Network Oriented Risk-assessment by In-situ Screening of Contaminated sites

NORISC

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Contents

1 Executive summary

A software package for guiding the investigation of contaminated sites has been developed. The software includes a decision support system (DSS) that provides the most appropriate combination of methods for investigation of contaminated sites. The system should be regarded as a guideline that gives potential users a substantial support when planning investigations for site characterisation purposes. The decision support system is based on various information from a number of tables that describe

- Guideline values for contaminants in European countries (soil and groundwater),
- Former industrial and other activities and corresponding contaminants to be expected,
- Geochemical investigation methods and the contaminants they can detect,
- "Other" methods, e.g. from geology, geophysics and hydrogeology, and information on site characteristics they can provide,
- Costs for the different methods, both for the geochemical- and non-geochemical methods,
- Restrictions in the application of "Other" methods.

In a practical guide, the application of the proposed methods is supported by various documents about site investigation strategy, desktop guideline, and rules for dealing with stratigraphy and quality assurance. This is supposed to support decisions on the estimated number of requested samples as well as the amount of drilling. However, more detailed descriptions on site investigation strategies can be found in various references and web sites.

The decision support system is requesting some information from the user about the site to be investigated. Considering the lateral and vertical extent of pollution at a site, the user is asked about the requested number of samples that have to be analysed. Thereafter, (1) groups of contaminants, either given indirectly by an estimated former activity on a site or chosen directly from a list, and (2) information on geology / hydrogeology has to be provided. This input facilitates the selection of relevant methods for investigating a site. Further, guideline values given in the tables will be visualised. These data are further used in supporting the selection of methods of best practice that have high detection limits. Known restrictions at a site, e.g., buildings or buried objects will reduce the "suitability" of certain methods. In this case the user is informed about possible limitations of the selected methods. In a separate sheet methods are given for supporting risk assessment.

The output of the software is provided as combinations of geochemical in-situ methods. The combinations are based on the suitability of different methods to deal with contaminants. If different combinations have the same ability to deal with a certain group of contaminants the cheapest alternative will be recommended as the first choice. In addition to the geochemical methods different combinations of geophysical and geological/hydrogeological methods will be suggested where again the cheapest combination will be ranked highest.

2 Introduction

The objective of this work is to establish a guideline for the investigation of contaminated sites with emphasis on a decision support system (DSS). This system will provide the most appropriate methods for providing the characteristics of contaminated sites and includes strategies to deal with them. Such characteristics are contamination profiles, prerequisites for the spreading of contaminants in terms of geological and hydrogeological conditions as well as anthropogenic ones. The DSS visualises guideline values for different contaminants according to European standards. The detection limits of the methods considered for the investigation should be equal or lower than the guideline values for corresponding contaminants. An important part in the investigation of a contaminated site is setting up rules and an adequate concept, namely a site investigation strategy (SIS). The SIS will guide the user through the different stages of such an investigation. Especially, the SIS emphasizes the role of integrating different methods of investigation in a dynamic working plan, i.e., an interactive one. The SIS ends up in some recommendations for risk assessment and remediation. The entire concept will be further explained below.

3 Work description

The work of establishing a decision support system (DSS) can be divided into four major parts:

3.1 Development of a conceptual model of the DSS

Number of samples
The DSS mainly requires information about the number of samples that are adequate to describe pollution at a site and about the contaminants themselves and site characteristics that the user wants to measure. The numbers of samples are used to estimate investigation costs and can be given either manually or being calculated by the DSS. The calculation provided by the DSS is either based on the area or on the proportion of the site, which is supposed to be contaminated:

$$N = \mathrm{Max}[1, 22.5 \times \mathrm{sqrt}(\mathrm{area}) - 12.5]$$

$$N = [\mathrm{Log}(1-0.95)] / [\mathrm{Log}(1-\mathrm{prop})]$$

Where N is the suggested number of sampling points, “area” is the area of the site given in ha and “prop” is the proportion of the site which is supposed to be contaminated. If more than one sample per sampling point is required the user may use an estimated number of samples per sampling point (i.e., a certain number of samples per drilling). However, it should be noted that the approaches to calculate the number of samples are mainly supposed to guide the user estimating the required number of samples and thus

costs. The actual number of samples necessary to characterize the pollution may largely depend on the very local settings at a site.

Combination of methods
When all available information about the site is provided to the DSS, its output gives the "best" combination of methods that are most suitable for further investigating the given site. This combined approach consists of

- 1-3 in-situ chemical methods,
- 0-3 geophysical/geological/hydrogeological methods.

The algorithm that combines the different methods and providing a first choice, i.e., the "best combination" is based on their "suitability", time and cost in relation to the site characteristics given. In addition to the in-situ methods a list of possible lab methods is provided.

Cost calculations – geochemical methods
When interpreting the formulas for cost calculation of geochemical methods the following notions should be considered

mde_time = Mobilization/demobilization time (minutes)
s_time = Time per sample (minutes)
n_sample = Number of samples
s_cost = Cost per sample (€)
eq_cost = Cost for equipment (€)
nr_person = Number of persons needed for equipment
use_factor = Factor for number of samples needed for the method. If a suggested grid uses 80 samples/nodes a use factor of 0.3 means that $0.3 \times 80=24$ samples is needed
fieldtime = mde_time + n_sample × s_time × use_factor

Cost calculation for one geochemical method is given as a sum of (1) cost for mobilization/demobilization of equipment, (2) sample cost, (3) cost for rental of equipment and (4) cost for people working at the site:

Cost for one geochemical method =
mde_time × cost of staff +
n_sample × use_factor × s_cost +
fieldtime × eq_cost × 0.01 +
nr_person × n_sample × s_time × use_factor × cost of staff

and

Total fieldtime (h) = maximum of individual fieldtimes
Total cost = Sum of individual costs

Cost calculations – hydrogeological/geological/geophysical methods

When interpreting the formulas for cost calculation of non-geochemical methods (i.e. geological/hydrogeological/geophysical methods) the following notions should be considered

mde_time = Mobilization/demobilization time (hours)
eq_cost = Cost for equipment (€)
nr_person = Persons needed for equipment
interpret = Factor of area_time for interpreting the geophysical data
area_time = Time (h) to investigate 1 ha
fieldtime = mde_time + area_time × area
cost_method = cost for one geological/hydrogeological or geophysical method
cost_depth = cost for one geological/hydrogeological or geophysical method where depth is considered

Cost calculation for one non-geochemical method (i.e. hydrogeology/geology/geophysics) is given as a sum of (1) cost for people working at the site (including mobilization/demobilization of equipment), (2) cost for rental of equipment and (3) cost interpretation of data:

cost_method =
fieldtime × nr_person × cost of staff +
eq_cost × 0.01 × fieldtime +
area_time × area × interpret × cost of staff

Most of the geological and hydrogeological methods (e.g. drilling) have been given a depth relation for the cost calculation. This means that the calculated cost for one method according to the formula described above is used as:

cost_depth = cost_method × depth

Total fieldtime (h) = sum of individual fieldtimes
Total cost = Sum of individual costs

Tables within the DSS
The performance of the DSS is based on the following tables:

- Table 1: Guideline values for contaminants in different European countries with reference to further land use and other aspects,
- Table 2: Activities (the use of a site) and corresponding contamination profiles (i.e., groups of contaminants),
- Table 3: Geochemical methods and corresponding contaminants to be looked for including “suitability” and ability to deal with contaminants in-situ,
- Table 4: The suitability of “other” in situ methods (geophysical, geological, hydrogeological and biogeochemical ones) for different site characteristics,
- Table 6: Restrictions for different methods.

3.2 Rearranging and updating of delivered tables

To a large extent, contaminants in the tables had different names and abbreviations. A part in the preparation of data was to establish a table with common codes for all contaminants involved in Tables 1, 2, and 3.

Table 2 with lists of activities and corresponding contaminants is largely based on the ISO 9002 standard. However, some activities have been removed while others have been added. In addition, contamination profiles have been slightly altered.

Table 4 is based on the “suitability” attribute of the methods, which has four levels A, B, C and D. Level A is ranked highest, i.e., a method with rank A is optimal for a given task. The ranking is used in the combination exercise where the best combination of methods is selected. Other table information, e.g., data on the method’s ability to work in-situ act as a switch, i.e., a selected method may be used in situ or not. A separate lexicon table with cost attributes provides the input for the cost calculations.

The methods are handled by their suitability to deal with various depth intervals. Every geophysical and hydro-/geological method has a suitability rank (A, B, C or D) for the depth intervals of 0-0.5, 0.5-5, 5-20, >20 m. The user has to select a depth interval, on which the investigation mainly concentrates. In addition, the selected depth interval of the investigation affects the costs of most of the hydro-/geological methods.

Table 6. Restrictions: Owing to specific characteristics of the investigation techniques, almost every method has certain limitations in their practical application. Therefore, all methods are ranked on four levels in respect to certain site-specific restrictions, i.e., the type of restriction due to the infrastructure at a site. The information is compiled in a separate table, which is also the base for the input-request from the user.

3.3 Software development

The software is based on Access and Visual Basic. The tables described above are used by Access in connection with Visual basic to make applications. The structure of the tables and the relation between them is given in appendix 3. The advantage using the named software is the possibility to create a run-time module that allows the software to be installed and to run on any personal computer that operates under the Windows operating system.

3.4 Site investigation strategy

Guidance for studying a site is provided by the site investigation strategy (SIS). The SIS contains an extended checklist for the user that is more accustomed with site investigations as well as some more extended paper plus appendices that aim on persons not that familiar with the investigation of contaminated sites. The SIS even describes strategies on desktop studies, risk assessment, remediation, and quality assurance (see Appendix 4).

4 Description of the software interface

The NORISC software package allows to enter the decision support system (DSS) on methods to investigate contaminated sites or the investigation strategy, and supports a specific site investigation (Figure 1). The DSS requires input on different levels, e.g., the number of samples given by the user or calculated by the DSS, and the area of a site and the hourly rate for staff (Figure 2). The site investigation strategy will provide some guidance about the required amount of samples. The selection of a target depth interval influences geological/hydrogeological and geophysical methods with respect to suitability and cost.

Input of geochemical site characteristics provides methods as output. A contamination profile (Figure 3) is selected from a list (selected from Table 2). The selected contamination profile gives a number of contaminants according to Table 2. However, the user may select other individual contaminants if a more site-specific group of contaminants is requested. The selected group of contaminants is compared with the table of geochemical methods (Table 3) which provides the methods that are able to deal with the specific contaminants. Methods will be named to investigate soil, groundwater and soil gas.

The detection limits of methods can be compared with those values of the guideline that are selected by the user. Guideline values can be visualised by selecting a certain country and a certain purpose of land use (Table 1) or by manually defining site-specific values. The latter option means that the user has to estimate site-specific guideline values. The guideline values should be compared with detection limits of the methods.

Geological/hydrogeological site characteristics as well as man-made underground objects are considered in another input frame (Figure 4). An important point within this part is that the user provides information on known site characteristics. Guidance on which site characteristics are appropriate to measure is given in the site investigation strategy. Unknown characteristics of a site that are essential to be investigated will be looked for in Table 4 (Geological / hydrogeological characteristics and methods) and the most appropriate methods to study the relevant characteristics will be recommended.

Possible restrictions when investigating a site, such as underground features like cables or buildings are requested as input from the user (Figure 5). This input will be used to automatically exclude methods because of these restrictions.

The output from the DSS for investigating a contaminated site is given in different Excel sheets on

- Suggested combinations of methods,
- All possible geochemical methods for the selected media,
- Detection limits for selected geochemical methods,
- All possible laboratory methods for the selected media,

- All possible geological/hydrogeological and geophysical methods for the selected site characteristics,
- Selected parameters i.e. all selected data in the input part of the software,
- Surveying and locating: general information including surveying, positioning and locating,
- Description of site characteristics ,
- Description of geochemical methods,
- Description of other methods (i.e. geological/hydrogeological and geophysical methods).

The output can be interpreted together with information given in the document about the site investigation strategy (see Appendix 4).

5 Appendices

Appendix 1: Figures showing the user interface of the software.

Appendix 2: Structure of the database.

Appendix 3: Description of tables.

Appendix 4: Guidance on Site Investigation Strategy and desktop study. (See separate)

Appendix 5: User's guide to the decision support system on site investigation methods in NORISC. (See separate)

Appendix 1. Figures.

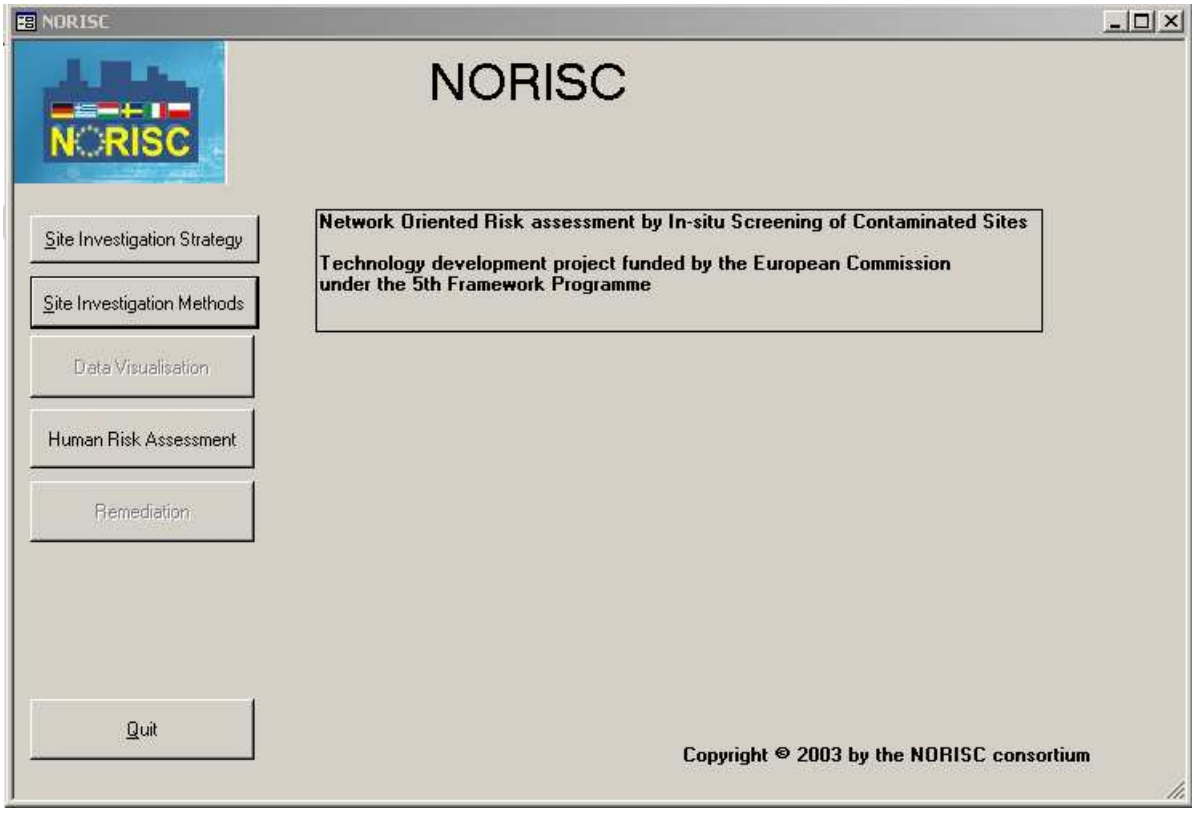


Figure 1. The guideline starts with the selection between different modules of NORISC.

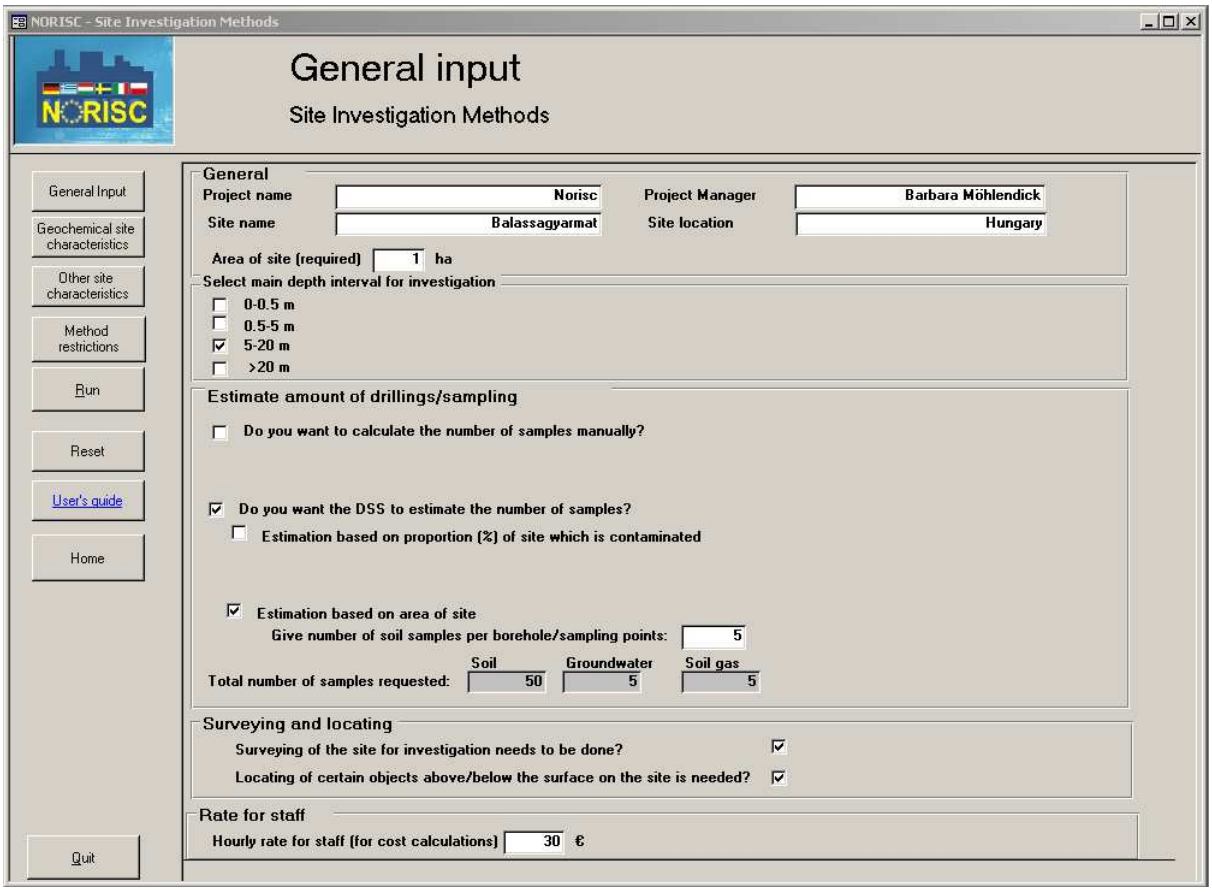


Figure 2. Input of number of samples, area of site, main depth interval to be investigated and hourly rate for staff. The input of samples can be estimated manually or calculated by the DSS. The area of the site is used for geophysical cost calculations and, if required, to estimate the number of samples. The main depth interval influences geological/hydrogeological and geophysical methods with respect to suitability and cost.

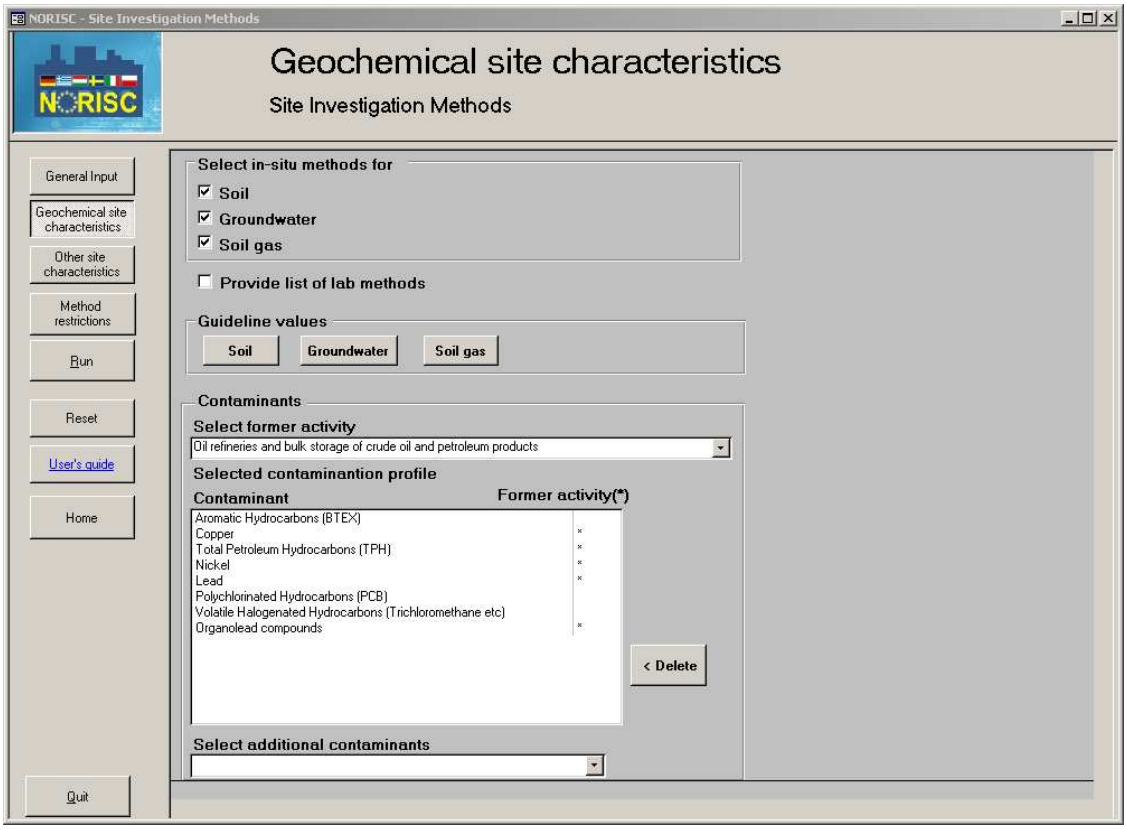


Figure 3. Geochemical site characteristics. Methods for surveying soil, groundwater and soil gas can be selected. Guideline values for contaminants in European countries can be visualised. Input of the former activity at a site generates a specific contamination profile.

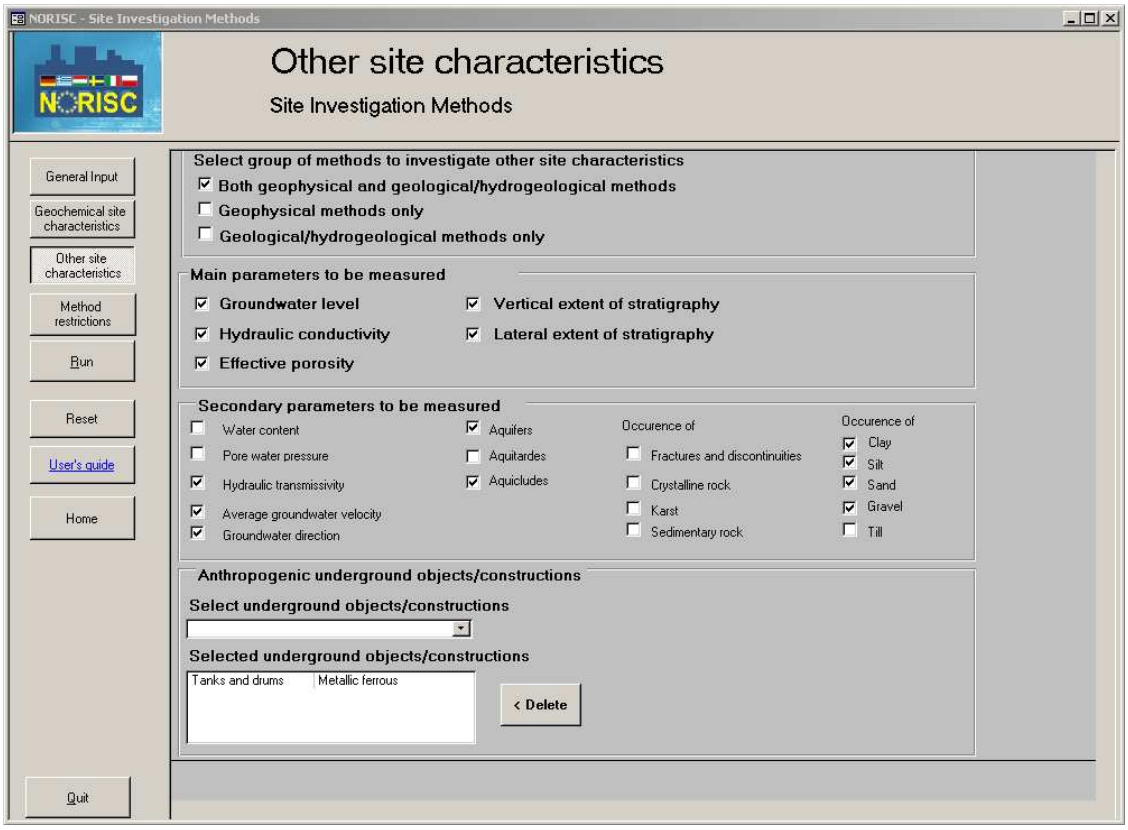


Figure 4. Input of requested “other” site characteristics. It is possible to select either geophysical or hydro-/geological methods or a combination of both.

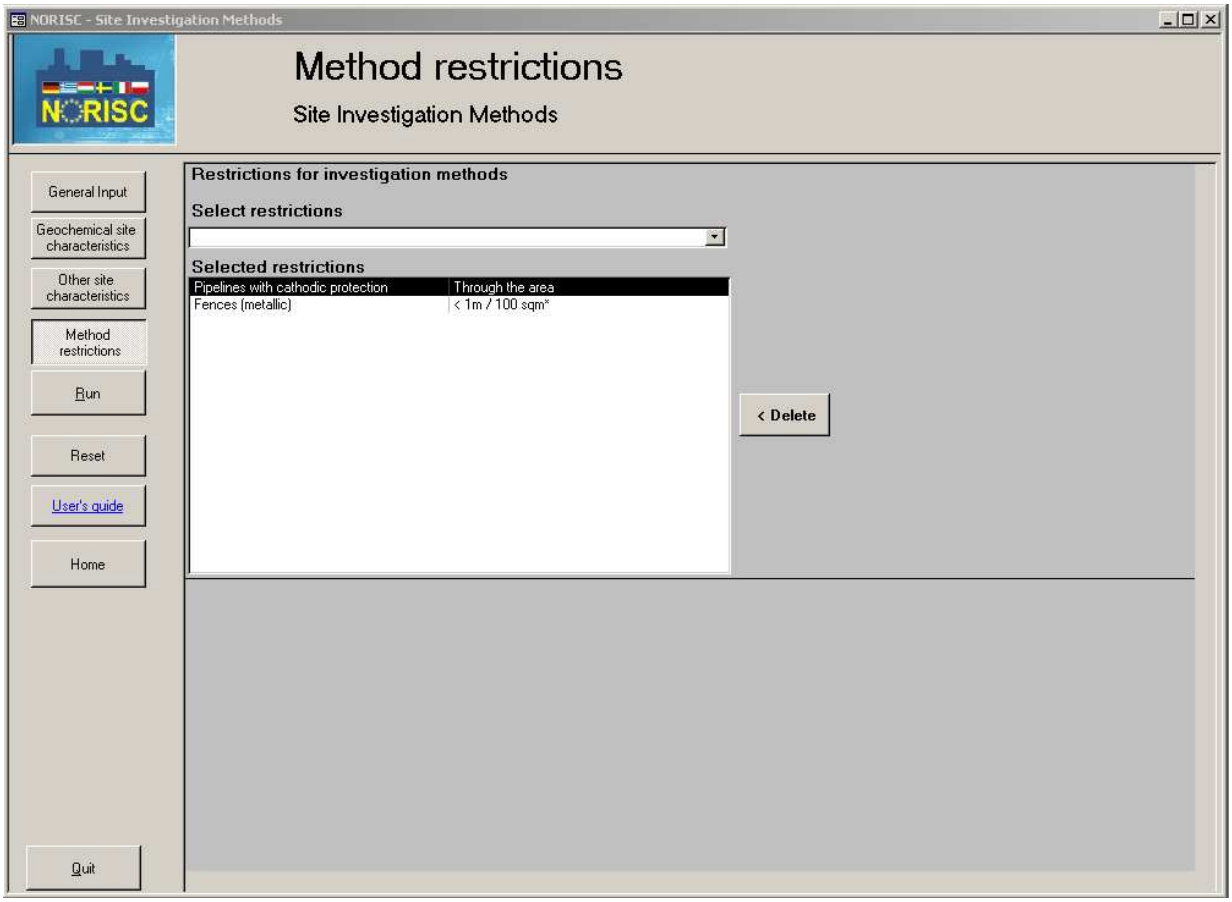
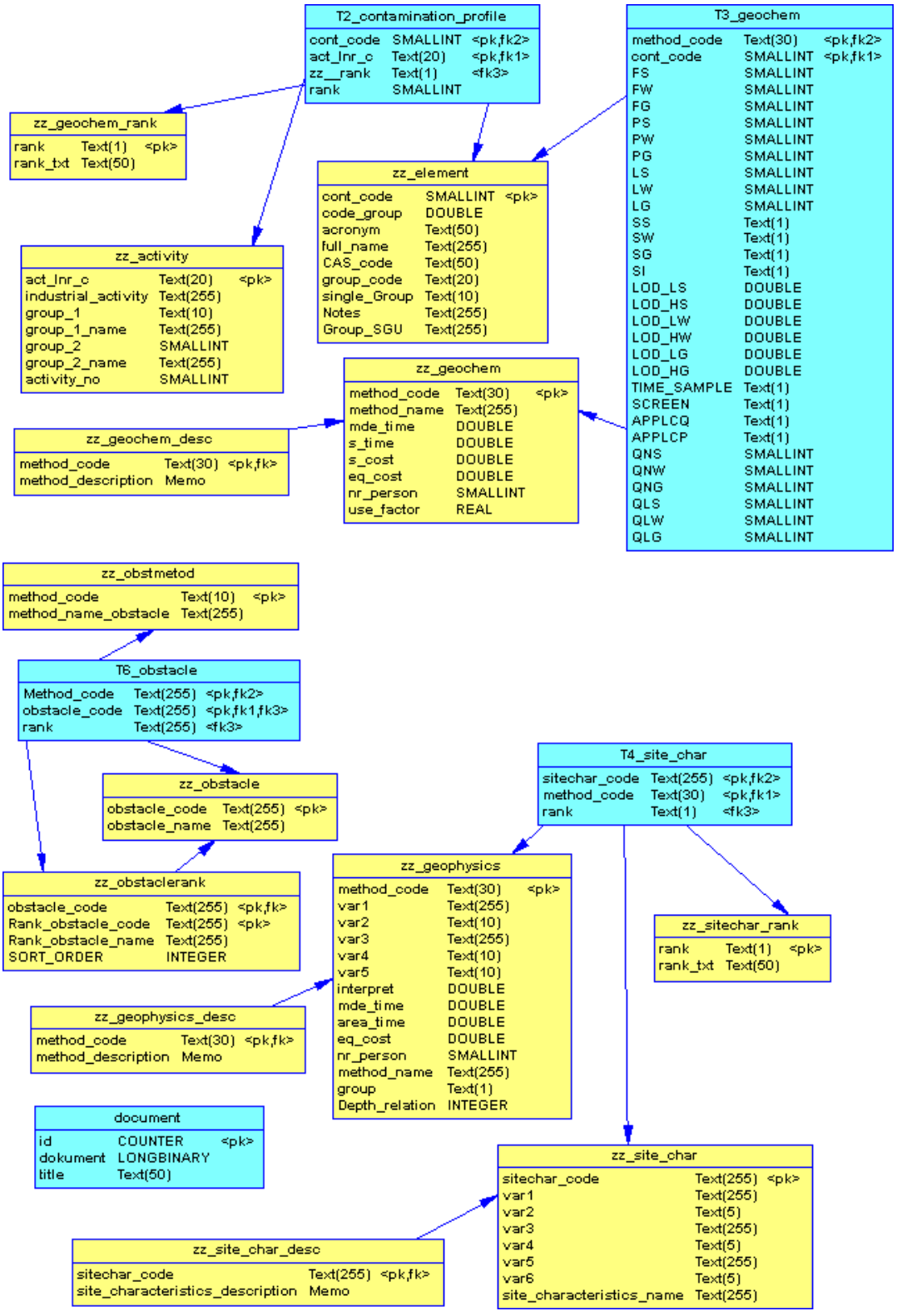


Figure 5. Input of known restrictions at a site that may affect the investigations of certain methods.

Appendix 2. Structure of the database.



Appendix 3: Overview on description of the tables and the most important columns in each table.

Lexicon tables referring to table 1 – 3:

1. Contaminant code.
2. Contaminant name.

Tables referring to Table 1 (Guideline values):

Guideline values (three separate tables for soil, groundwater and soil gas):
1. Contaminant code.
2. Value. The given guideline value or background value etc.
3. Code of country and the reason for the “Value”. Description: For example Italy has been designated two codes I_01 and I_02 thereby indicating Italy-land use: "Residential and for green park utilisation sites” and "Commercial utilisation and industrial utilisation sites”, respectively.

Lexicon table:

Land use codes:
1. Country. Description: Name of country.
2. Threshold group. Description: Threshold group such as “Land use” or “Risk classification”.
3. Threshold criterion. Description: Criterion for the threshold value such as “sensitive use” or “less sensitive use”.
4. Code of country and the reason for the “Value” . Description: For example Italy has been designated two codes I_01 and I_02 thereby indicating Italy-land use: "Residential and for green park utilisation sites” and "Commercial utilisation and industrial utilisation sites”, respectively.

Tables referring to Table 2 (Contamination profile):

Table with activities and corresponding contaminants:
1. Activity code. Sequential code for activity.
2. Contaminant code. Code for the contaminant.

Lexicon table:
1. Activity code. Sequential code for activity.
2. Activity name. Name of activity.

Tables referring to Table 3 (Geochemical methods):
1. Method code. Sequential code for method.
2. Contaminant code. Code for the contaminant.

3. Suitability. A rank code indicating the suitability of the method to deal with a certain site characteristic. A = High level of suitability, B = Medium level of suitability, C = Low level of suitability and D = Not suitable at all.
4. Field (Y/N) Indicates if the method is applicable for in-situ measurements.
5. Portable lab (Y/N) indicates if the method is applicable for measurements with portable laboratory equipment.
6. Lab (Y/N) indicates if the method is applicable for laboratory measurements.
7. Detection limit (Num).
8. Cost data. Several columns with cost data.

Lexicon table:
1. Method code. Sequential code for method (Table 3).
2. Method name. Name of method.
3. Method description. Description of method.
4. Cost data. Several columns with cost data.

Tables referring to Table 4 (Hydrogeological methods):
1. Method code. Sequential code for method.
2. Site characteristic. Name of the site characteristic to be investigated.
3. Suitability. A rank code indicating the suitability of the method to deal with a certain site characteristic: A = High level of suitability, B = Medium level of suitability, C = Low level of suitability and D = Not suitable at all.

Lexicon tables:
1. Method code. Sequential code for method (Table 4).
2. Method name. Name of method.
3. Method description. Description of method.
4. Cost data. Several columns with cost data.

1. Site characteristic code. Sequential code for method (Table 4)
2. Site characteristic name. Name of method.
3. Site characteristic description. Description of site characteristic.

Table referring to Table 6 (Restrictions):
1. Restriction code. Sequential code for restriction.
2. Method code. Sequential code for method (Table 4).
3. Rank code. A restriction specific rank with four levels.

Lexicon table for restriction code:
1. Restriction code. Sequential code for restriction.
2. Restriction name. Name of restriction.

Lexicon table for restriction ranking:
1. Restriction code. Sequential code for restriction.
2. Rank code. A restriction specific rank with four levels.
3. Rank name. Explanation to the rank code.