RECLAIMING ABANDONED MINING SITES: REURBANIZATION CONCEPTS AND EXAMPLES[1]

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Abstract: The Ruhr District in Germany, one of the oldest and largest hard coal mining regions in Europe, has been in a process of constant change over the last 40 years. Since the end of the World War II, the coal industry has been declining. There have been a number of successful attempts to establish new industries in the Ruhr District. However, the initiation of new industries depends strongly on the availability of space. Since the Ruhr District is a rather populated region, the only chance to gain space is to reclaim the areas formerly used by now obsolete industries. The remediation of former mining sites in the Ruhr District and the reestablishment of alternative industries have now become both a challenge for city planners and a prestigious attribute for ambitious politicians. It has become the declared goal of the German government to convert the Ruhr District into the greenest industrial region in the world. This paper discusses geotechnical techniques, as well as economical risks involved, in the recycling of abandoned mining sites. To demonstrate remediation techniques used in Germany, a recent remediation project is described and analyzed.

Additional Key Words: Recycling of derelict land, contaminated sites, remediation techniques.

Reactivation of Abandoned Sites

In North Rhine-Westphalia, Germany's most densely populated industrial province, a growing need for land for commercial and industrial use has become apparent. To meet the increasing consumption of open space, and faced with the need to protect open space, to assist cities and communities in their development, and at the same time to reactivate now-abandoned industrial sites, the province of North Rhine-Westphalia has resolved to make land reactivation a central goal of its land policy.

Strategies for the renewal of old industrial areas are being developed internationally and discussed intensively. The Ruhr area represents a particular challenge in this field.

On average, in North Rhine-Westphalia more than every other usable piece of land with a size of more than 5 ha is an abandoned industrial site. The areas of the abandoned sites range from 0.3 ha to more than 70 ha, with about 47% of the sites having an area of more than 10 ha. Corresponding to the industrial history and changes in the infrastructure in North Rhine-Westphalia and in the Ruhr area in particular, most sites were formerly mines, coke plants, or steel works. So, for example, in the eastern Ruhr area about 80% of the abandoned sites are old mines, and in the coming years further similar areas will be released.

The rehabilitation plans for the areas currently under development entaila future return to commercial or industrial use for 51% of the areas. 45% is allocated for parkland and recreation. The remaining 4% is to be used for future housing. The wide range of prior uses of the sites, their usually large area, and their often very long history of use are usually reflected in the extent of the problems of dealing with contaminated sites, which will be examined below.

Characteristics of Abandoned Sites

As stated above, the commercial, industrial, and transportation sites described have a number of features in common, even though they differ with regard to prior use, which creates highly specific problems regarding the handling of contaminated sites and demands specific procedures for so doing. They are, after all, not the typical degraded sites (such as gas stations) with one or a few contaminants, or large storage facilities or dumps with a more or less broad spectrum of contaminants but limited extent. Rather, they are mostly extensive, fully structured, and contaminated former industrial or commercial sites. The history of industrial or commercial use, often extending back for

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[1]Paper presented at the International Land Reclamation and Mine Drainage Conference and the Third International Conference on the Abatement of Acidic Drainage, Pittsburgh, PA, April 24-29, 1994.

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Proceedings America Society of Mining and Reclamation, 1994 pp 212-120

DOI: 10.21000/JASMR94030212

https://doi.org/10.21000/JASMR94030212

more than 100 years, has left numerous traces on these abandoned sites, which are characterized by increased concentrations of contaminants in ground and surface water, sometimes considerable contamination of the soil, contaminated remnants of structural material, disorderly accumulations of production waste, extensive heaps of builder's rubble, mining material, slag, and ash. In addition, there are underground tanks, shafts, and basements of cooling towers filled with trash, production conduits that have not been removed and are still filled, as well as massive foundations and remains of former buildings. Not infrequently, one must reckon with surface contamination due to uncontrolled demolition.

The large-scale sites of the coal and steel industries are characterized by their extensive area and their usually vast heaps and dumps with enormous quantities of contaminated material. With the small-scale industrial sites (e.g. metalworking), on the other hand, the problem lies mainly in the complex spectrum of contaminants.

Abandoned sites like those described here must in every case be treated as areas of suspected old contamination. Such suspicion has proved to be justified in the overwhelming majority of the projects handled up to now.

Guidelines for Reclamation of Contaminated Sites

The contamination of soil and ground water has become a peripheral restriction on recycling. The process of recycling abandoned sites is hindered and delayed to a considerable extent by soil and ground water contaminations. Legal problems, the unavailability of suitable reclamation technology, inadequacies in assessing potential hazards, and, above all, the bottleneck in financing lead at least to time delays in the planning and execution processes.

However, the land recycling process cannot stop at merely removing hazards. Reclamation, and hence all strategic considerations for reclamation, must be oriented toward a demanding usage profile. Aspects of dealing with contaminations must be harmonized with marketing. There must not remain any incalculable risks for users or investors. Precautionary measures play a considerable role. The aim is a broad spectrum of uses, on the basis of city planning considerations and the site profile. Restrictions to this are set by limited finance and time and by technical insufficiencies.

Reclamation of contaminated sites, therefore, cannot result in the production of a piece of land uncontaminated and original as if untouched by humankind. After more than 10 years' experience in dealing with contaminated sites, we have realized that it is frequently impossible to achieve anything more than a reduction in contamination.

The authors' understanding is that reclamation measures are measures to ensure that a reclaimed contaminated site poses no danger to human life or health and no threat to the living or nonliving environment in connection with the existing or planned use of the site. The authors' understanding is also that the reclamation of contaminated sites must be designed to be as environmentally and socially acceptable as possible. As criteria for the environmentally acceptable reclamation of contaminated sites, the following apply especially:

- not transferring the problem to other environmental media or other locations,
- the reduction in environmental hazards at the site due to reclamation must exceed the environmental hazards caused by the reclamation,
- upon conclusion of the reclamation measures, the land should be suitable for a broad spectrum of uses.

Important aspects of a socially acceptable reclamation strategy are the intelligibility, practicability, and justification of evaluations and decisions, the openness of data, decisions, and plans, in short the "glass-clear reclamation". For socially acceptable reclamation, acceptance should be gained in particular by the people in the area.

Reclamation Management and Procedures

Besides the complexity of the task and the manifold interlocking of the different fields of activity in the process of recycling, it is frequently the shortage of time, the limited availability of funds, and the large number of projects needing to be worked on that make effective reclamation management -- integrated into the overall management of the project -- a necessity.

Experience in the Land Management Funds with the reactivation of contaminated abandoned sites shows that the successful completion of a project is possible only if:

- the reclamation process is completely and purposefully structured,
- the management is centralized in one person's hands,

- demolition and reclamation measures are implemented on the basis of comprehensive demolition and reclamation plans,
- the execution of measures is monitored and controlled by a reclamation supervisor.

Complete and purposeful structuring is the basis of any project planning. The reclamation process must be divided into sections that result in sensible interfaces and correspond to the planning process, e.g., in the working steps of other working areas. The structure should be chosen in such a way that the sections can be delimited from one another as to content; the units are small enough to be readily surveyed, planned, and controlled; and the intelligibility and reconstructability of the reclamation process are promoted.

In the Land Management Funds, it has proved expedient to prescribe a standard structure and to lay down binding rules for the content and sequence of decisionmaking and communication processes to facilitate internal and external coordination.

The procedure for the handling of contaminated abandoned commercial and industrial sites can be described in terms of the following working steps:

1. Determination of potential hazards
   1.1 Site investigation / present condition / prior use
   1.2 Assessment of hazard

2. Reclamation
   2.1 Investigation of demolition
   2.2 Planning of demolition and reclamation, environmental acceptability, safety at work
   2.3 Controlled demolition
   2.4 Decontaminating and improving soil and ground water
   2.5 Confirming success of reclamation / documentation / monitoring

3. New use and preparations
   3.1. Preparing the site
   3.2 New use

The actual order of procedure must, however, be worked out for each site from the specific circumstances; <u>the</u> strategy for investigating and reclaiming contaminated sites does not exist. Neither does <u>the</u> technology for carrying out reclamation, even though advertisements often try to persuade us otherwise. Each contaminated site is unique. Contaminated sites are "individuals" and thus need to be handled individually. They conceal surprises that we have not anticipated or prepared for and that necessitate measures specific to the site in question.

Reclamation Strategies

For the reclamation of a contaminated site, it is generally necessary to distinguish between the strategies of:

* use-dependent reclamation and
* contaminant-dependent use.

In the case of use-dependent reclamation, the reclamation requirements for the site are determined by the planners in light of the intended future use, and reclamation occurs in accordance with these goals. In the case of contaminant-dependent or contaminant-related use, the contamination of the ground is accepted as a restriction and the use is determined accordingly. Both strategies have in the past been employed by the Land Management Funds. Measures for contaminant-dependent use, i.e., adaptation of use to the contaminant situation, have probably composed the vast majority of cases. Thus, zoning as parkland, i.e., about 45% of the planned usage of the sites bought, generally involves highly or very highly contaminated lots.

This orientation of the Land Management Funds toward the strategy of contaminant-dependent use can be understood against the background of the general, original task and aim of the Funds, the limited availability of resources, and the almost complete absence of reclamation technology that prevailed up until the second half of the 1980's. It is necessary to examine this passive, reactive strategy from various viewpoints:

On the one hand, there is the development of awareness of the problem and of standards and requirements. On the other hand, there are new technical capabilities, improvements in methodological know-how, and experience from a multitude of projects that allow new possibilities to be contemplated. Above all, however, it is the increased demands on the sites, especially in the "Work in the Park" projects, which were partly implemented within the framework of the Emscher Park International Building Exhibition.

In the Land Management Funds, the development of reclamation goals and reclamation strategies -- in short, the reclamation process -- is closely linked to the development of city planning goals. Integrated reclamation and use plans, which come into being in an iterative, interdisciplinary planning process, have proved to be an effective instrument for the reactivation of abandoned sites.

Integrated Use and Reclamation Plans

Reclamation plans for land areas that are currently in use differ from those that are developed for abandoned sites in the framework of recycling. In the former, the existing uses and the safeguarding of these play a central role, and in the majority of cases preventive measures are the ones employed, i.e., hazard prevention by interrupting contamination pathways; but reclamation planning for abandoned sites or unused industrial or commercial areas can lead to more far-reaching solutions. To this end, the development of integrated use and reclamation plans is desirable. Such integrated use and reclamation plans are characterized by:

- Guaranteeing minimum legal standards and standards of environmental technology (interruption of contamination pathways etc.).
- Integration of decontamination/remediation and future use by dealing creatively with contamination situations and usage plans. As far as this is compatible with the usage plan, use sensitivities and contamination situations are matched up. As far as possible, remediation features, e.g., sealing, are harmonized with uses that also have a sealing character. Site sections that have been made safe should be used in such a way that if reclamation is later found to be necessary, they will not impede reclamation measures.
- Former abandoned sites should be used for residential purposes only if decontamination is carried out that involves complete removal of the contamination potential. Old sites that have not been merely made safe should not be zoned for housing.
- Besides the integration of future use, it is also necessary to coordinate the procedure for preparation and production, the location and removal of equipment, and finally the demolition or (preferably) dismantling of the industrial or commercial buildings, with the planning and execution of reclamation measures. Thus, the production of a load-bearing construction base over the entire surface (including the removal of cavities and foundations) results in different reclamation needs, a different reclamation strategy, and possibly a different investigation strategy compared with site-centred preparation.

Reclamation plans should allow for different solutions for different parts of the site. Different remediation measures may be envisaged for different parts of the site depending on the contamination situation found.

Reclamation Methods

It is possible to react in different ways to hazards and environmental effects emanating from contaminated sites:

- Protection measures and limitation of use of the site as a temporary solution until measures for remediation are carried out.
- Making safe as a measure to reduce or prevent the issuance of contaminants for a limited time by interrupting the contamination pathways.
- Decontamination aims at the final removal of hazards at the source and in the contaminated area by destroying the contaminants or permanently separating the contaminants phase by various technical methods.

The choice of the most suitable reclamation method depends basically on three factors:

1. Location, i.e., topography, environment, geology/hydrology, soil physics (substrate, permeability, pH value, etc.), planned use,

2. Contaminants, i.e., spectrum, concentrations, mobility, toxicity, medium, etc.,

3. Goods to be protected.

The use of reclamation technologies must also be preceded by careful and detailed planning and feasibility studies, which enable project-related decisions to be made in individual cases. In the comparative evaluation of reclamation methods, a variety of criteria are used, such as acceptability, effectiveness of the method, condition of the ground after decontamination, ease of monitoring and control, flexibility, persistence, quality, and quantity of residues, primary and secondary emissions (transfer of the problem), energy requirement, technical safety risks, stage of development and availability, operational experience, costs (process, associated, and consequential costs), complexity and operational safety, efficiency (duration of reclamation), space requirements, suitability for mobile equipment, requirement for authorization procedure, etc.

In connection with making-safe, the following criteria in particular should be investigated and compared: spatial and material effectiveness of barriers and hydraulic, pneumatic, and immobilization measures, information that allows assessment of the long-term behavior of potential contaminants, findings concerning the long-term effectiveness of the method, nature and extent of necessary auxiliary and monitoring measures, reparability of barrier systems, keeping open a wide range of reclamation options, influence on later changes of use, objective (by scientific criteria) and subjective (taking account of psychosocial factors) compatibility with the intended use, costs (including monitoring measures), requirement for authorization procedure.

The making-safe of abandoned sites can be considered when suitable material and (hydro)geological conditions exist, if the making-safe procedure is both objectively and subjectively compatible with the intended use. The interruption of relevant hazard pathways must be guaranteed with high probability. Measures for making safe have the character of temporary, intermediate solutions. This results on the one hand from the long-term behavior of potential contaminants and safety devices being often impossible to predict, and on the other hand from the provisional nature of the criteria that can be invoked for the decision to make safe. Procedures for making safe require continuous monitoring of their effectiveness. Further, it is necessary to check at regular intervals whether the state of technology and the hazard assessment findings permit continuing with the strategy of making safe. Changes of use may make it necessary to rethink. In the long term, therefore, reclamation of contaminated sites that have been made safe may prove necessary.

The advantages of making-safe procedures are that they are rapidly available, are frequently inexpensive compared with decontamination methods, are often implemented using simple and well-tried methods of building technology, and that authorization is usually unnecessary or easily obtained. Disadvantages are the limited availability of the sites and the consideration that further taxes may be imposed and reclamation measures may possibly become necessary at some future date. Making-safe procedures make it essential that knowledge of the contamination potentials and restrictions be guaranteed for the long term.

On the basis of the selection criteria for the individual reclamation technologies and considering the infrastructure of the abandoned sites, it is easy to conclude that making-safe procedures will find frequent application within the framework of recycling of land. Especially on the extensive sites of the coal and steel industries, most of which have widespread and sometimes deep-reaching soil contamination, a great variety of making-safe procedures are frequently employed. The use of decontamination procedures fails on these sites, mostly because of the insufficient availability of suitable techniques for the range of contaminants and the types of ground involved. In addition, these sites are usually characterized by enormous quantities of contaminated soil and other materials. The use of decontamination techniques, which are usually cost-intensive, would here exceed the bounds of any financial framework.

Abandoned small-scale industrial sites often have a broad spectrum of contaminants, but usually small quantities. In the framework of integrated use and reclamation plans, they demand a high level of creativity because the smallness of the area and the number of contaminated sections often prevent restorage of material on-site, decontamination methods are often ruled out by the types of contaminants, and adaptations of use are usually impossible. Here, different methods are frequently used for different parts of the site -- a combination of decontamination and making-safe procedures and restorage or dumping.

Case Study

The former mine and coking plant "Graf Moltke 3/4" is located in the northwestern part of the Ruhr District close to the city of Essen and covers an area of about 230,000 m^2. In 1873, the first shaft was excavated, with three more following within the next 30 years. A coking plant was built in 1903-04 followed by benzol and ammonia factories. Over the next 50 years, additional industries were established, turning the site into a multiuse industrial complex. Coal production went up to 1 million tons annually in the 1960's until the mine was closed in 1971.

In the following years, the Graf Moltke Mine became a typical industrial wasteland with all its negative attributes. The positive point, however, was the existing and still intact infrastructure of the surroundings and the immediate neighborhood of the site to the A2 Autobahn, one of the most frequented German highways and an important east-west traffic connection, especially in light of German reunification. It was therefore decided to remediate the site as a project of the "Internationale Bauaustellung" and establish a high-quality industrial park. The European Community provided the project with appropriate funding (European Fund for Regional Development EFRE) so that only about 50% of the remediation costs had to be supplied by the owners of the former mining site.

Figure 1 illustrates the geology of the site. The subground of the Brauck site can be divided into three parts: an upper filling with foundation fragments (2 to 9 m), a middle stratum of quarternary sediments (about 10 m below surface), and a fractured cretaceous marl as bedrock. The ground water table is located at a depth of about 5 m.

A serious hydrocarbon contamination has been detected in the vicinity of the former coking plant (figure 2, upper graph). During the past decades, the pollutants have migrated through the porous sediments into the fractured rock, where they have been percolating through the joint network.

For the remediation of the "Graf Moltke" site, it was required by the environmental protection agency to minimize all excavation. Therefore, the sealing and reinforcing technique was chosen for the heavily contaminated sectors (figure 2, lower graph).

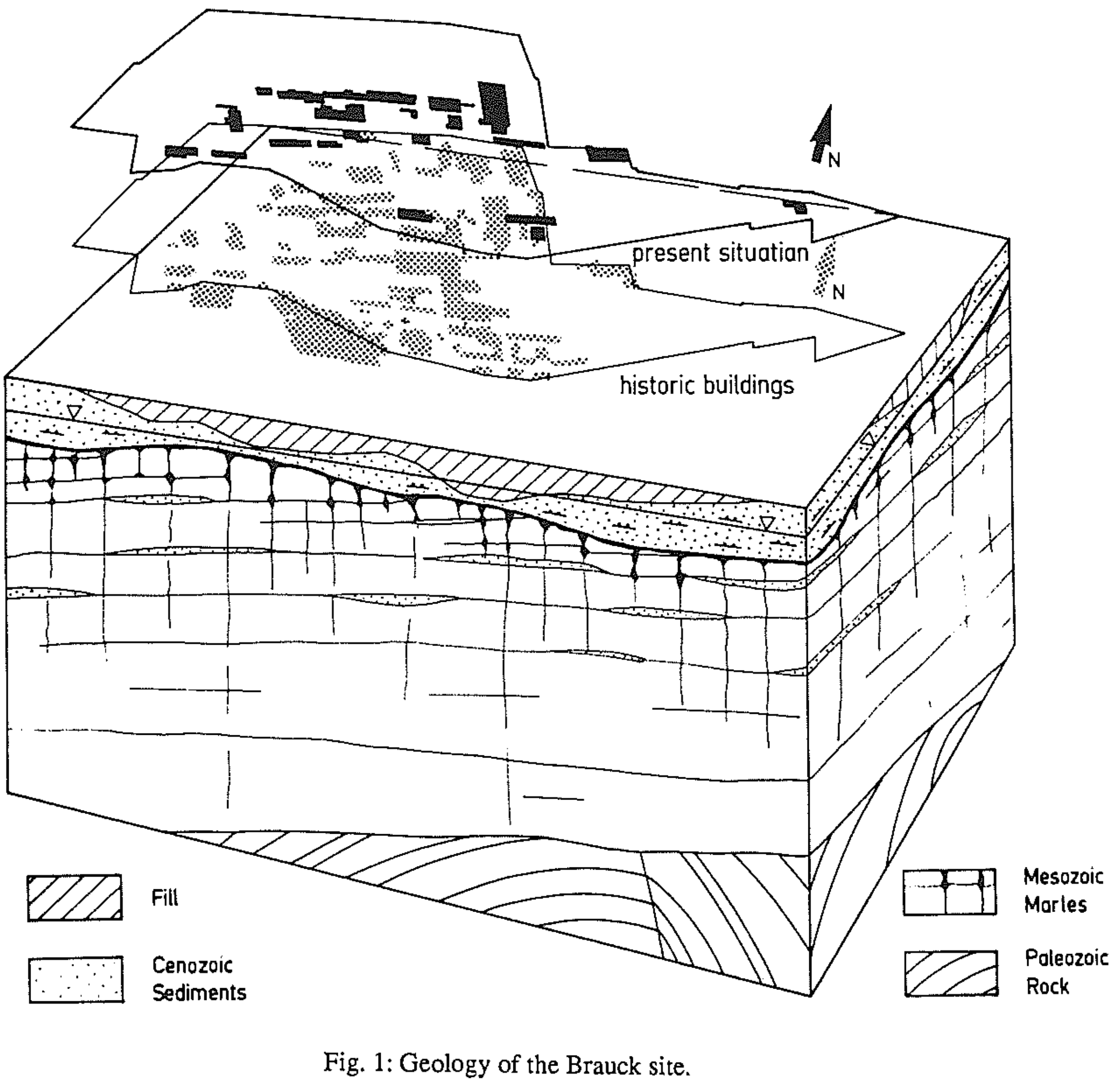

Fig. 1: Geology of the Brauck site.

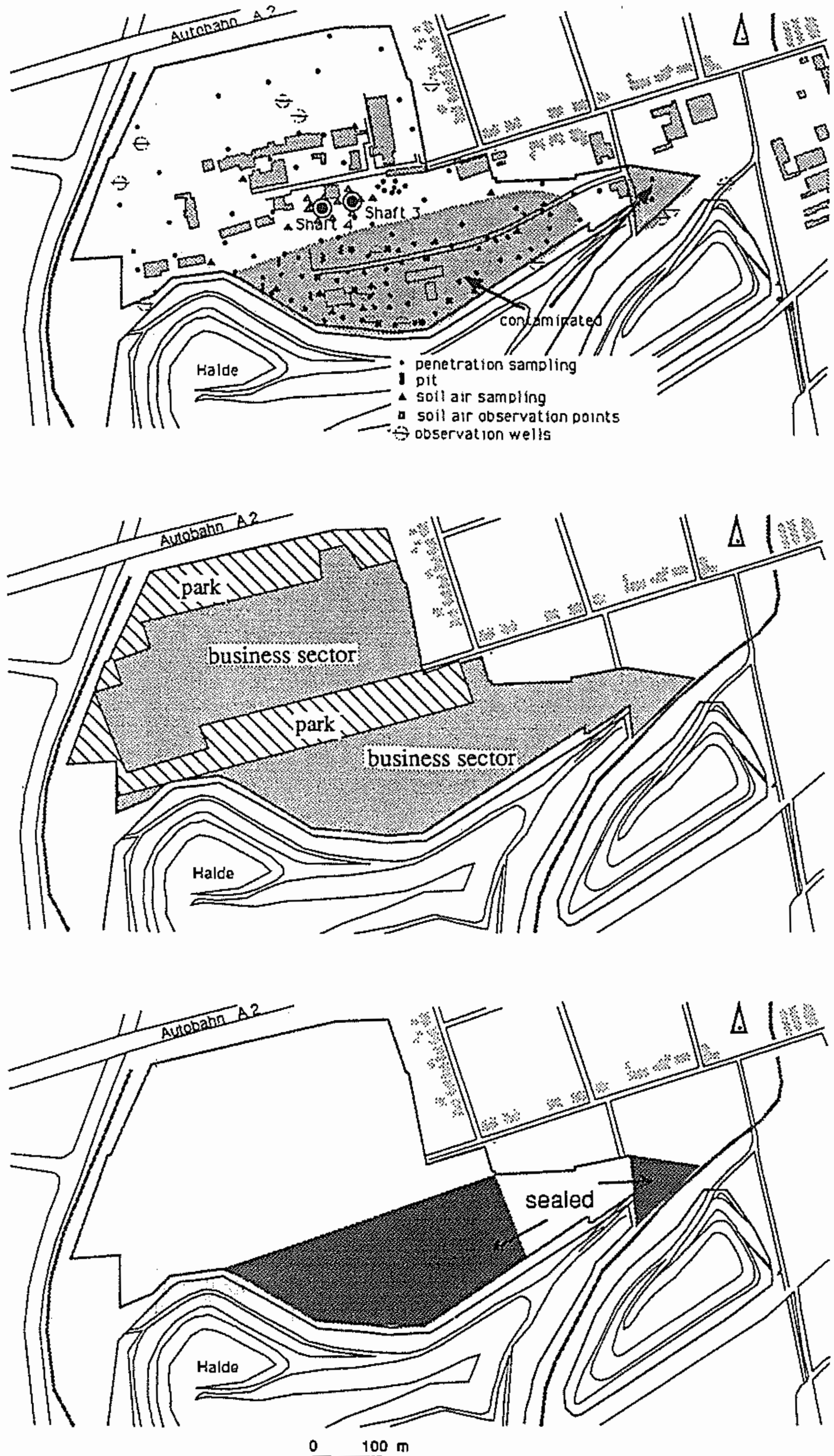

Fig. 2: Contamination, future land use, and remediation strategy for the "Graf Moltke" site.

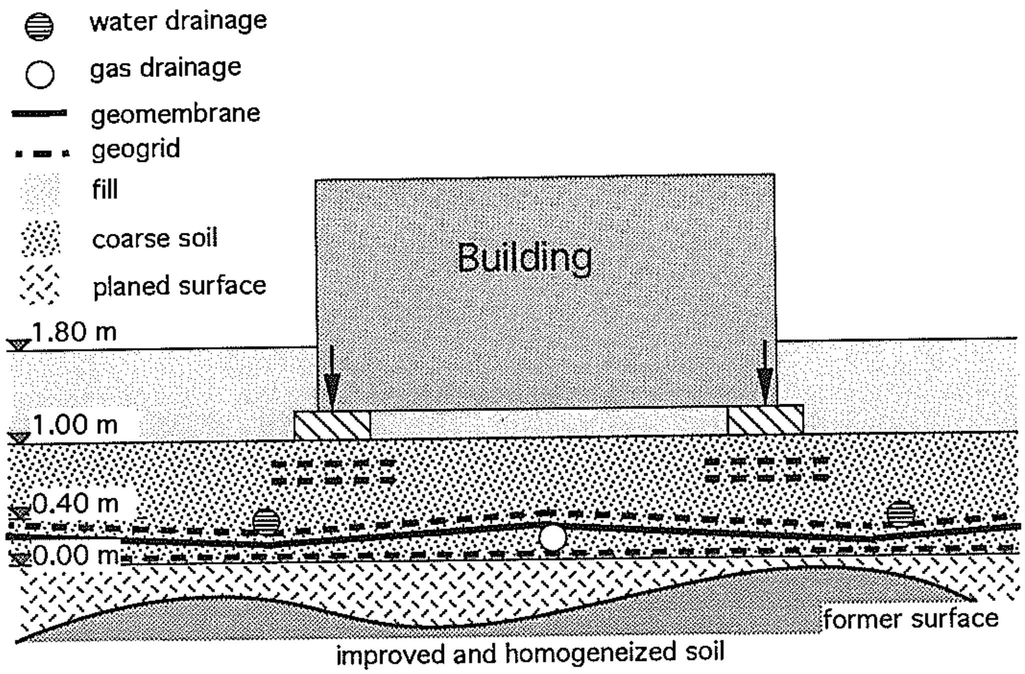

Fig. 3 A reinforced geotextile sandwich system. Besides the reinforcing geogrids, a geomembrane is integrated.

Figure 3 depicts a composite soil - geosynthetic - system that was designed to satisfy all three objectives mentioned above. Basically, this "sandwich" system is composed of three elements:

1. a lower supporting layer reinforced with geogrids,
2. a drainage and sealing system using geotextiles and geomembranes,
3. an upper reinforced foundation layer to account for structural loads.

Because the chosen technique is a rather innovative one, it was decided to design and construct a 500-m^2 full-scale test field on the site. The aims of the field test were to:

1. study the feasibility of using geosynthetics,
2. establish quality control tests and measures,
3. investigate possible damages during construction,
4. create new design criteria for such structures.

The test field location was chosen at an area within the derelict mining site where the ground conditions were representative for the whole site. To monitor the stress-strain behavior of the two reinforced layers using geogrids as reinforcing elements and the performance of the waterproofing geomembrane, several measurement devices were placed within the test field. A loading test was conducted to observe the stress-strain behavior within the sandwich system with special regard to the deformation of the sealing geomembrane. Also, the absolute and relative settlement at the surface were measured. The results from this test field appear to be promising. They are commented in Genske et al. (1993a, 1993b).

To monitor the quality of the ground water, a number of observation wells were installed, some of which may become recovery wells if a certain degree of contamination of the ground water is exceeded. The tolerable concentrations were negotiated with the environmental protection agency.

Conclusion

Recycling of derelict sites is one of the most challenging engineering tasks of the future. There are not many geotechnical problems that can be compared with the complex task of remediating contaminated sites. An interdisciplinary approach is needed to account for all the different aspects. Geotechnical engineers, environmentalists, politicians, financial experts, and the local citizens involved all must cooperate to ensure that the remediation project will be successful.

Each recycling project is unique. Too many aspects and boundary conditions give every site to be recycled a unique profile. This calls for individual concepts. In this paper, different aspects of land recycling are indicated. Aspects and guidelines as to land recycling are discussed, and several questions to be resolved are raised. A case study of a German derelict coal mine is presented, and the remediation strategy chosen is demonstrated.

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