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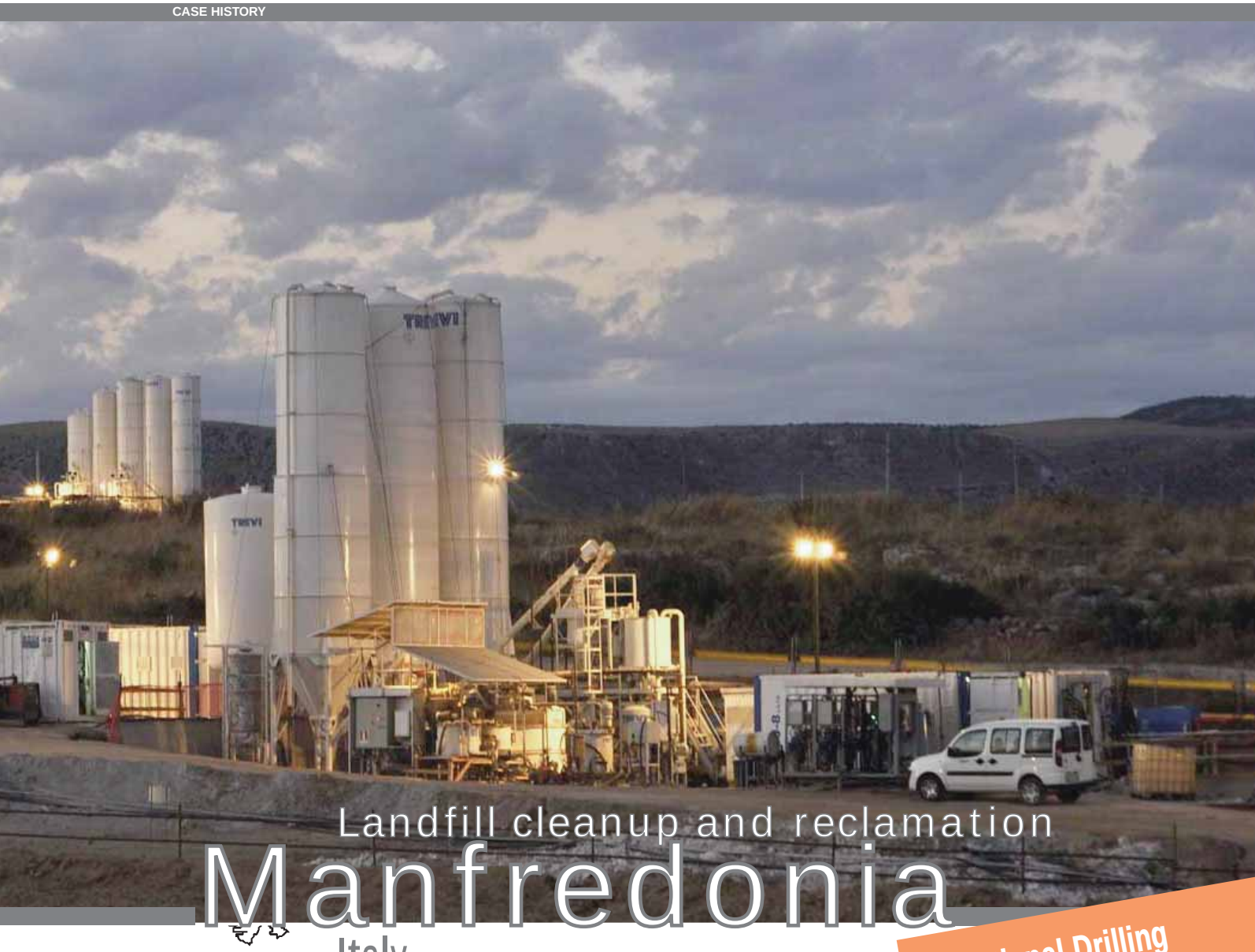
CASE HISTORY



Landfill cleanup and reclamation

Manfredonia

Italy

Directional Drilling

Cliente : Owner :	**Uff. Comm. Delegato per la bonifica di discariche pubbliche di Manfredonia**
Contrattista principale : Main Contractor :	ATI - Lead contractor Mucafer (CCC Cons.Coop. Costruzioni) (Executive project: SI-Sviluppo Italia Engeneering-Consulenza Geotecnica Studio Sintesi)
Durata dei lavori : Duration of work :	2010 - 2011

Introduction

Trevi spa, the underground engineering division of Trevi Group, has been working in Manfredonia with innovative techniques to permanently reclaim two contaminated sites used as landfills for municipal solid waste.

The Pariti 1-RSU and Conte di Troia landfills have been disused for decades; they are located in the city of Manfredonia, within the Province of Foggia, about 6km south-west of the town centre.
The sites are actually two abandoned calcarenite mines (soft, yellowish, tufaceous limestone) which are located at different heights, respectively on the hydrographic right and left of a small gorge dividing them and named Vallone di Mezzanotte *(see photo)*. The two landfills are about 25,000 sqm each; the total volume of discharged waste is 400,000 m^3 with maximum thickness ranging from 16 m (*Conte di Troia)* to 25 m *(Pariti 1).*

In the years after the landfill was abandoned, ground water analyses were carried out in the area of the city of Manfredonia and significant traces of leachate percolation were found. After a number of legal actions and the opening of an infringement procedure by the EU, in November 2008, the Court of Justice passed a judgement of conviction for the non-completion of the cleanup of the two sites with severe sanctions. Such decision was suspended as the Italian Government committed to reclaiming the sites by 2010.

A long and complex bureaucratic procedure followed and resulted in the declaration of a state of emergency in May 2009; then a Commissioner of Reclamation and Enforcement Subject were appointed and, during the first months of 2010, the works for the permanent cleanup of the areas were started.

Features of the area and geognostic surveys

The landfills are located in an area characterized by high biodiversity and a number of gorges *(small canyons)* of erosive origin creating a highly naturalistic rocky environment. This karstic territory has almost no surface water streams due to the permeability of the formations dating from the Mesozoic era. This is especially relevant to understand the importance of the cleanup of the sites and the feasibility of the identified solutions. In the period 2003-2009 several geotechnical hydraulic surveys were carried out. They revealed that the bottom onto which waste lies is uneven and characterized by steps, which come from the farming technique used in the pre-existing caves.

Area generale di intervento

Vallone di Mezzanotte - Lato mare (a destra, il corpo della discarica Pariti 1)

Vallone di Mezzanotte - Lato monte

The collected data show a land profile of a 25-40m layer of soft rock in the form of calcarenite dating from the Neogene period: the particle size varies from fine to coarse and cementation from low to high. In this case, the primary permeability *(through interstitial porosity)* of the calcarenites, given the formation homogeneity, is very low - k = 10-8 cm/sec. However and likely due to tectonic events or other geomechanical actions, the calcarenites have macro-fissures – the distribution of which can be hardly reconstructed - that create a high *(local)* increase of conductivity depending on the quantity and type of fissures *(detected during the test)*. Calcarenites lie over a formation of whitish or pink limestone *(calcilutites)*, well stratified and highly fissured, the fissures being often extended by karst dissolution having higher mechanical features. The permeability of the said limestone is from high to very high and it is of secondary type - only due to fissures and karst phenomena.

In the **Conte di Troia** site, the calcarenites under the bottom of the

landfill have a 10m thickness; the soil samples taken during investigation did not show any contamination evidence. Moreover, the impossibility to measure the leachate level indicates the presence of communicating fissures having such permeability features - although they have not been detected during the project investigations – that it allows for the complete drainage of leachate and rainwater. The Pariti site is located at a lower altitude and on the opposite side of the Vallone Di Mezzanotte. In this site the thicknesses of the calcarenites over the limestone is smaller and, in some points, it even reduces to a few metres. Cementation is lower than the one found in the Conte di Troia site. Right under the waste, altered portions have been found featuring layers with poor to zero cementation, considerable primary permeability and manifest contamination. It has also been suggested that this situation may have been caused by the presence of residues of farming

in the cave that, over time, have been filled with leachate. The measured rock strength (UCS) is 5-15 MPa for calcarenites and 20-35 MPa for lutites.

The project

The first project hypothesis envisaged the possibility to completely remove the waste ad transfer it to another landfill, or alternatively, to temporarily stock it in another site and move it back to the original site after cleanup. However the abovementioned hypothesis was rejected for reasons of cost, time and environmental impact. In order to create an effective on-site barrier without transferring the waste offsite, the project *(developed by Sviluppo Italia Engineering with geotechnical advise being provided by Studio Sintesi)* identified an intervention method aimed at considerably reducing secondary permeability *(due to fissures)* and, locally, primary permeability *(where dissolved calcarenite was present)*. The major technical challenge was to build a bottom-tight liner for the landfill. As a waterproof screen by material replacement was not technically feasible, it was decided to waterproof a strip of rocks beneath the waste, by injecting cement and silicate grouts to fill up the fissures, discontinuity and gaps responsible for its permeability. A final permeability of the strip of rocks of 5 Lu *(Lugeon Unit)* was estimated.

The screen had been specially sized to match the contour of the landfill bottom and to be placed at a distance of 2.5-3m from the waste bottom, seamlessly joined end-to-end to the perimetral barrier. The rock has been subjected to treatment through a 3m thickness.

The construction of the screen by using traditional techniques would have required thousands of vertical drillings crossing the waste to reach the rock layers to be injected beneath it. This solution was however considered too expensive, time-consuming and environmentally risky. As a result, an innovative solution was put forward, inspired by the recent introduction in the geo-engineering sector of the Horizontal Directional Drilling *(HDD)* techniques, which are widely used in the oil industry and for laying of underground utility services (named *No-dig technology*).Adequately modified and integrated, the abovementioned techniques (renamed **TDDT: Trevi Directional Drilling Technology**) enable to drill sub-horizontal curvilinear boreholes of increased length (in this case up to 180m). In this specific case the horizontal directional drillings were performed from one of the sides of the landfill and under it as well, in order to fully cross it from underneath, while at the same time intersecting the two sides of the vertical perimetral screen.

The project specification was to achieve a drilling directional accuracy of 30cm. Steel sleeve port pipes have been placed inside the boreholes for cement and silicate mix grouting.

The same solution was adopted for the realization of the perimetral barrier. In his case, straight boreholes were drilled in two rows, tilted by 15 degrees *(in the opposite direction for each row)* with respect to the vertical axis, in order to cross all the fissures when drilling and grouting the cement mix. A third central row of vertical boreholes, grouted with long-lasting silicate grouts, was drilled to complete the intervention.

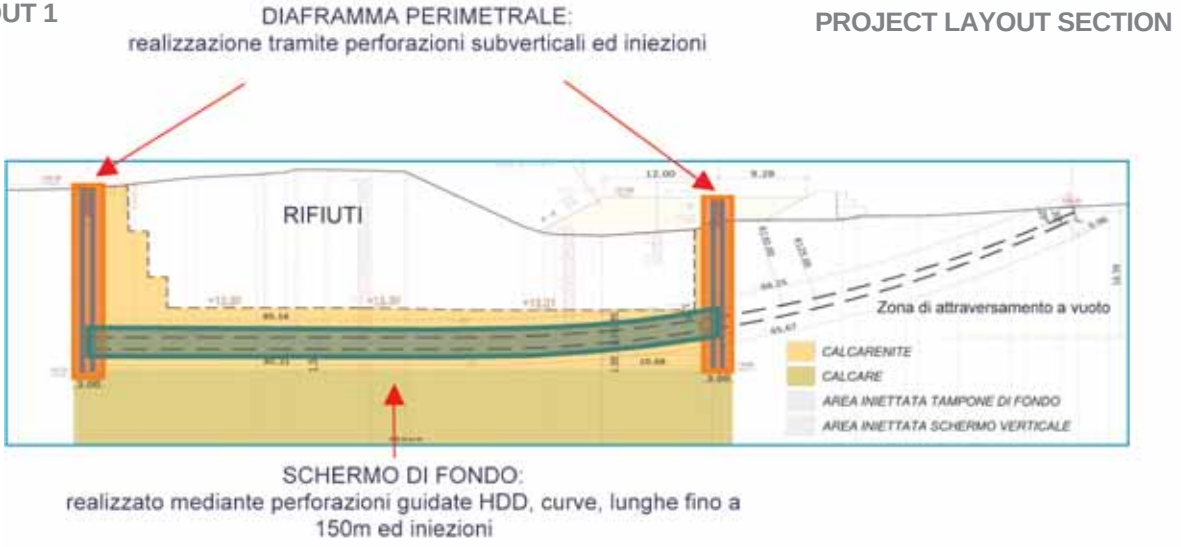
The solution adopted for the construction of the bottom-tight liner of the landfill is innovative, cost-effective and has zero environmental impact, as the interventions never affect the waste. Therefore it can be applied to any landfills featuring similar problems to Manfredonia landfills.

grouting as sub-contractor, whereas Mucafer performed all preliminary and assistance activities (tracks, laying out, partial displacement of waste, waste coverage and guide curbs), as well as the ìfinal cappingî *(that is the reshaping of the mass of waste and final coverage by placing a geotextile and vegetable soil)*.

Preliminary activities

To define the construction project, during the realization phase, additional investigations were carried out both along the perimeter *(a borehole was drilled every 30 metres)* and in the area of the two landfills, through core boring, video camera investigations and permeability tests of the areas subjected to the treatment. Furthermore, test fields were also used to refine the technological and operating details and assess whether the project goals had been achieved.

LAYOUT 1



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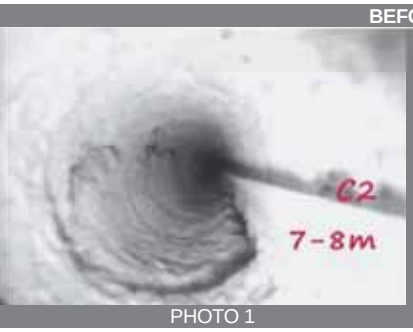
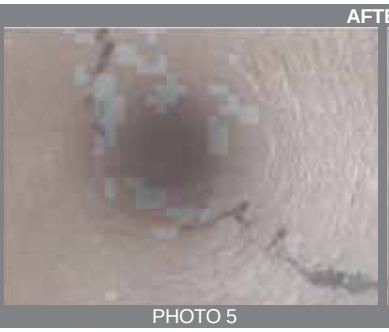


PHOTO 1

PHOTO 2

AFTER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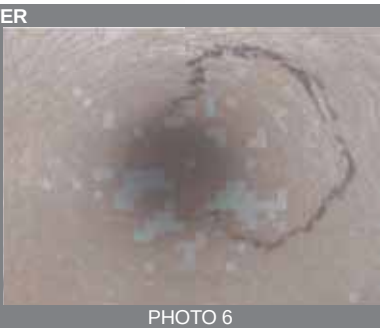


PHOTO 6

Jobsite set-up and logistics

Jobsite set-up

The project solution provided for a rapid jobsite set-up and allowed to work with several teams in various areas of the landfills at the same, thus ensuring high executive flexibility and the possibility to face any unforeseen events by modifying the work plan and/or executive technology, to complete the works by the absolute deadline.

The works were let out on contract in October 2009: they were assigned to an A.T.I *(temporary Grouping of Companies)* having CCC as lead contractor and Coop Mucafer as selected tenderer. The works were carried out under the supervision of the Enforcement Subject and the works management by SOGESID SpA. Trevi SpA *(ground engineering division of Trevi group)* carried out the specialised works of drilling and

Technologies adopted

Besides helping to better define the configuration of the landfill and highlight some anomalous situations, the preliminary activities revealed the presence of interconnected macro-fissures – from a few centimetres to many decimetres - in 20-30% of the drilled boreholes. The size of the fissures was such that the whole water injected during the tests was absorbed, thus making it impossible to measure permeability *(Lu value could be measured)*. Such a situation was also confirmed by the video camera investigations ***(photos 1 and 2)*** carried out inside the drilled boreholes; as a result, we deemed it necessary to integrate the drilling and grouting techniques encompassed by the project both for the perimetral holes and the HDD. Namely the drilled boreholes were divided into primary, secondary and tertiary, by gradually reducing the distance between them. In the event of loss of circulation (which

PHOTO 4

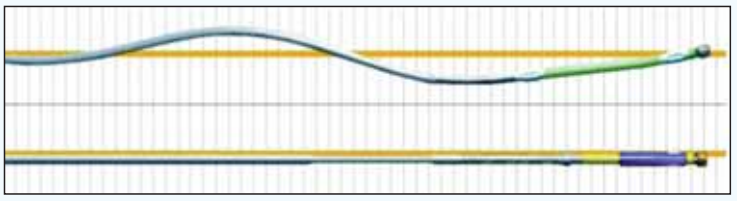
is very common in primary boreholes), a special technique named ***down-stage*** was implemented: drilling is interrupted, special expanding cement mixes are grouted, then drilling is resumed *(after re-drilling of the grouted portion)*. The use of expanding grouts allowed us to limit grouting to the area of interest, thus minimizing absorptions, times and costs.

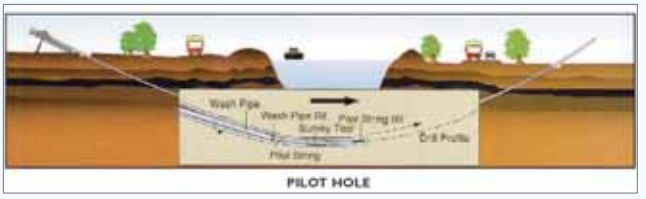
The preliminary grouting being made as described above, for the following ones we used the technique identified in the project, which is suitable for lithoid formations, and is named ***MPSP*** *(multiple-packer sleeved pipe system)*.

With this technique, grouting is made using specific pipes fitted with ports and collars slipped around them. Once the collars have been inflated, the hole is divided into stages that can be grouted separately at the pressures set by the project.

To carry out the HDD, a number of tests were conducted to identify the best guide system. The traditional technique of drilling position detection by radio emitter and surface receiver was rejected, as the distance from the surface of horizontal drilling (*up to 30-35m from the ground level)* prevents any signal transmission.

We chose a technique that allows to detect the drilling progression by measuring artificial magnetic fields previously created in the site, using special sensors assembled onto the drilling string. Data are brought to surface in real time; they are processed by a software and compared with the pre-calculated ones concerning the theoretical drilling progression. If the deviation tolerance is exceeded,





By TDDT (Trevi Directional Drilling Technology) it is meant a set of technologies that enable to drill small-diameter (50-200mm) and long (usually from 25-30m up to a few hundred metres) boreholes with high positioning accuracy (10-30 cm) for various applications in the foundations engineering sector. Diameters and thicknesses of rods/pipes permitting, drilling can be either rectilinear or curvilinear, executed in all directions (including vertical and horizontal), and in any soil type (cohesive or non-cohesive), including rocks.

special eccentric tools are used to correct the drilling progression and bring it back within the envisaged deviation range.

Boreholes were drilled using HDD in two sub-horizontal rows with quincuncial arrangement and a 1.8m distance between them. Drilling and grouting were executed following the sequence tested in the test fields.

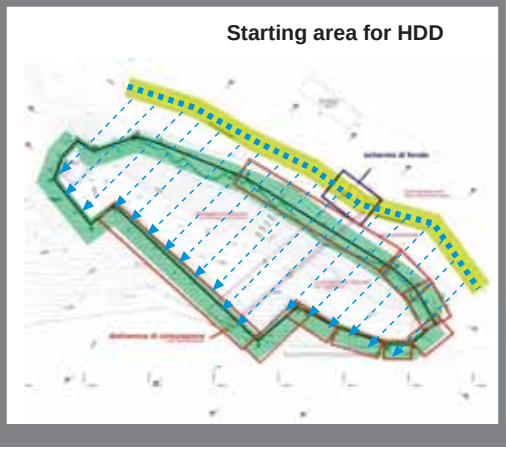
In both sites, boreholes were drilled using Soilmec drilling rigs that have been working outside the waste perimeter - *Soilmec is the industrial division of the Trevi Group manufacturing machinery and equipment for foundation and consolidation*. Grouting was made by connecting the grouting pipes to grouting stations *(supplied by Soilmec)* by means of double-packers. In the said stations there were tens of injectors controlled by a sophisticated control and data recording system. Next to the grouting stations stood the mixing stations and material stocking tanks. These plants require very good organisation and the continuous presence of specialized personnel. The foreseen permeability standards and the perfect water-tightness of the screen over time clearly depend on the quality and conformity of the grouts to contract specifications *(volume of grouting, percentage of components depending on a set of parameters such as temperature, distance, depth, etc.)*.

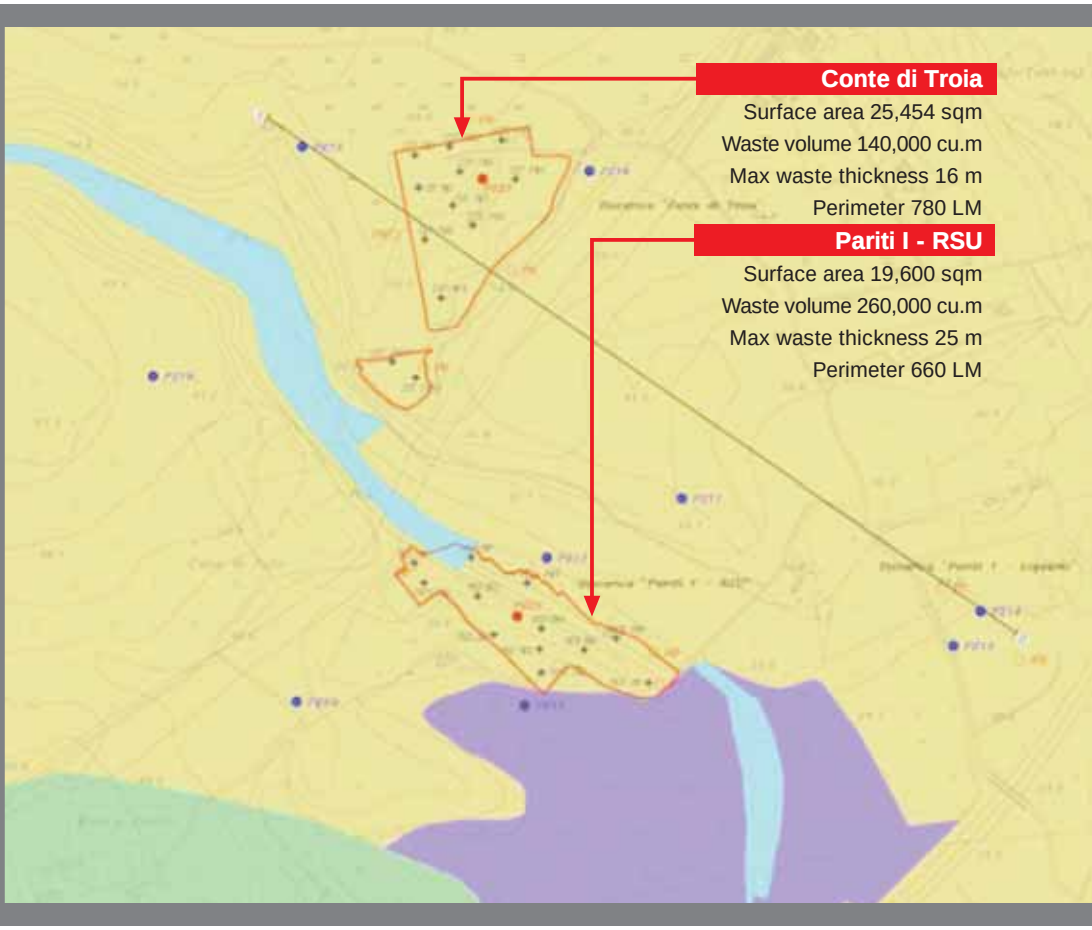
Checks andTests

Checks during construction

Grout absorption was accurately recorded, divided per homogeneous absorption areas and noted in tables for a comprehensive assessment.

As an example, the scheme below *(interventions carried out in Conte di Troia)* shows, by means of a colorimetric scale, the grout absorption percentages with respect to the corresponding theoretical volume in the uniform areas *(vertical and horizontal screen)*. The values are consistent with the ones envisaged in the project *(21%)*





Core boring and video camera investigations

After the completion of the interventions, core boring with video camera investigation inside the borehole were performed at regular distances and according to the project management. The photos ***(photos 4,5 and 6)*** clearly show the quality of the final result.

Number of drillings - Conte di Troia and Pariti landfills (down-stage re-drilling excluded)		
Sub-vertical drillings for perimetral screen	No. of holes 2,350	for 49,170 LM (average L = 21 LM)
Sub-horizontal drillings for bottom-tight liner (downstage re-drilling excluded)	No. of holes 565	for 58,380 LM (average L = 103 LM)

What they said about the “Manfredonia Project”:

- **Stefania Prestigiacomo** - Minister for Environment

  “After Pioltello Rodano, Italy has shown to Europe once again, after a few days only, that we are able to reclaim sites effectively and rapidly.”
  “In one-year time we did what we had not been able to do in 15 years”.

- **Nichi Vendola** - Presidente of the Puglia Region

  “It is an extraordinary result”and a “case study at European level”.

- **Angelo Riccardi** - Mayor of Manfredonia

  “Rapid intervention, cutting-edge technologies never used in Italy before...this reclamation intervention gave work to 125 people for 18 months”
  “I think that the Puglia Region is presenting today a result of excellence and can be proud of it”

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