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Risk Management of a Complex Remediation of the Former Feijenoord Gasworks Site in Rotterdam

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Abstract. This paper will show how the project's geotechnical risk profile was put into design and contract, the experience of the risk monitoring and risk measures, followed by a short evaluation.

Keywords. Risk Management and Communication, Contractual Issues, Gasworks, Excavation, Geo-Impuls

1. Project Introduction

1.1 Gasworks remediation program

The former Dutch ministry of Housing, Planning and Environment (VROM) started a long term subsidy program to remediate polluted soil of former gasworks sites in the Netherlands. This program aims to minimize the environmental risk to an acceptable level before 2015. The next-up remediation location was the former Gasworks Feijenoord, situated in the south of Rotterdam.

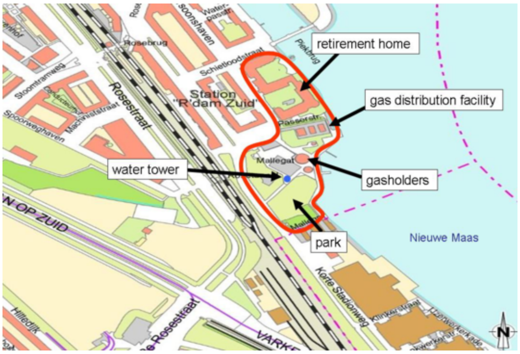


Figure 1. Project site

Nowadays the site accommodates a recreational park, a gas distribution facility, factory monuments, utility buildings and a retirement home. The actual remediation involves the soil excavation of the southern part of the former gasworks site and an afterward in-situ remediation. The northern (inhabited) part of the location as well as the gas distribution facility will be remediated depending on future redevelopment.

1.2 Location history

From 1877 until 1969 the Feijenoord gasworks was in operation for the production of gas for lighting purposes and household use.

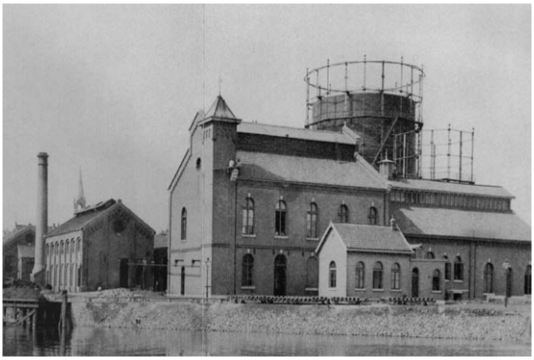


Figure 2. Feijenoord gasworks in 1909

The century-long production process, resulted in severe soil pollution due to the spill of oil and the dumping of cokes and contaminated earth. Many changes in plant configurations, buildings and installations resulted in a diverse range of foundation remains and underground debris. In the late 1960's the gasworks became redundant as a result of the gradual switch to natural gas. After the closure the southern part was redeveloped into a public recreational park with a water tower and two gasholder domes remaining as reminders of an industrial era. The northern part of the gasworks was closed a few years later. The (natural) gas distribution facility is still in operation.

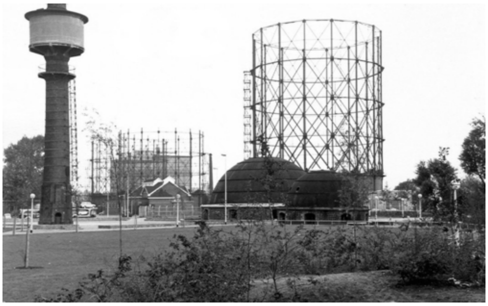


Figure 3. Monuments in the park in 1972

1.3 Project goals

Although there are no risks for human beings and the ecosystem, the contamination could in fact move towards the first aquifer and towards the surface water of the river. The main goals of the project are to eliminate risks of further diffusion of contamination and to ensure future redevelopment possibilities, as reported in the remediation plan [1] for this project.

1.4 General conditions

The soil remediation took place under complex conditions. The excavation site is situated in a densely populated area. Excavating the highly contaminated soil could result in health risks for civilians and workers in the area. There are safety and operational risks for gas and water pipelines and utility buildings. The excavations have to withstand high river water levels and the integrity of the embankment has to be secured. The condition of the gasworks monuments, founded on wooden piles, have to be preserved.

2. Risk management approach

2.1 Method

Decisions to minimize the project risks are made throughout the project. In Rotterdam a Standard Method of Project-based Work (RSPW)[2] provides general principles for risk management. This method addresses technical, financial, social, environmental, planning and legal risks during each project phase.

In this project a specific risk log was introduced in order to minimize the high impact risk of the excavations, groundwater changes, influences on pipelines and structures, etc. Therefore the RisMan[3] based technique was used to make a classification of underground and environment related risks. This 'geotechnical' risk log is an important design tool. The risk classification was updated after taking design measures in order to evaluate the residual risk. Residual risks are shared with the project management and project team by integrating them in the RSPW risk log.

2.2 Baseline information

In order to make the project a success, the goals have to be reached. A high ambition for remediation often means taking high risks. By a proper project organization and thorough technical preparation these higher risks can be taken in a responsible manner by collecting all base-line information. In this project the preparation included collecting the underground information by an extensive geotechnical soil investigation[4], environmental soil investigation, a geo-hydrological survey, an archival research for the possible underground obstacles, an extensive survey of all cables and pipelines, a ground radar survey and debris penetration tests.

2.3 Risk based design

The first geotechnical design considerations were made in generating various remediation variants, as reported in the Remediation Survey Document. Risk analysis was used in the selection of the preferred variant. Geotechnical risk measures were defined in the:

- Remediation plan
- Design and Excavation plan
- Contract
- Choice of equipment
- and the Monitoring Program.

2.4 Review of risk management

In addition to the general quality management according to the RSPW, this project was also reviewed specifically on the geotechnical (and underground related) risk management. This review was performed and reported by an independent third party Geo-Impuls[5], which provided geotechnical experts to examine the risk management by a recently developed standard GeoRisicoScan 2.0. Just before the realization phase the geotechnical documents, risk logs, contract and the monitoring program were reviewed and the geotechnical expert and the project manager were interviewed.

The review was both on the *content*, the way in which geotechnical risks were addressed, and on the risk management *process*, including risk communication and allocation of risks. The project passed the test with good results on both content and process.

3. Design phase

3.1 Initial situation

Based on the archive study and the soil survey the possible obstacles such as foundation remains and former underground oil reservoirs are mapped (see Figure 4). It was uncertain which part of the building foundations were demolished in 1969. Only a part of the wooden foundation piles have been removed. This underground information is both of use for understanding the pollution situation, exploring the excavation possibilities and locating possible underground obstacles.

Figure 5 shows the excavation site with two contamination hotspots. The two gasholder domes (in use by a sports club) and the water tower (not in use) are in the middle of the excavation area, as well as the high pressure gas pipeline, a data cable and a double main water supply pipeline all in operation. Around the site there's a bundle of utility pipelines.

Figure 4. Projection of lay-out of former buildings

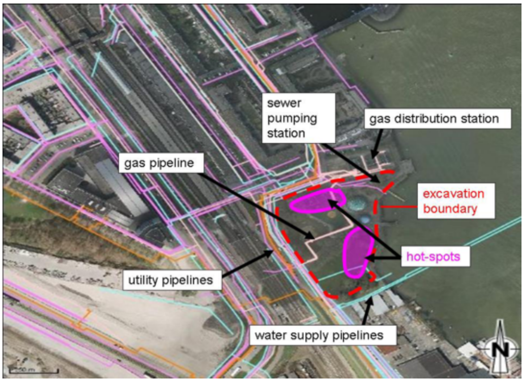


Figure 5. Excavation area with contamination hot-spots

3.2 Excavation plan

The excavation area is divided in five sections (see Figure 6). Section A is a shallow sloped excavation. B and C are deep excavation pits (8 m) with sheet pile walls at the hotspots. Section D was a deep sloped excavation (up to 6 m). For section E less pollution information was available and a shallow excavation was required to ensure the stability of the gasholder foundations.

Figure 6. Excavation plan

The main risk of the project was the 50 year-old high pressure gas pipeline. This steel pipeline was deformed by ground settlement over the years and situated in a contamination hotspot. Expected deformations by large excavations, vibration loads of installing sheet piles and predicted additional soil settlements would lead to unacceptable operational and safety risks and were decisive reasons to reroute the pipeline before excavation.

The exact degree and extent of the contamination could indeed only be determined during excavation, so the majority of the contaminated soil was removed by sloped excavation which provided flexible excavation boundaries. Around the water tower the excavation was symmetrical to prevent uneven lateral earth pressures and unacceptable deformation.

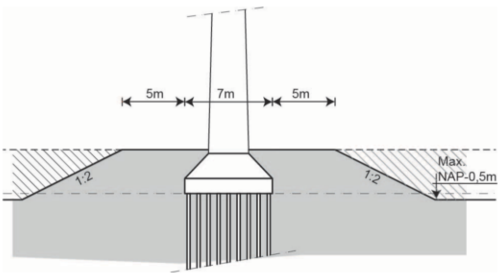


Figure 7. Excavation around water tower

Sheet pile walls in pits B and C were designed to withstand excavation up to 8m in combination with high river tide and prevent deformation of the nearby gasholder foundations.

The contaminations deeper than 6m (8m at the hotspots) will be remediated by an in-situ remediation afterwards, based on groundwater extraction and treatment of ground water.

4. Risk management in contract

4.1 Type of contract

Despite the large amount of information gathered throughout the years of preparation, there are often many uncertainties during soil remediation. The exact degree of contamination and amount of underground objects is uncertain. Based on these uncertainties and the specific conditions the Specification System for Works of Civil Engineering Constructions *(Dutch: R.A.W.)* was established including MEAT *(Dutch: EMVI)* criteria. By choosing this type of contract a part of the responsibility for these uncertainties lies with the client instead of the contractor. The advantage of this type of contract is exclusion of excessive risk pricing in contract biddings.

4.2 Selection phase

During the selection process, interested bidders must present their reference projects in order to demonstrate that they have sufficient knowledge and experience in conducting a major soil remediation in a residential area combined with the sheet piling and underground demolishing. Also a vision of the project was asked. For example, contractors were asked how they plan to prevent odor, vibration, noise and how to optimize soil transport.

4.3 Tender phase

After completion of the selection phase, qualified contractors were selected who were allowed to subscribe for the tender phase. In the tender phase the award criteria were formulated: social return, environmental requirements (transport, energy) and environmental management (noise, vibrations, deformations, odor, dust, etc) and communication. The contractors were asked to describe there methods in an action plan.

A higher score was given for preventive measures and a less higher score was given for curative measures. In addition, the monitoring method was assessed. The action plans are part of the contract and are therefore not voluntary. A total of 1 million Euros could be deducted from the contract price if the maximum score was achieved. In case of plans of action with a low score an amount was added to the contract price or the contractor was excluded. Based on the evaluation and ranking the final contract price was determined. Finally the soil remediation was awarded to one contractor. This contractor must submit several detailed plans of action for approval prior to the start of the project.

4.4 Roles in risk monitoring

It is the task of the contracting party to provide all available information during the tender procedure. If there is insufficient information the tender procedure may fail. In addition, it may happen that because of the lack of information, the contractor will have to pass these risks on in their costs. It is the responsibility of the tendering party to notify the contracting party in time about imperfections (e.g. design flaws or forgotten items).

4.5 Risk allocation

From the formal start until the formal end of the soil remediation project the contractor is responsible for the implementation. In case of damage, the client as a designing party, will be held liable for design flaws or withholding information for instance. The contractor can be held liable for negligence, carelessness, improper actions or failure to comply with what is described in the approved plans or permits. Eventually, the situation could escalate and will need a court order to fix the case.

4.6 Risk communication

During the realization phase the associated risks will be discussed on a regular basis. This usually happens during the construction meetings and during other consultation moments. In this meetings the results of the monitoring are discussed. If necessary, the activities will be adjusted to meet the requirements, standards, laws and regulations. The contractor and the supervisors keep a logbook in which the results of the measurements and the measures taken are listed. A sum of the results is presented on the website of the project. Each quarter, the contractors' approach to risk management is evaluated in a special form called 'Past Performance'. The results of this evaluation will be kept in the database of the Municipality of Rotterdam and will be used in future contracting.

5. Realization phase and monitoring

5.1 Monitoring set-up

A monitoring plan was made by the contractor. According to contract specifications vibration indicators and displacement sensors were installed to prevent damage to the two gasholders and the water tower.

Also emission of pollutants, odor and noise were measured. During the excavation several wells were installed for monitoring groundwater levels. The degree of soil contamination was sampled regularly to determine the required excavation depth. Also a groundwater pumping test was performed to determine the influence of groundwater extraction on the nearby railway. The test showed that no water retaining screen between the excavation and railway was necessary and groundwater lowering effects were less extensive than expected.

5.2 Excavation

Realization started begin 2014. The excavations were limited to section A for safety reasons of the still present gas pipeline. In May the gas pipeline was cut-off and rerouted, which made the open slope excavation of section D possible.

The sheet piles for pit B were installed in June, after which the first pollution hotspot could be excavated to a depth of 8m. A deepwell was active for several days to prevent the bottom heave of the pit due to ground water pressure. In September the excavation pit B was partly filled up and the sheet piles were reused at pit C.

Installing the sheet piles for excavation pit C was obstructed by the remains of a wooden pile foundation which resulted in a change in lay-out of the pit. A crusher was used to remove the obstacles.

An additional deep excavation was carried out in section E in order to remove contaminated soil at the hotspot between the small gasholder and the sheet pile wall of pit B. A Berliner Wand was used as a retaining wall, which made excavation possible to a depth of 5,5m.

Figure 8. Deep excavation in section E

5.3 *Monitoring results*

Both high water levels and deep excavations did not result in exceeding limits for deformations. Odor and noise nuisance barely took place, partly due to fair weather conditions.

The installation and removal of the Berliner Wand resulted in minor settlements of the small gasholder (see chart 1), but these were still below the intervention limit of 10mm.

The deformations of the water tower stayed below the intervention value of 7mm.

Chart 1. Settlements small gasholder

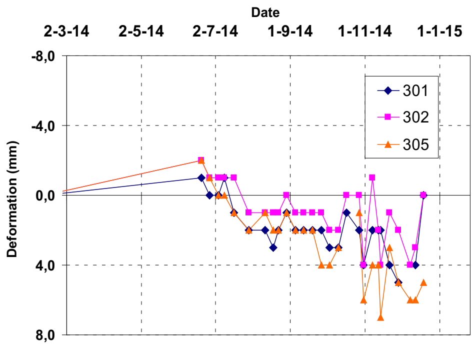
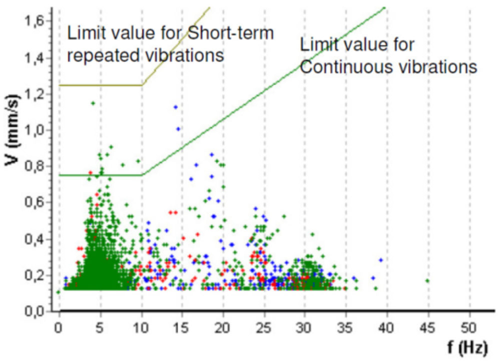


Figure 9. Excavations around water tower

Sheet piles were installed with high frequency vibratory hammers. A few limit exceeding values were reported. Chart 2 shows overruns occur at low-frequency activities ranging 0-10 Hz, typical for every day traffic and heavy vehicles.

Chart 2. Monitored vibrations (*Hanselman 2014*)



6. **Conclusions and recommendations**

Despite risk management and extensive soil investigation there will still be uncertainties about the actual soil pollution. Therefore in this remediation project a lot of effort was put into:

- a robust and flexible realization plan,
- a (reviewed) risk management approach,
- the selection of an experienced contractor,
- an excavation monitoring program,
- environmental management.

In this project geotechnical risk management has contributed to a successful design, contract

and realization. The review by Geo-Impuls ensured that geotechnical risks were managed properly before the realization of the project.
Rerouting the high pressure gas pipeline was a successful measure to prevent safety risks and guarantee the continuity of the gas supply. The monuments and infrastructure on the project site remained undamaged during excavation.
However some monitoring activities (settlements and vibrations) were not performed in time and communication about the results could be improved.

An online monitoring system for vibrations and settlement is essential for monitoring high risk activities.
The contract should be more specific on risk monitoring communication between contractor, construction supervisor, the project manager and supervising specialists. Penalties could be given to the contractor when he does not meet the contractual obligations for monitoring.

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