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PACCHIOSI DRILL

ROCK - SOIL TECHNOLOGY AND EQUIPMENTS

WATERPROOFING

CLIFTON (NEW YORK - U.S.A.)

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PROJECT:

Jet Grouting remedial works to eliminate or mitigate the threats associated with the presence of the subsurface contaminants at the Former Clifton OU-1 Manufacture Gas Plant (MGP), located in the Borough of Staten Island, New York.

PERIOD:

2006 – 2009

CLIENT:

National Grid - Keyspan Corporation.

Fig. 1. Former Clifton OU-1 MGP site.

Background.

From 1856 to 1957 the Clifton MGP facilities produced combustible gas by heating coal and petroleum products. The OU-1 site is the location of a former relief holder used to store gas. The structure was demolished in 1959, leaving in place the subsurface portion of the 26 m diameter circular brick foundation. Over the years, by-products, such as coal tar generated from the MGP operations have leaked or been released from the former relief holder resulting in the contamination of soil and groundwater. In 2004, the New York State Department of Environmental Conservation (NYSDEC) issued a record of decision recommending a remedial concept for the OU-1 Site.

A key element of the remedial project was the installation of a vertical barrier containment wall consisting of a combination of shallow steel sheet piling with sealed interlocks and deep jet grouted column wall to surround and encapsulate the foundation structure associated with the former relief holder structure as well as the impacted source material.

Considering the nature of the contaminants present at the site, sophisticated methods for collecting the jet grouting spoil had to be implemented to prevent the uncontrolled releases of contaminants or vapors into the environment during the performance of the remedial work.

Subsurface Conditions. Nature of contaminations

The jet grout containment barrier wall was installed through very challenging ground conditions including bouldery glacial till, flowing sand and artesian water conditions.

Fig. 2. Perimetral shallow steel sheetpiling .

Four major stratigraphic units were identified at the Clifton OU-1 site:

Superficial Fill - loose and non-cohesive, consisted of silt and gravel mixed with slag, coal fragments, brick, concrete, wood, metal, porcelain fragments, transite, ash and clinkers; maximum depth of 6 m bgs;

Alluvial Deposits - mix consisting of sub-units of sand, gravelly-sand, gravelly-silt, silt, silt-clay, and peat extended beneath the fill layer to 9 m bgs;

Glacial Deposits - consisting from approximately 9 m and 25 m bgs of a dense to very dense cohesive clayey-silt with varying amounts of sand, gravel, cobbles and boulders, transitioning below 25 m bgs to a dense to very dense non-cohesive sand of fluvio-glacial origin with some gravel and cobbles until the top of the saprolite formation at a depth of 36.5 m bgs;

Saprolite - or weathered bedrock, beneath 36.5 m bgs; the saprolite was formed by the in-place weathering of bedrock, likely the Manhattan Schist.

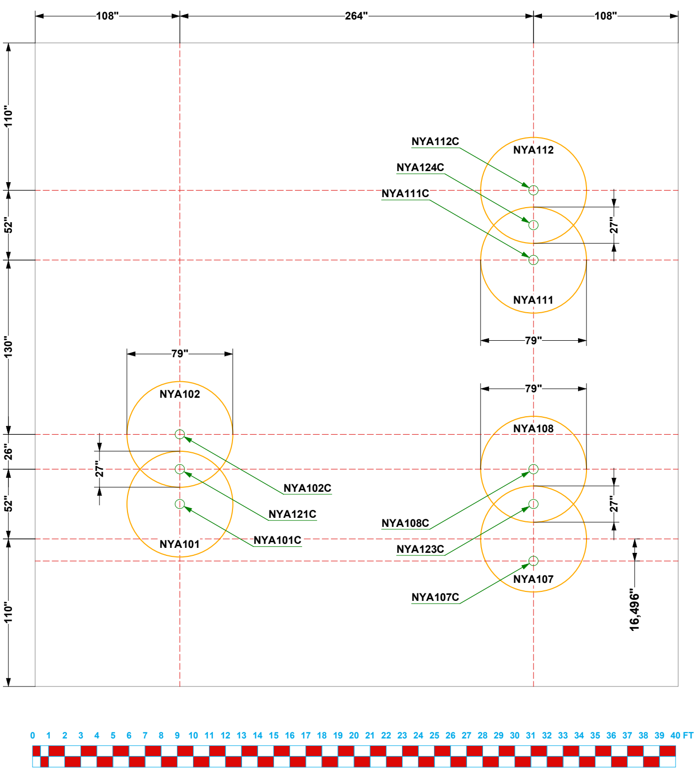
Two aquifers were present at the site, a shallow unconfined aquifer (water table) at a depth of approximately 1 m bgs and a deep aquifer confined within the fluvio-glacial deposits below the depth of 25 m bgs. Artesian water conditions were present in this deep confined aquifer with hydrostatic pressures of 2 m to 3.5 m above the ground surface.

The main categories of subsurface contaminants that exceeded their SCGs (standard, criteria, and guidance values) were volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs) and inorganics (metals).

Description of works.

2006 Jet Grouting Trial Field.

In 2006, a jet grouting trial field was performed by Pacchiosi Drill within the OU-1 Site, approximately 30 m outside the alignment of the jet grout barrier, in a zone free of subsurface contamination, in order to obtain advanced information that would be used in the design of the jet grouting remedial work.



Jet Grout Columns	X ft	Y ft	Minimum Diameter ft	Top Ground Surface	Top Jet Grout Columns	Bottom Jet Grout Columns
NYA101	10,0000	12,1667	6,583	12,000	-23,000	-114,000
NYA102	10,0000	16,5000	6,583	12,000	-23,000	-114,000
NYA105	0,0000	0,0000	6,583	12,000	-23,000	-114,000
NYA106	0,0000	0,0000	6,583	12,000	-23,000	-114,000
NYA107	32,0000	10,0000	6,583	12,000	-23,000	-114,000
NYA108	32,0000	14,3333	6,583	12,000	-23,000	-114,000
NYA111	32,0000	27,3333	6,583	12,000	-23,000	-114,000
NYA112	32,0000	31,6667	6,583	12,000	-23,000	-114,000

post exploratory holes	X ft	Y ft
NYA101C	10,0000	12,1667
NYA121C	10,0000	14,3333
NYA102C	10,0000	16,5000
NYA107C	32,0000	8,6253
NYA123C	32,0000	12,1667
NYA108C	32,0000	14,3333
NYA111C	32,0000	27,3333
NYA124C	32,0000	29,5000
NYA112C	32,0000	31,6667

Fig. 3. Trial field lay-out.

Six (6) jet grouted columns, consisting of three separate groups of two columns each, were installed as part of the trial field. The columns were installed on a spacing of 1.2 m, between the depths of 9 m and 38 m, to the same depths and through the same soils as anticipated for the production area.

Prior to the start of the trial field, a concrete working slab was constructed for the drill rig and 30 cm diameter steel sleeves inserted through the concrete of the platform at the center location of the jet grout columns and post-exploratory core borings. The waste tub collection system and the T-preventer collection head system devised by Pacchiosi Drill to collect the drill and jet grout cuttings would connect and seal to these steel sleeves.

Use of compressed air in the jet grouting process having been banned by the owner as a necessary precaution to prevent the possible migration of compressed through the pervious soil layers present at the site, all jet grout columns of the trial field were performed using the PS2W (water-grout) double-fluid jet grouting system. The PS2W system uses a high-speed water jet to cut the soil in place while simultaneously high-speed grout is introduced through a separate nozzle located lower on the injection monitor to mix with any remaining soil left in place by the action of the upper water jet.

Two methods of drilling were tested during the trial field: rotary drilling using tungsten button tri-cone roller bit and percussion drilling using water-activated down-the-hole hammer. The later method proved the most efficient in dealing with the numerous cob-

Fig. 4. Trial field operations.

bles and boulders present in the glacial deposits and was used for the majority of the jet grout columns of the trial field. An average drilling deviation of 0.96% at a depth of 38 m bgs was obtained for the six columns, with the largest deviation measured at 1.51%.

The grout mix used in the performance of the jet grouting consisted of a 50/50 dry blend of Ordinary Portland Cement (Type I) and Granulated Blast Furnace Slag (Grade 120) with a water-to-solid weight ratio of 0.7.

Drilling and jetting parameters were recorded in real time using the PRS3 data recording system developed by Pacchiosi Drill. Alignment of the jet grout boreholes was surveyed full depth of drilling using a bi-axial inclinometer specially designed to fit inside the inner tube of the rod stem. Data collected from the PRS3 system and from the inclinometer were automatically stored into the rig's computer and used to produce graphic reports and as-built drawings of the column installation.

The jet grouting treatment was cored at six different locations, including all the overlaps of columns at a point corresponding to the mid-distance between the two adjacent columns. Deviation of all core holes were surveyed full-depth of drilling and the results used to generate as-built drawings showing in plan view, in 3 m depth increment, the actual location of the core hole in relation with the actual center location of the columns. This information allowed the Owner's Engineer to calculate that a diameter of 1.8 m had been achieved through all stratigraphic layers.

Fig. 5. Trial field operations.

Pump-down water tests were performed in each core hole to evaluate the in situ permeability of the jet grouted columns, and camera inspection was performed inside each core hole after having pumped the water out. The results of the water tests indicated that the permeability value of the jet grouted soil was of the order of 1 x 10-6 cm/s which was well in compliance with the criteria of maximum in situ permeability value of 1 x 10-5 cm/s established for the project.

Additional field testing performed in 2007showed no deterioration of the conditions of the grout after more than one year in situ, but rather an improvement of the low-permeability characteristics of the jet grouted material with in situ permeability values significantly lower than those measured in 2006.

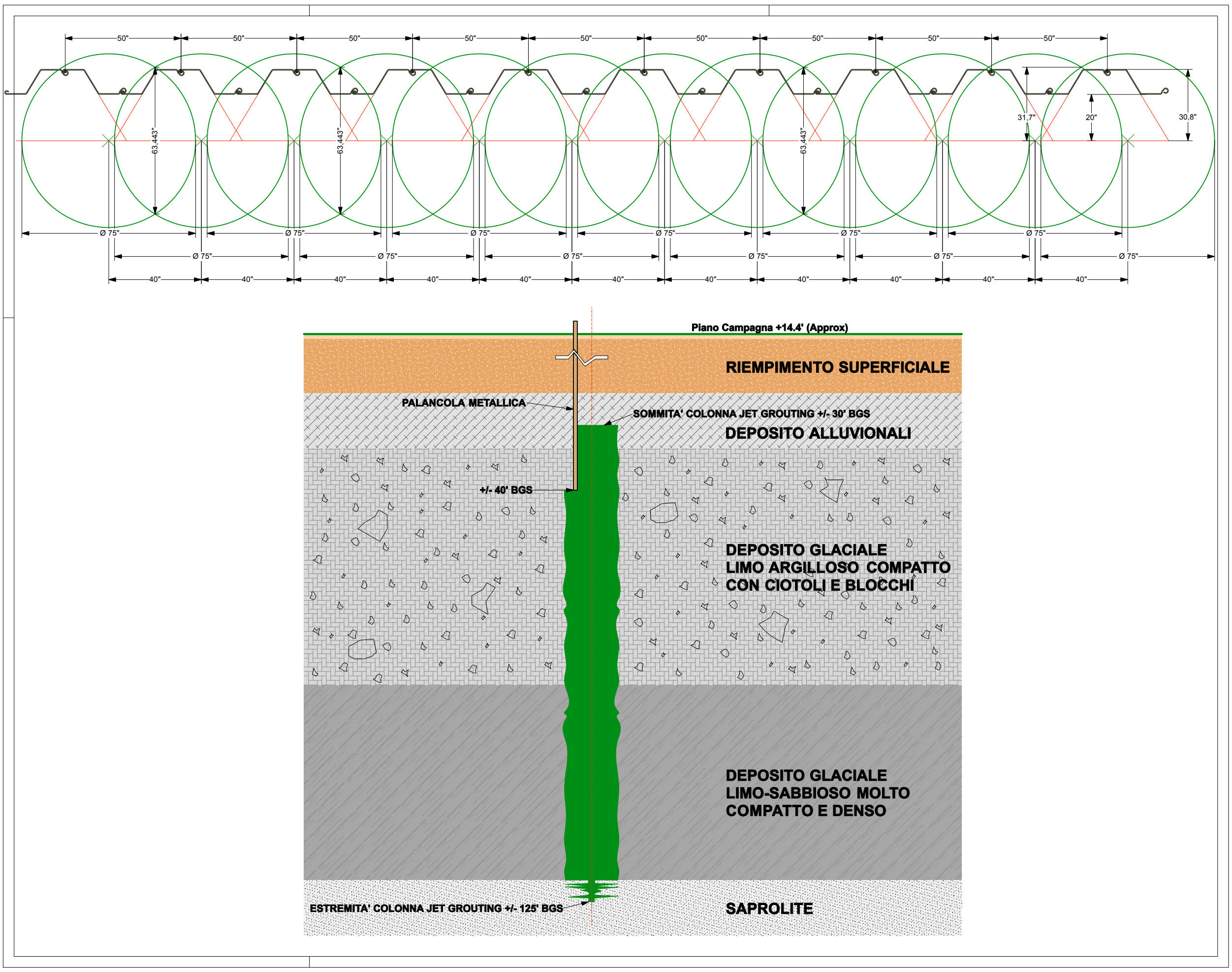


Fig. 6. Typical Jet Grouting lay-out.

Jet Grout Vertical Barrier Wall Construction.

Pacchiosi Drill began the construction of the jet grout vertical barrier wall in 2008, after the installation of the shallow steel sheetpiling wall with sealed interlocks to an average depth of 9.5 m had been completed by Others.

The jet grout wall consisted of a single line of double-fluid PS2W (water-grout) 1.8 m-diameter jet grout overlapping columns. A column spacing of 1.0 m was selected for the wall based on the consideration that the presence of numerous debris in the fill

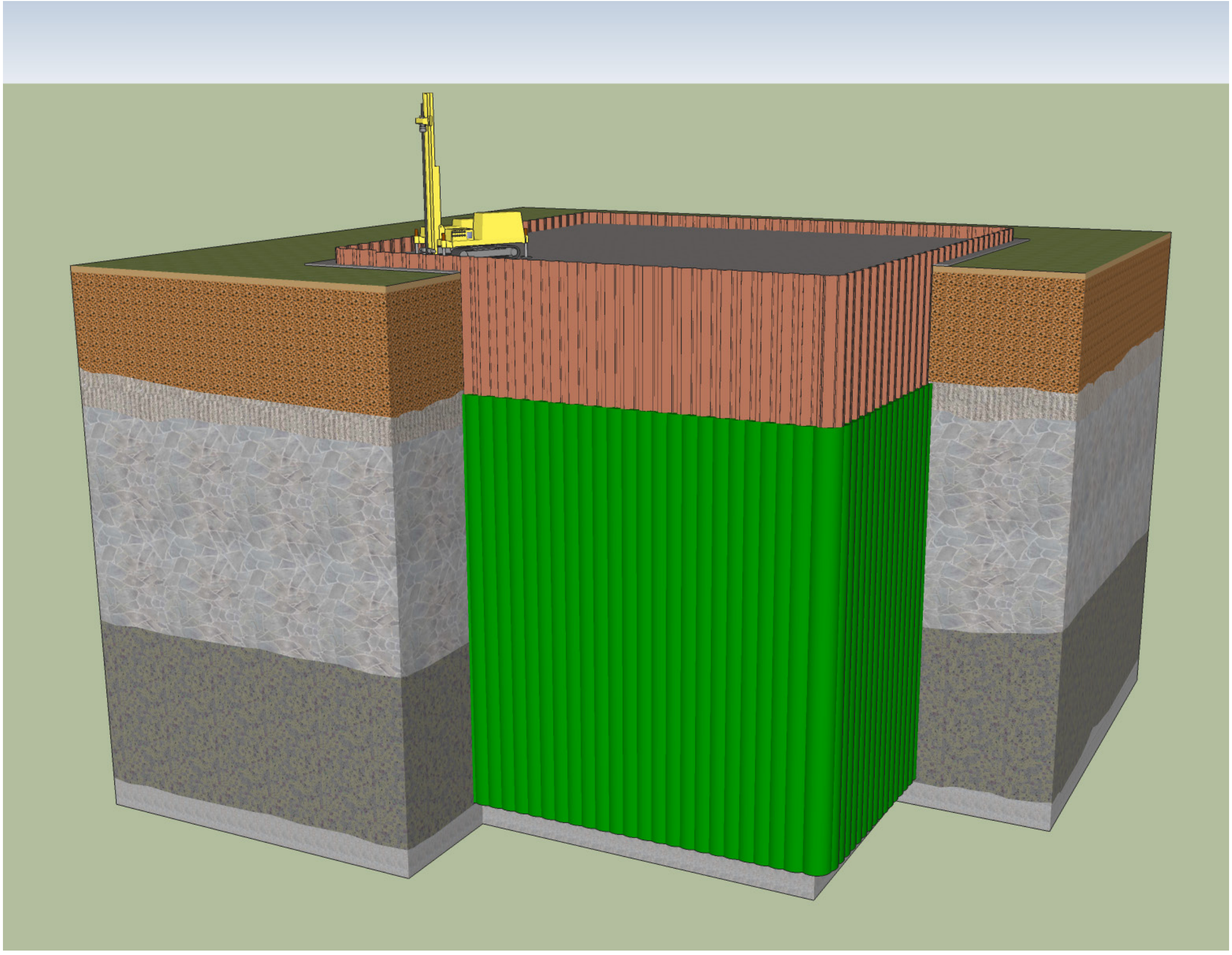


Fig. 7. 3D sketch of Jet Grouting vertical containment barrier.

layer (cast iron pipes, concrete, bricks, timbers, and others) might have an adverse effect over the good control of the drilling deviations (target maximum drilling deviation of 1.25%). A total of 126 columns was thus required for the construction of the 126 m long jet grout barrier wall.

The jet grout columns were installed between the depths of 8 m and 38 m bgs, providing for an overlap of 1.5 m with the bottom of the sheet piles and a penetration of 1.5 m into the low-permeability saprolite formation. Center location of column was positioned at a distance of 50 cm from the inside face of the steel sheet piling wall.

Fig. 8. Panorama view of site.

The operations were conducted essentially using the approach developed during the 2006 trial field: a concrete slab was constructed within the sheetpiling wall enclosure

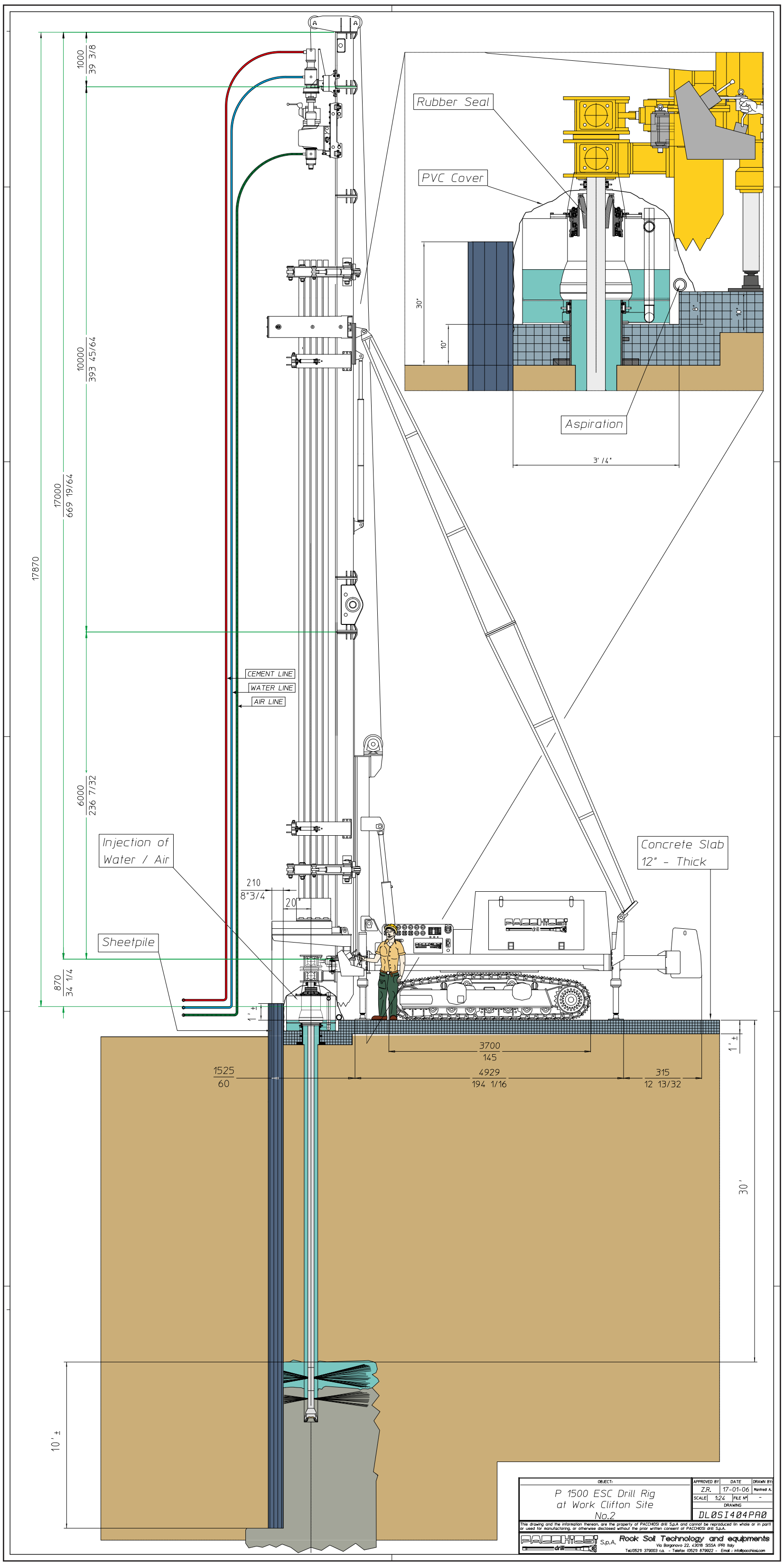


Fig. 9. PACCHIOSI injection system with spoils' collecting devices.

area, 30 cm diameter steel sleeves were inserted through the full thickness of the slab at the center location of each jet grout column and core hole, waste tub or preventer system was used for collecting of the jet grout spoils, drilling was performed using tri-cone roller bit and water-activated down-the-hole hammer, full-depth alignment survey of all boreholes was performed, the PS2W double-fluid (water-grout) jet grout system was used, the grout mix consisted of the 50%-50% blend of slag and Portland cement with a solid-to-water weight ratio of 0.7, recording of drilling and grouting parameters

Fig. 10. PACCHIOSI Jet Grouitng plant installations.

was performed using the PRS3 real time data collection system.

Two drill rigs PACCHIOSI P1500 ECS model, equipped with an automatic rod charger, were used for the performance of the jet grouting work. One rig was used for the full depth pre-drilling of the jet grout boreholes while the other rig was assigned to the jet grouting operation.

After verifying in the fall 2008 with preliminary columns that the proposed jet grouting procedure would provide in situ results in compliance with the project specifications, construction of the jet grout wall started in February 2009 and was completed in October 2009, including all associated verification coring and field testing.

During the work, the systems devised by Pacchiosi Drill for collecting the jet grout wastes proved very efficient in preventing the uncontrolled releases of spoils or vapors in the environment. The jet grout spoils were collected and pumped over a distance of approximately 90 m, through piping partially buried below Willow Avenue, directly into the containment cells specially built inside an existing building where vapors and odors were managed using sophisticated air filtering systems. After the waste grout had sufficient hardened in the containment cells, the solid waste was loaded into dump trucks and transported to pre-approved treatment facilities for final treatment and disposal

Controls and verifications.

To confirm the quality of the in situ jet grouting treatment and the compliance with the contract specifications, core drilling was performed at 15 locations along the jet grout wall, using a double-tube core barrel assembly providing core samples 108 mm in diameter. The majority of the core hole locations were selected by the Owner's Engineer to correspond to minimal overlap of columns as shown by the as-built column drawings. Full-depth alignment of all core borings was surveyed using the bi-axial inclinometer.

Excellent core recovery, close to 100%, with very good quality and continuity of jet grouting treatment, was obtained for all core borings and through all stratigraphic layers, including in the jet grouted soil zones with a large content of boulders and cobbles.

Fig. 11. Coring of fine alluvial deposit.

Boulders up to 1.5 m in length were sampled during the coring program.

Water pump-down tests were performed in all core holes to evaluate the permeability of the in situ jet grouted material. All water tests showed permeability values well below the maximum permeability of 1 x 10-5 cm/s established for the project with all,

Fig. 12. Coring of grouted glacial deposit, with boulders and cobbles.

but one, permeability values lower than 5 x 10-6 cm/s and typically in the 1 x 10-6 cm/s range. Considering the high stress induced to the in-situ jet grout treatment by the core drilling process itself, it was generally believed that the true permeability values of the undisturbed in situ jet grouting treatment were lower than those actually measured by the field tests. Considering the relative young age (14 to 28 days) of the in situ grout at the time of the coring, it is also anticipated that the low-permeability characteristic of the in situ grout will continue to improve over time.

All core holes were also visually inspected using a borehole camera remotely controlled from the surface, further confirming the good quality of the jet grout treatment and the good stability of the in situ grout under extreme high differential water head.

Conclusions.

The following conclusions can be drawn for this case study:

- Highly effective deep jet grout cut-off wall can be constructed through soils contaminated by coal and petroleum by-products
- Methods for collecting the jet grout spoils can be implemented that would prevent the uncontrolled releases of contaminants in the environment
- Jet grouted cut-off wall can be constructed through soil formations with high content of boulders and cobbles using one single-row of overlapping jet grout columns
- Full-depth alignment survey of all jet grout boreholes is a critical feature of any quality control program associated with the construction of a deep jet grouted cut-off wall.

Fig. 13. Borehole camera inspection.

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