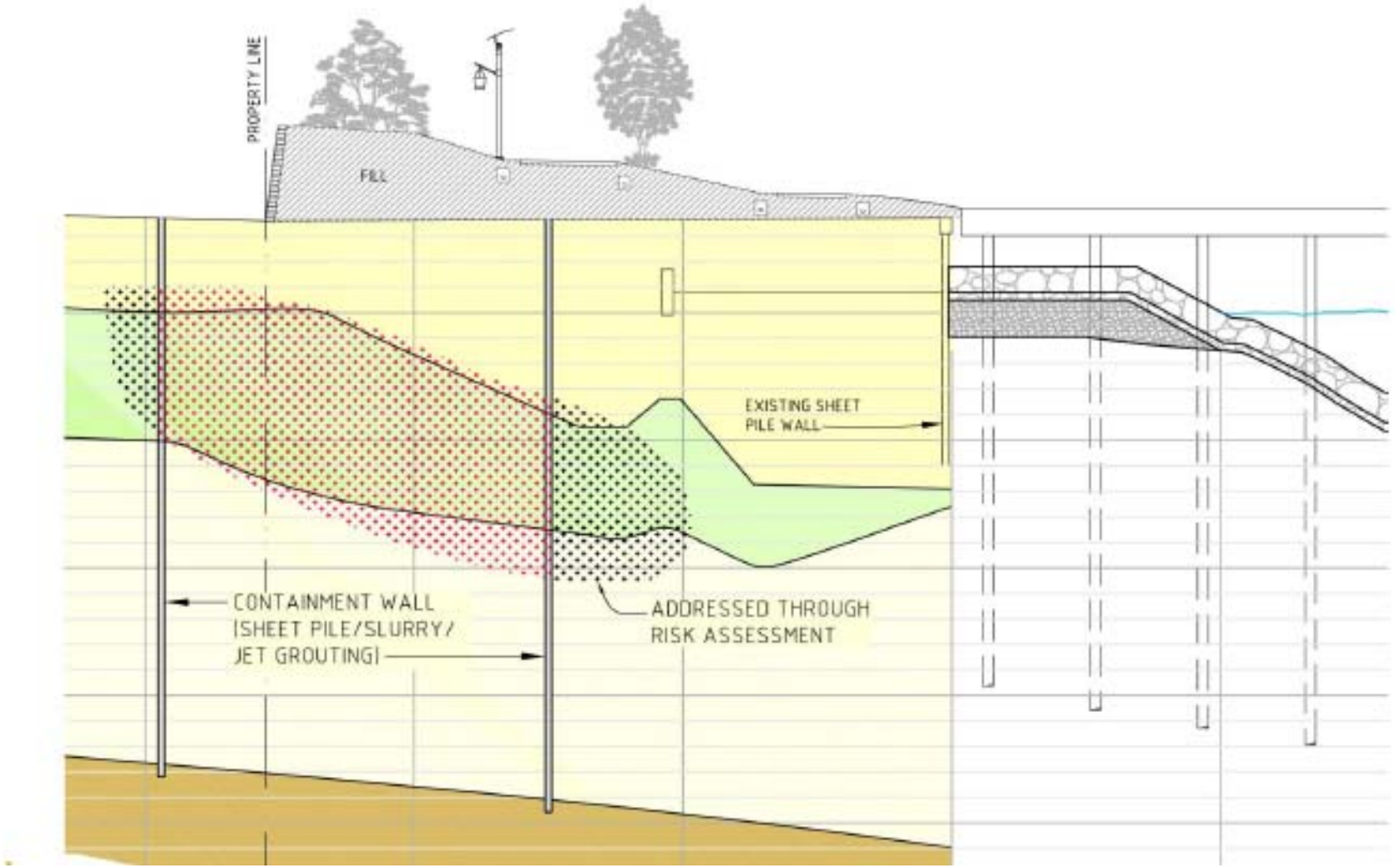
The Problem

Solvent Plume Area



The Options


PROPERTY LINE
FILL
EXISTING SHEET
PILE WALL
CONTAINMENT WALL
(SHEET PILE/SLURRY/
JET GROUTING)
ADDRESSED THROUGH
RISK ASSESSMENT

The Site

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The Site

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The Site

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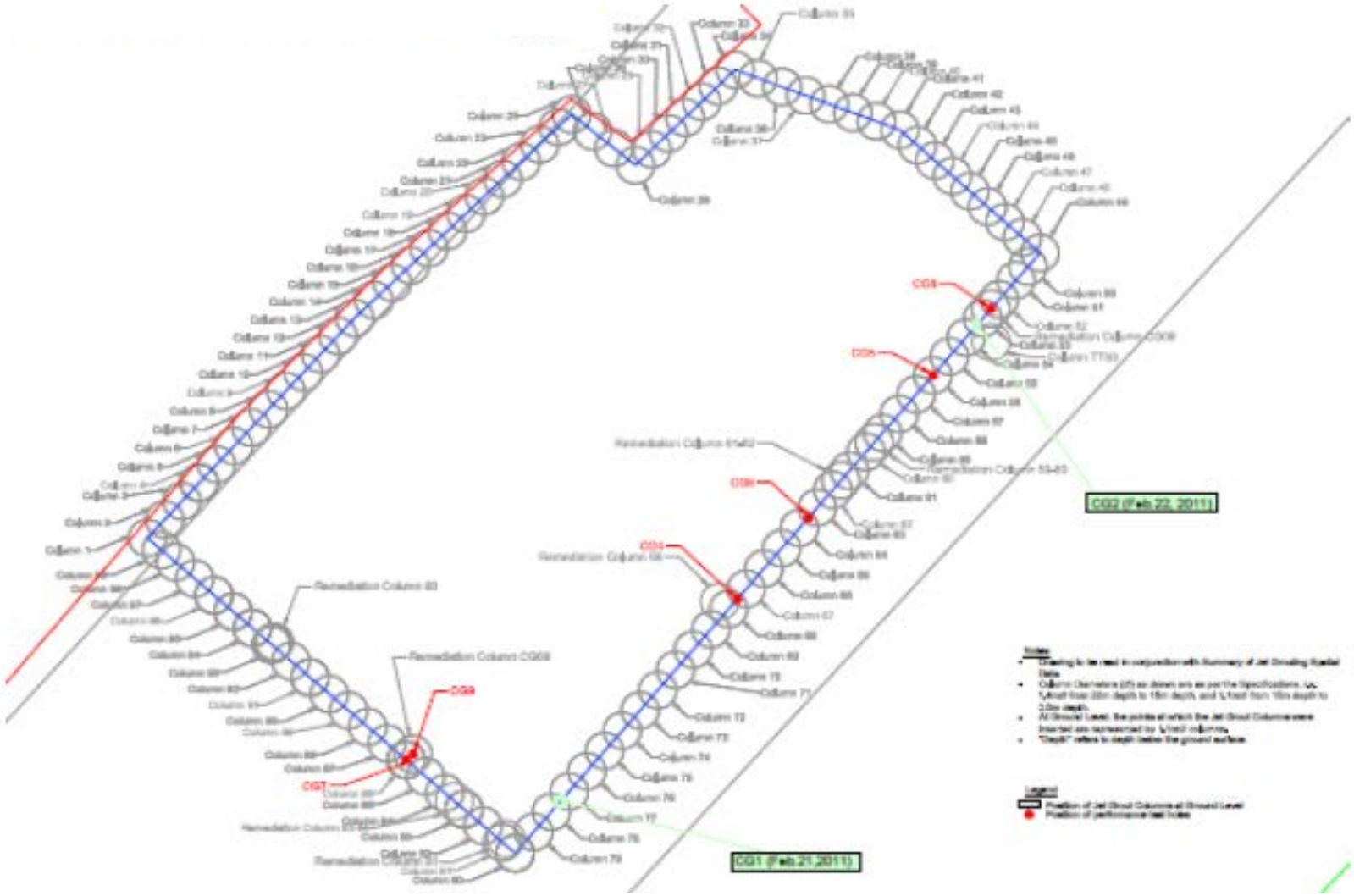
Verticality Control

Mapping The JG



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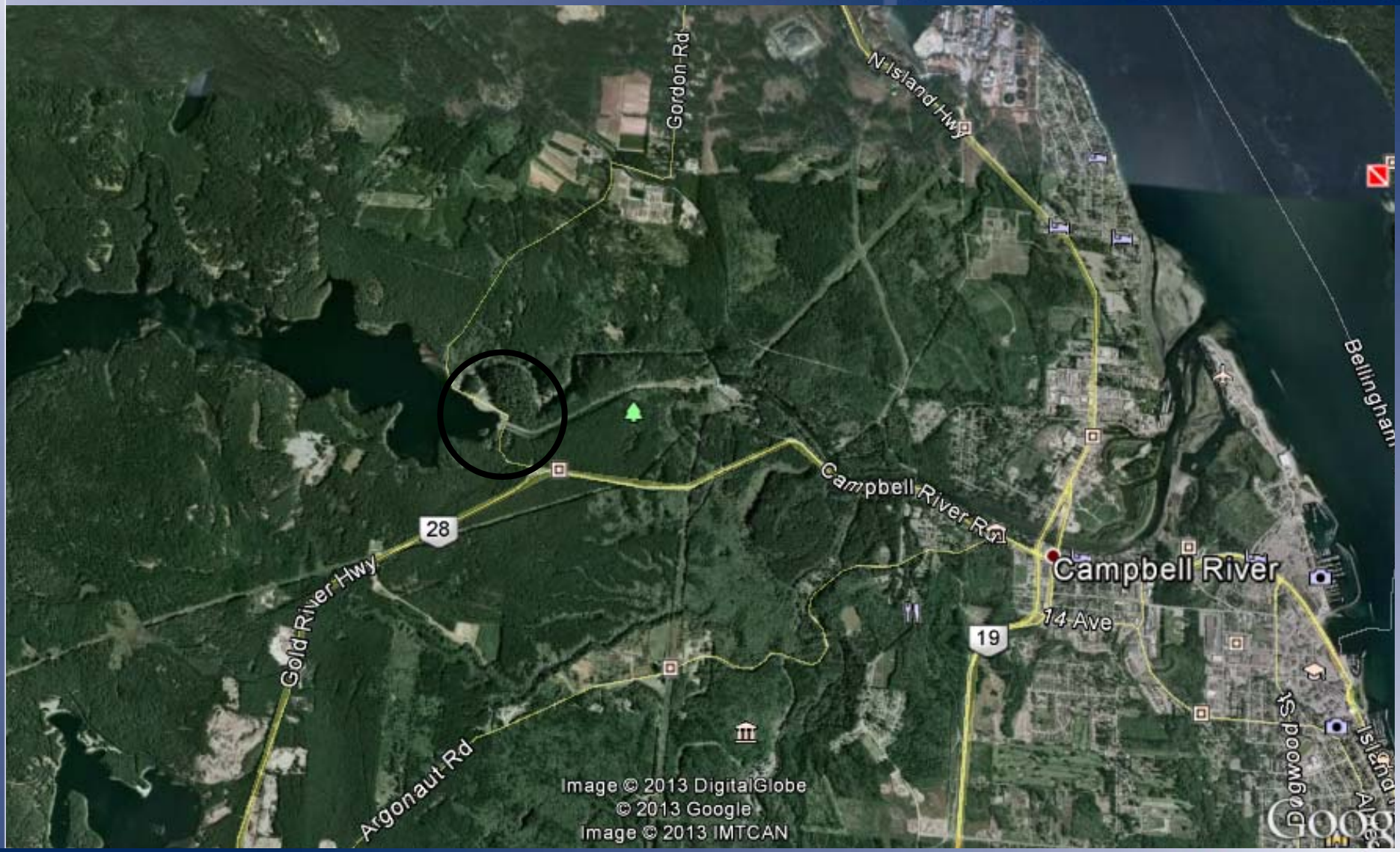
John Hart Dam



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Location

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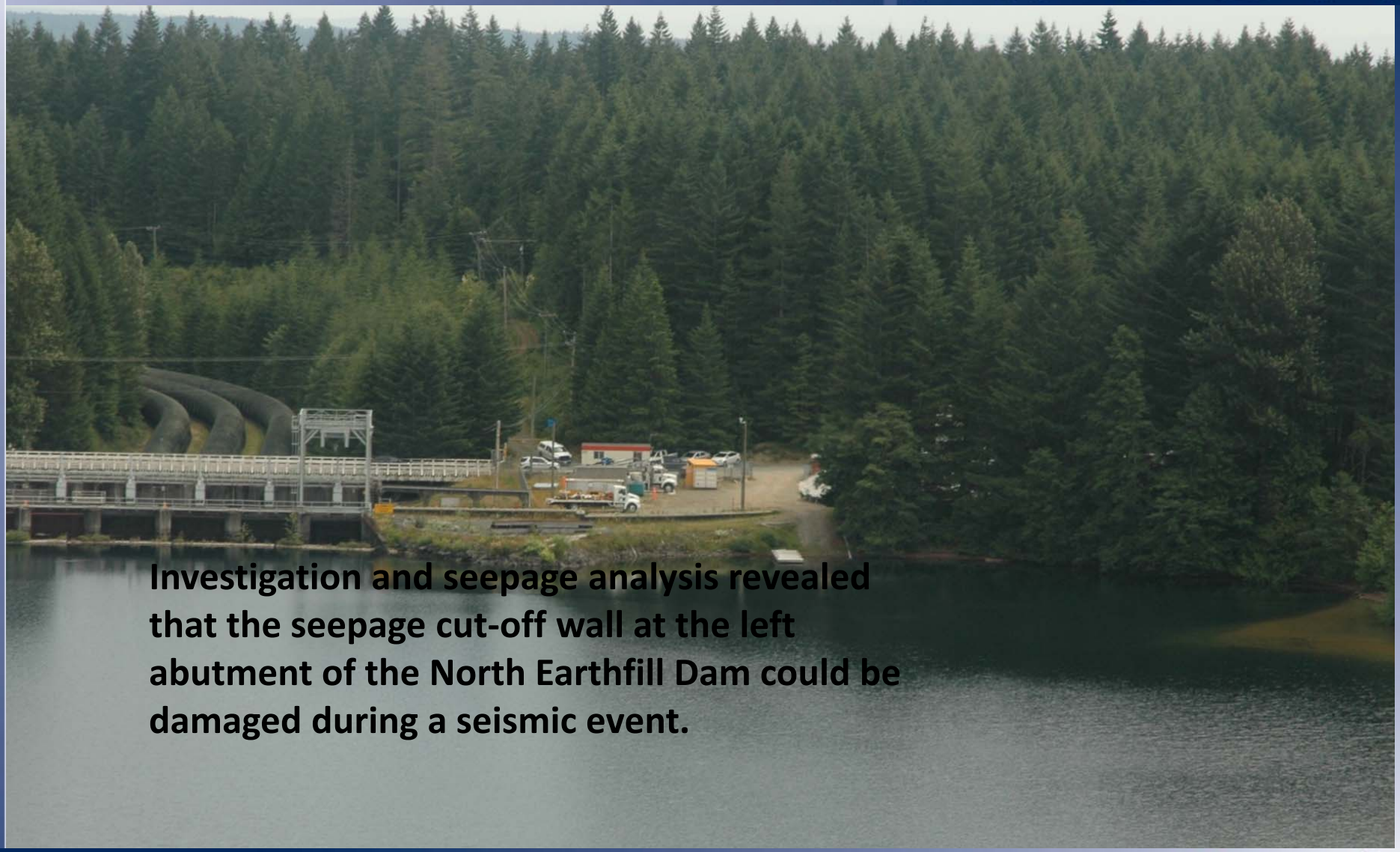
Backup Seepage Control



Investigation and seepage analysis revealed that the seepage cut-off wall at the left abutment of the North Earthfill Dam could be damaged during a seismic event.

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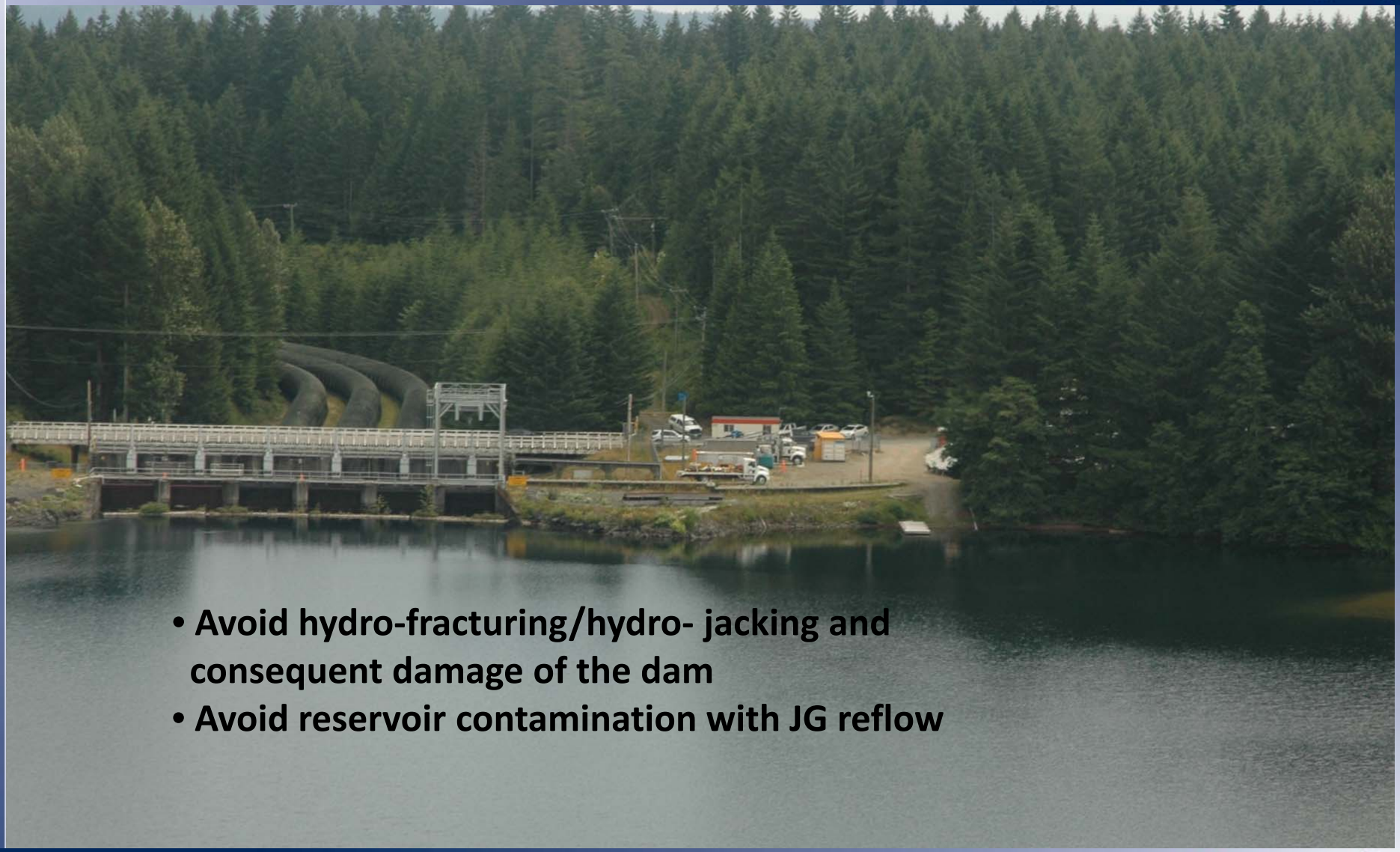
The Challenges



- Avoid hydro-fracturing/hydro- jacking and consequent damage of the dam
- Avoid reservoir contamination with JG reflow

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ECI Process

Early Contractor Involvement (ECI)
Jan –Jun 2011

Target: Study and discussion of procedures/ methodologies to avoid hydro-fracturing of the dam embankment, to be verified in a field test.

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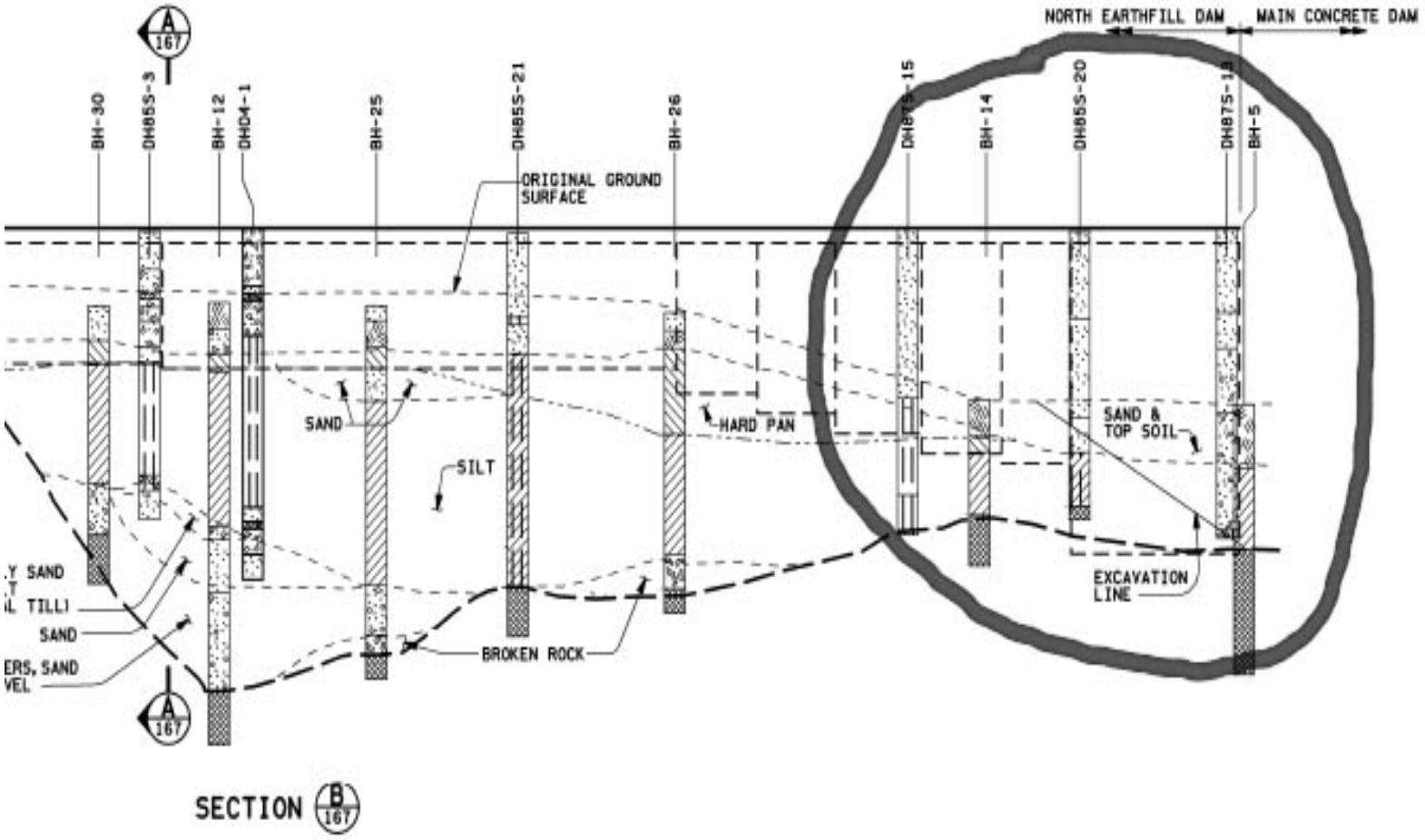
Soil Conditions



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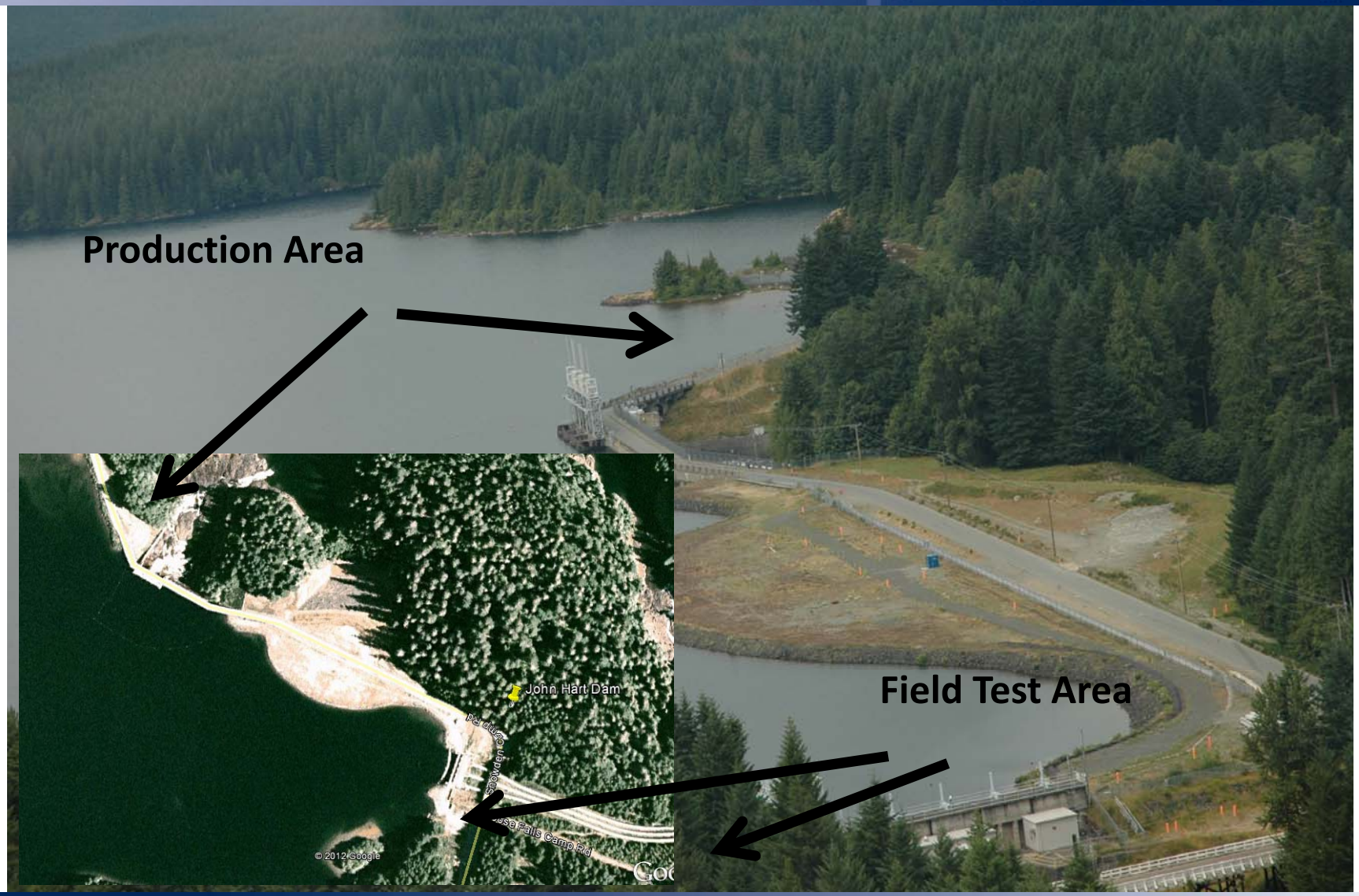
Field Test



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Field Test

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Drilling Procedures

Pre-drilling and
PVC installation

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Verticality Measurement

Field Test Results

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Field Test Results

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Production Works

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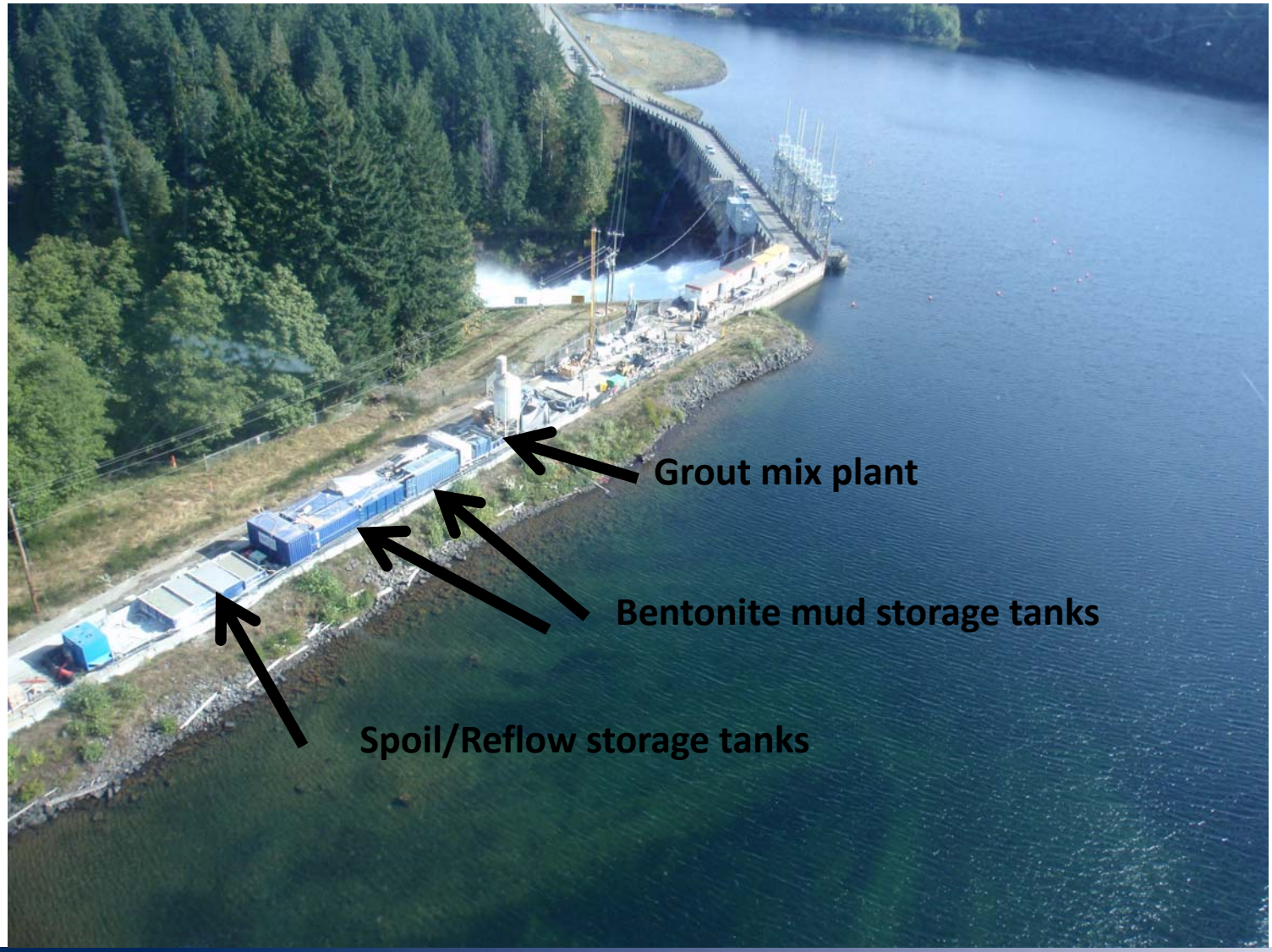
Very Congested Site!



Spoil/Reflow Management

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Spoil/Reflow Management

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Spoil/Reflow Management

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Spoil/Reflow Measurement

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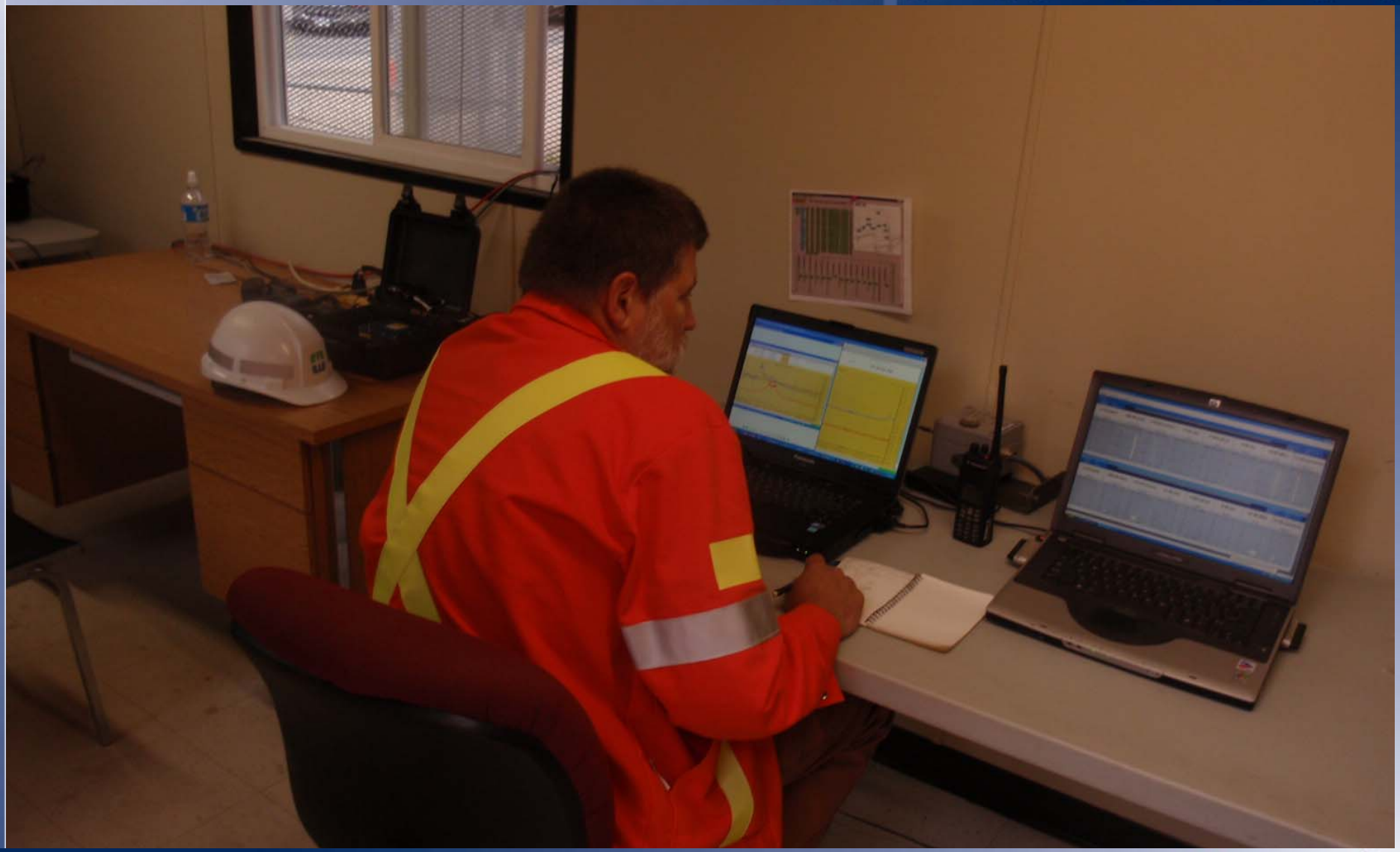
Real Time Control



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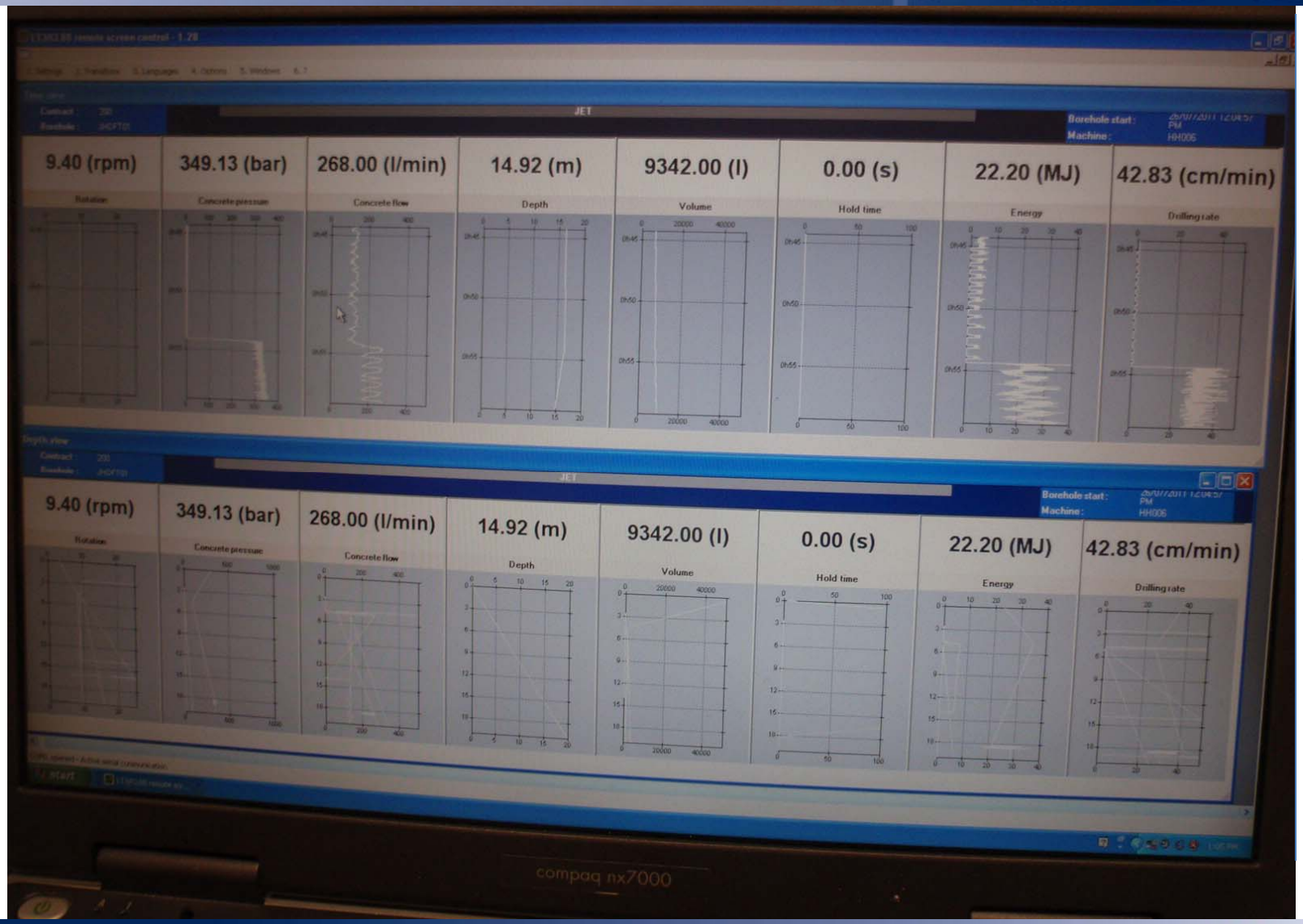
Real Time Control



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QA/QC

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Coring

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Columns	Distance between columns at rock elevation (m)	Geometrical wall thickness (m)	Column #	Length
P1 - T2	736,66	1071,55	P1	26150
P1 - T33	758,14	1098,04	T2	25950
P1 - T34	807,15	1029,07	S3	25890
T2 - S3	389,62	1240,84	T4	25750
S3 - T4	667,05	1015,82	P5	26290
T4 - P5	816,22	1010,21	T6	25440
P5 - T6	782,83	1037,80	S7	25650
T6 - S7	714,43	1086,14	T8	25770
S7 - T8	631,14	1136,43	P9	25560
T8 - P9	737,86	1073,06	T10	25460
P9 - T10	709,54	1089,89	S11	25560
T10 - S11	599,12	1153,77	T12	25540
S11 - T12	771,82	1046,09	P13	25860
T12 - P13	772,93	1045,87	T14	25890
P13 - T14	811,24	1017,82	S15	25640
T14 - S15	609,68	1148,84	T16	25670
S15 - T16	615,82	1146,89	P17	26020
T16 - P17	847,74	984,85	T18	26220
P17 - T18	699,86	1129,78	S19	26240
T18 - S19	744,53	1085,68	T20	26100
S19 - T20	630,96	1136,61	P21	26,800
T20 - P21	685,26	1104,43	T22	26,980
P21 - P22	662,41	1138,61	S23	26740
P22 - T22	542,39	1194,84	T24	26330
T22 - S23	432,80	1225,33	P25	26460
S23 - T24	769,52	1047,70	T26	26760
T24 - P25	753,57	1059,42	S27	26780
P25 - T26	715,27	1087,64	T28	26830
T26 - S27	862,81	972,40	P29	27090
S27 - T28	767,91	1048,96	T30	26620
T28 - P29	688,00	1103,02	T31	23860
P29 - T30	605,52	1159,47	T32	26450
T30 - T31	1281,42	632,44	T33	26020
T30 - T32	548,53	1178,61	T34	27040
			Average	26080

Wall Length

A - C	= 2728,11
C - D	= 1858,27
D - E	= 2201,34
F - G	= 2968,24

LEGEND

- As built centre of column (Top) - Surveyor data
- Theoretical centre of column (As per drawing MESL-Z11026-010)
- As built centre of column at rock elevation

NOTES:
Columns are indicated at 1.3m in diameter at rock elevation, centered over as-built points

Top of sheet pile wall as per MacMahney survey

N

SCALED 1:50 — 0 1 2 3 4 METERS

MATCON Excavation & Shoring Ltd.

DATE: SEPT. 29, 2011
DRN. BY: AD | APP'D.
SCALE: 1:50

JOHN HART DAM
JHT NORTH EARTHFILL DAM
Bottom of TIGOR location & Column Lengths

FILE NO.:
DWG. NO.: MESL-Z11026-013

REVISIONS:
REV.A SEPT. 30, 2011 REV.D OCT. 12, 011
REV.B OCT. 3, 2011
REV.C OCT. 7, 2011 RM

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Results

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Top of the Wall

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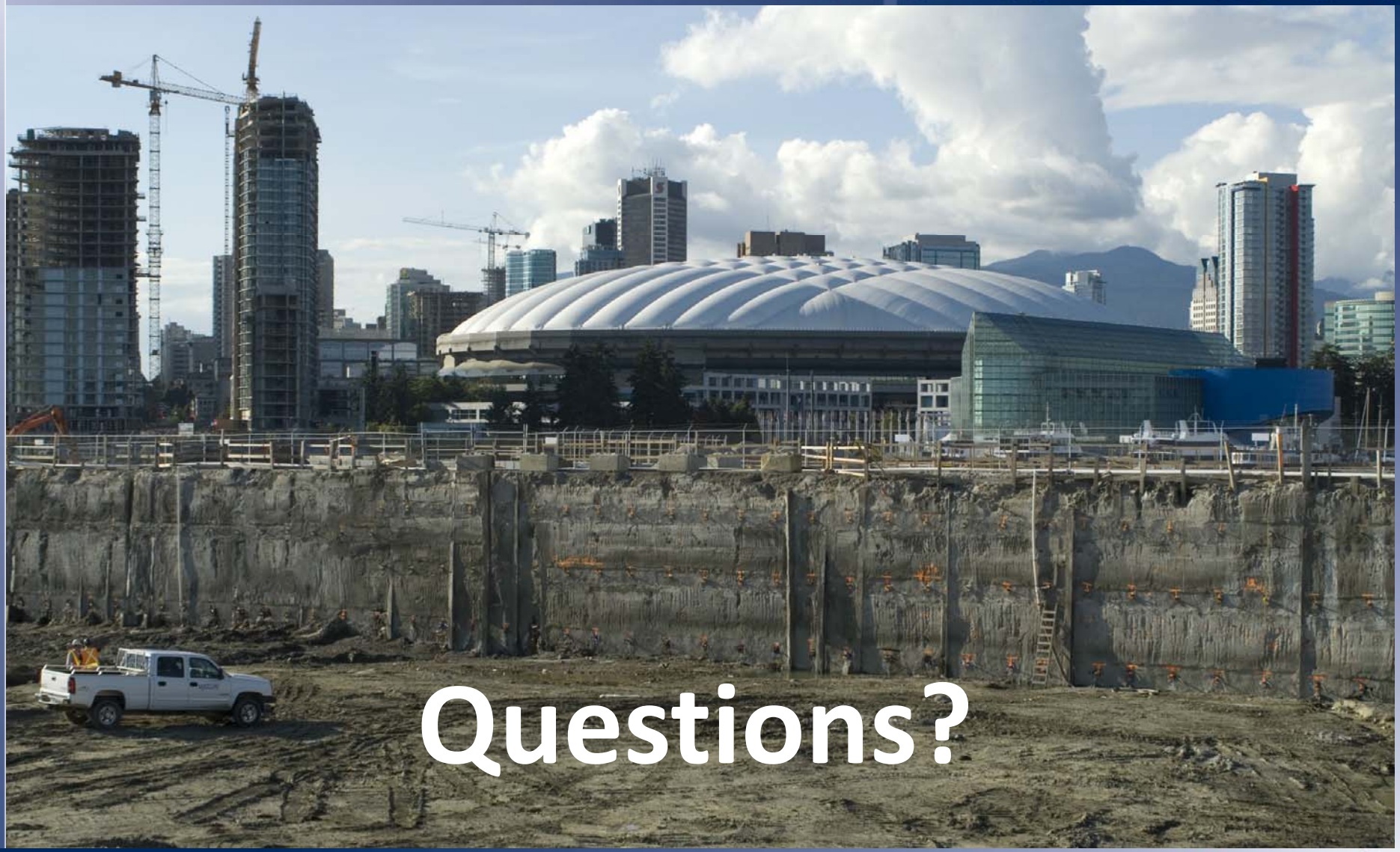
RemTech 2015



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