The development of a data structure for the storage of preliminary site investigation data

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Abstract: The investigation of a contaminated site requires both the collection of qualitative information and quantitative data, which then need to be evaluated and assessed in terms of the effect on the environment, human health, construction materials and other sensitive targets. Hence, multi-stage investigations are usually undertaken on potentially contaminated sites to provide data for the risk assessment process. Addressing the complex parameters involved in the risk assessment process comprehensively and successfully requires expertise and knowledge from a number of disciplines ranging from geotechnical engineers to chemists. To assist with this process at the preliminary stage of the investigation, a prototype knowledge-based system (ATTIC: Assessment Tool for The Investigation of Contaminated Land) and database have been developed to capture the wealth of knowledge required and enforce a structured approach to the investigation.

This paper describes the development of the database component of the system which allows the storage of preliminary site investigation data. The design process and the implementation of the data structure are discussed. The data structure developed has the ability to store all aspects of preliminary site investigation information, ranging from historical data relating to the site to data relating to vegetation and fauna. Details of the database tables with examples are also presented within the paper. The data structure was implemented using Microsoft Access Relational Database Management System.

With the preliminary investigation data stored in such a manner it also allows data to be passed to other software, hence making data available for the knowledge-based system, to use within its rules.

Résumé: L'examen d'un site contaminé exige à la fois la collection d'information qualitative et de données quantitatives, qui doivent être évaluées en termes des effets sur l'environnement, la santé humaine, les matéraux de construction et d'autres facteurs sensibles. De ce fait, les examens sur les sites potentiellement contaminé sont d'habitude entrepris en plusieures étapes pour fournir des données pour le procédé d'évaluation de risque. Traiter correctement et completement les paramètres complexes impliqué dans le processus d'évaluation de risque exige une expertise et des connaissances dans plusieurs disciplines couvrant de l'ingénierie geotechnique à la chimie. Pour aider avec ce processus à l'étape préliminaire de l'examen, un prototype d'un système à base de connaissances (ATTIC : l'Outil d'Evaluation pour L'Examen de Terre Contaminé) et de sa base de données a été développé pour capturer la richesse de connaissances exigées et appliquer une approche structurée à l'examen.

Cet article décrit le développement de la base de données du système qui permet l'emmagasinage des données d'examen de site préliminaires. La conception et l'implémentation de la structure de la base de données sont discutés. La structure développée a la capacité d'emmagasiner tous les aspects des informations d'examen de site préliminaire, depuis les données historiques sur le site, jusqu'aux données lies à la végétation et la faune. Les détails sur la base de données et des exemples sont aussi présentés dans l'article. La structure de la base de données a été construite avec Microsoft Access, un système de gestion de données relationel.

Avec les données préliminaires d'examen emmagasinées de cette manière, les données peuvent aussi être transferées à d'autre logiciels, mettant ainsi ces données à disposition du système à base de connaissance, pour l'application de ses règles.

Keywords: contaminated land, site investigation, geoenvironmental engineering, database systems.

INTRODUCTION

It is widely recognized that due to the hazardous nature of the redevelopment of contaminated land, it is essential that the investigation is undertaken in a number of stages (preliminary, exploratory, detailed investigation and an investigation for compliance and performance if required) and that each stage of the investigation is revised as more information becomes available. The qualitative information (site use, past use, etc.) and quantitative data (ground conditions, contaminant concentrations, etc.) collected during these stages of the investigation provide information for the risk assessment process. The risk assessment process highlights factors such as hazards to end users, site workers and the local environment. It also gives an indication to the size and cost of reclamation programme required. The basic data blocks for the risk assessment process consist of: definition of contaminants on site, identification of possible pathways for the movement of contaminants and location of vulnerable targets on and off site. Hence, as more information regarding the site becomes available the risk posed by the site can be minimised. Addressing the complex parameters involved in the risk assessment process comprehensively and successfully requires expertise and knowledge from a number of disciplines, ranging from geotechnical engineers to chemists.

A prototype knowledge-based system (ATTIC: Assessment Tool for The Investigation of Contaminated land) and database have been developed to assist with this process at the preliminary stage of investigation. The system has been developed, using CLIPS software, consisting of four knowledge-bases (source, pathway, target and health & safety knowledge-base). The knowledge within the system was obtained from two main sources. The initial and main source being technical literature and the second from domain experts via a knowledge elicitation exercise. Details of the knowledge elicitation exercise are given by Martin (2001).

The system assesses information collected during the preliminary stage of the investigation and assists with the risk assessment process, with the prediction of potential contaminants, hazards and risk to neighbouring areas. In order to store facts required by the system to produce the results for the risk assessment process a database was also compiled in conjunction with the knowledge-based system. The need to design a database to store preliminary investigation data was an important part of the development, as this would allow the end user to store such data independent of the knowledge-based system.

DATABASE DESIGN

A database provides a useful tool for the manipulation of large volumes of data. This therefore fits well with the needs of storing preliminary investigation data. However, to achieve this, it was essential that a clear plan was developed from the onset of the design process. To develop this plan involved examining a number of factors; these include;

- Understanding the purpose of the database
- Assessing the type and volume of data to be stored
- Selecting an appropriate database model and hence designing a data structure which fits the requirement of the data to be stored
- Choosing development software that allows the data structure to be implemented in a logical manner
- Considering the best procedures for data input, including the design of a suitable user interface

Failure to consider such points is likely to result in poor storage and therefore creating problems with processing and data access, which in turn reduces the processing speed and counteracts the main advantage of using database technology.

The Purpose of the Database

In order to achieve a well structured database it was important that all the requirements of the database system were identified at the start of database design. The main requirements of the proposed system were outlined as;

- Preliminary Investigation data storage
  Data to be stored will essentially be preliminary investigation information (past use, geological maps, hydrological maps, abiotic and biotic indicators. Enforcing a structured approach to data input encourages the user to undertake a full and structured preliminary investigation (this includes both desk study and site reconnaissance).
- AGS format
  A similar structure and format to that used for the AGS (1994) data transfer format. This allows data to be placed into groups within the structure and uses key fields to identify each group. It allows links to be forged between existing AGS tables and newly designed preliminary investigation data tables. This also makes data available for transfer between parties involved in projects relating to the redevelopment of contaminated land.
- Data Input
  Data input via a user friendly interface within a Windows environment, thus allowing data to be input by non-computer experts. The data entry should also be either using a network system (multi-user platform) or via a single stand alone personal computer.
- Allow links to knowledge-based system
  The data within the database needs to be accessible for the knowledge-based system to use. Therefore it is important to allow the user to input data either by direct entry into the knowledge-based system or via the database for the knowledge-based system to use at a later date.
- Data manipulation
  Data should be available for use with other packages that the user may require. Other packages may include GIS packages (e.g. ArcView) or other commercial geotechnical packages.

Implementation

A “top-down” approach (Malenke, 1991) to design and implementation was adopted. The "top-down" approach starts with more general requirements for the database and gets progressively more detailed as the final design is reached. By contrast the "bottom-up" approach starts detailed and develops towards a more general concept or design. For the purpose of this design process a "top-down" approach was found to be the best solution, as it seemed logical to highlight the main areas that needed to be considered for storage, and to work down through the subject areas, pin-pointing the detailed areas that required consideration. In contrast, the “bottom-up” approach may result in some subject areas being overlooked, especially if the detailed level has not been fully completed.

The first stages in the implementation involved defining the data entities to be stored in the final data structure. The entities were selected using technical literature (Department of the Environment (1994a-e), (1995), BS10175 (2001), Harris, Herbert & Smith (1995), Barry (1991), Young, Pollard & Crowcroft (1997)). The entities consist of general types of data that need to be dealt within the database, such as geology, topography etc.

On completion of identification of the relevant entities their inter-relationships and attributes were identified. An Entity-Relationships, E-R, diagram was constructed, allowing the relationships between entities to be clearly defined. The entities typically have "one-to-many" relationships that is, one record in an entity could possibly relate or join with many records in another entity. For example, entities known as project and site were identified. The site entity contained information relating to the area under investigation; such information included site address, owner etc. The project entity contained data regarding project name, project client etc., therefore it was concluded that within a large project there may be a number of sites. Hence project can have a one-to-many relationship with site. This process also helped to eliminate undesirable relationships that may occur. These included many-to-many relationships; in this case one of the entities was decomposed into two entities. This resulted in two of the entities showing a "one-to-many" relationship with the new entity.

After the entity relationships had been established the attributes (properties possessed by an entity) were identified. A normalisation process was undertaken in order to identify individual tables from the entities and reduce the level of duplication and redundancy to a minimum. This led to each entity being translated into an individual table, although, in certain cases, entities were broken into two or more tables, depending on how general the entities were. For example, an entity known as "hydrology" was initially identified. On examination it became apparent that this was too general and therefore was split into tables "groundwater" and "surface water".

Once individual tables had been derived from the entities, fields within the tables were identified along with referential keys required to link the tables. The referential key consists of a single or multiple field that uniquely identifies that table.

Data Structure

From the technical literature regarding site investigation of contaminated land, it was clear that there were a number of subject areas that are usually taken into consideration. These areas are: topography, geology, hydrology, services, geography, history, fauna, meteorology and vegetation. The identification of these areas made it possible to split the subject areas further and form a relational data structure, with such a data structure allowing the storage of preliminary information in an electronic format.

An outline schema for the database is shown in Figure 1. The boxes represent tables within the relational database structure. The tables within the structure are data groups that represent the parameters required for the preliminary investigation. The structure allows potentially large volumes of data to be retrieved, searched and handled in an effective manner. The names of the tables have been adopted to be compatible with the AGS format. A full list of the database tables is given in Table 1. The details of all the database tables are outlined in Martin (2001).

Table 1. Legend for Database Structure

Legend	Table Name
PROJ	Project
SITE	Site
ZONE	Zone
PREL	Preliminary Investigation
VEGE	Vegetation - General
FAUA	Fauna – General
SERV	Services – General
SURW	Surface Water – General
GEOL	Geology – General
STFT	Geology Structural Features
HIST	History – General

Legend	Table Name
GRDW	Groundwater
TOPO	Topography
GEOG	Geography
METE	Meteorological
VEDT	Vegetation - Detail
FADT	Fauna - Detail
SEDT	Services - Detail
SUDR	Surface Water Drainage
SUST	Surface Water Storage
GEDT	Geology - Detail
HIDT	History - Detail

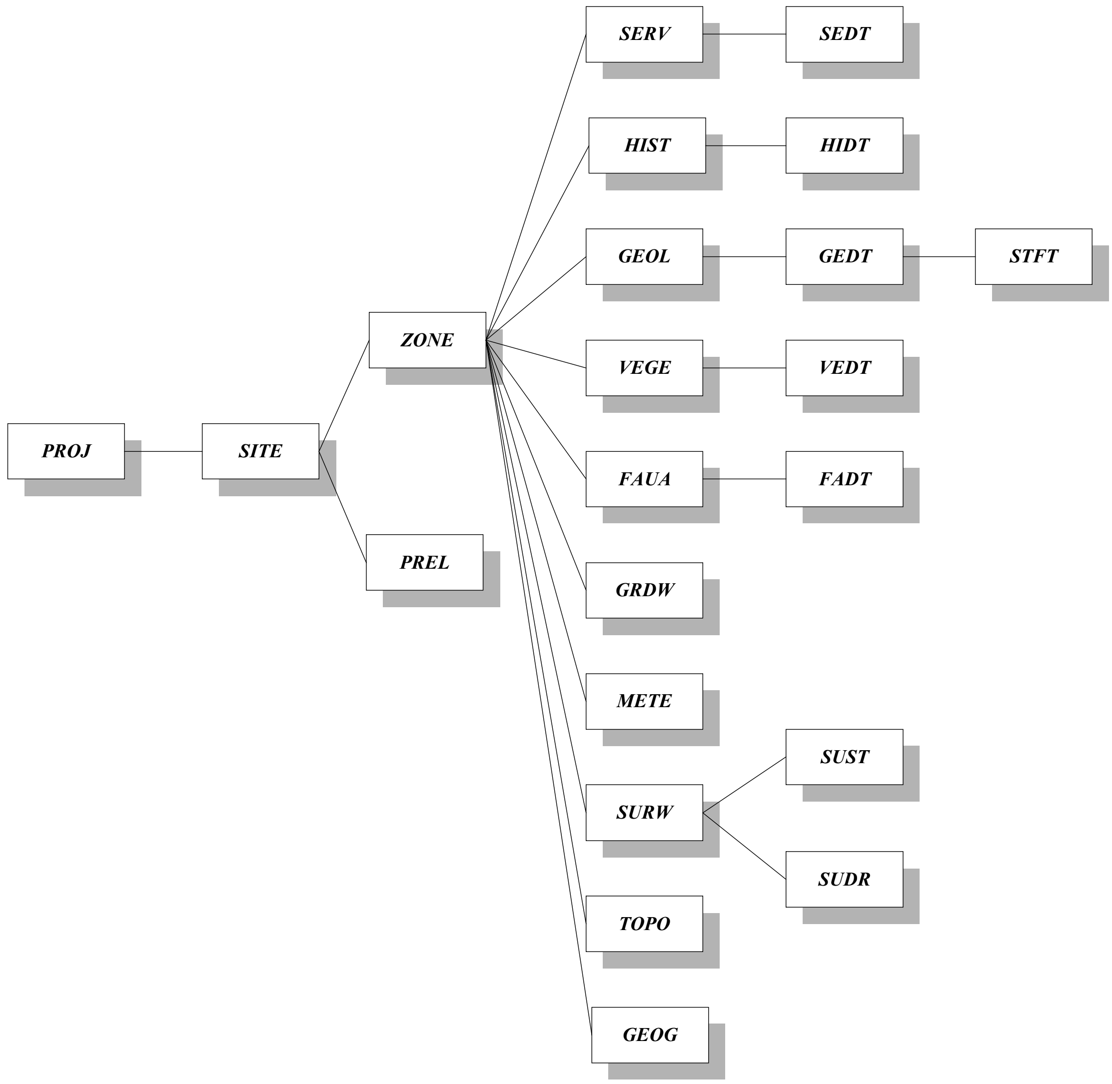

Figure 1. Schema for Database. (see Table 1 for Legend)

There are six identifiable levels within the structure, with the top-level table being the project table. This is one of the original AGS format tables; it contains information on the location and date of the project and the parties involved (The table only shows some of the possible fields and does not show new fields introduced in AGS version 3.1 (www,ags.org.uk).). Each project will therefore have its own table, which is identified by a *Project ID* key (Table 2). Using this table also allows the preliminary investigation information to be linked to the ground investigation data, as both types of data could be assigned to the same project table.

Table 2. Project Table

PROJ	
Field Name	**Field Description**
PROJ_ID	Project Identifier
PROJ_NAME	Project Title
PROJ_LOC	Location
PROJ_CLNT	Client Name
PROJ_CONT	Contractors Name
PROJ_ENG	Project Engineer
PROJ_REM	General Remarks
PROJ_DATE	Date of Production of Data
PROJ_AGS	AGS Issue Number

The next level down contains a site table (Table 3). This is a departure from the AGS format.

Table 3. Site Table

SITE	
Field Name	**Field Description**
PROJ_ID	Project Identifier
SITE_ID	Site Identifier
SITE_NAM	Site Name
SITE_ADD1	Site Address (line 1)
SITE_ADD2	Site Address (line 2)
SITE_CITY	Site City
SITE_CONT	Site County
SITE_COTR	Site Country
SITE_CORT	Type of Co-ordinates
SITE_XCOR	X-Co-ordinates
SITE_YCOR	Y-Co-ordinates
SITE_AREA	Area Site Covers
SITE_CUOW	Current Owner
SITE_ADAU	Administration Authority
SITE_PLRS	Planning Restrictions
SITE_ACBY	Accessibility
SITE_ACPT	Access Points to Site
SITE_REM	Remarks

The site table allows storage of the location of the site, including a full postal address and co-ordinates of the site, along with general information such as current ownership, accessibility and planning restrictions. Having information regarding accessibility is extremely useful at the preliminary investigation stage, as it allows the investigator to gain an understanding of how equipment (drilling rigs etc.) may be bought on to site. Planning restrictions can often play an important role in deciding investigation and construction methods; therefore having such knowledge early in the project is vital. For example, Regional Important Geological Sites (RIGS), often prevent shotcrete being used on rock slopes. Therefore on such sites, an appropriate alternative must be decided early in the project. This type of table becomes particularly useful on major development projects where there are a number of sites within a project. An example of this may be a major road development project. One site may be involved in the construction of an underpass and another involved in the construction of a bridge. Both constructions are part of the same project but on different sites, therefore highlighting the need for the site table.

The level below the site table splits into two further tables, preliminary investigation table and a zone table. The preliminary investigation table is linked directly to the site table, with the *SITE_ID* key. This table contains information regarding the details of the desk study and site reconnaissance. The data stored includes the date the preliminary investigation was undertaken, the engineer responsible and any remarks relating to the investigation.

At the same level as the preliminary investigation table, a zone table (Table 4) is linked to the site table. This allows a site to be divided into various sub-areas (zones), with the principle that zones are selected to reflect changes within the site. For example, a zone may be identified due to a change in land use (historical or current), which may give rise to distinct ground contamination changes. A change in the subsurface ground conditions may also warrant identification of another zone. Besides physical conditions, zones may also be identified to represent different components of a redevelopment project. For example, one zone may be used to represent the construction of an embankment, another for the foundations of a building. Therefore, the zoning system plays a useful role in the investigation process. If varying zones have been identified during the preliminary investigation the investigator may select an appropriate ground investigation technique to suit the zone.

Table 4. Zone Table

ZONE	
Field Name	**Field Description**
PROJ_ID	Project Identifier
SITE_ID	Site Identifier
ZONE_ID	Zone Identifier
ZONE_RESN	Reason for Zone
ZONE_AREA	Area of Zone
ZONE_COR1	Co-ordinate of Zone
ZONE_COR2	Co-ordinate of Zone
ZONE_COR3	Co-ordinate of Zone
ZONE_COR4	Co-ordinate of Zone
ZONE_COR5	Co-ordinate of Zone
ZONE_REM	Remarks

In order to represent this concept, the zone table contains co-ordinates of the zone and the reason for its selection. The co-ordinates of the zone relate to a polygon shape made up of a number of nodes, representing the geographical area of the zone. Further coordinates could be added to provide more complex zone shapes. It is also important to note that the number of zones within a site is unlimited, as each one has its own identifier which can be linked back to the site table. The zoning system also allows zones to inherit properties from the zone it is within.

The fourth level consists of the ten main parameters, derived from the nine subject areas highlighted earlier, the parameters are namely: geology, topography, geography, groundwater, surface water, history, services information, vegetation, fauna, and meteorological data. These tables are linked to the zone table by the *ZONE_ID* key, and each table has its own unique identifier. Each zone can also have as many general tables linked to it as required.

The information contained within these tables is likely to be general information. For example the history table (Table 5) contains information such as archaeological interest, evidence of subsidence or evidence of seismic activity. The more detailed information regarding the history is stored in the next level down.

Table 5. History Table

HIST	
Field Name	**Field Description**
PROJ_ID	Project Identifier
ZONE_ID	Zone Identifier
HIST_ID	History General Identifier
HIST_ARCH	Archaeological Interest
HIST_REMA	Archaeological Interest Remarks
HIST_SUBS	Evidence of Subsidence
HIST_REMS	Remarks regarding Subsidence
HIST_EVSA	Evidence of Seismic Activity
HIST_REMSA	Remarks regarding Seismic Activity
HIST_SOIF	Source of Information
HIST_REM	Remarks

The fifth level of the data structure contains detailed information regarding five main subject tables in the above level (vegetation, fauna, services, geology and history), and for this reason are known as detail tables. Again each detail table has been assigned a unique identifier. In the case of the history detail table *HIDT_ID* (Table 6), this allows the general table to have connections to as many entries within the detail table as required. Therefore, in the case of the history, most areas (zone) being investigated are likely to have a number of past uses, which can be represented by assigning a history detail table entry to each use.

Table 6. History Detail Table

HIDT	
Field Name	**Field Description**
PROJ_ID	Project Identifier
ZONE_ID	Zone Identifier
HIST_ID	History General Identifier
HIDT_ID	History Detail Identifier
HIDT_NAME	Name of Owner
HIDT_USE	Previous Use
HIDT_FEAT	Features Associated with Use
HIDT_STAT	Start Date of Use
HIDT_FINS	Finish Date of Use
HIDT_DURT	Duration of Use
HIDT_LVOD	Level Above Ordnance Datum
HIDT_SOIF	Source of Information
HIDT_REM	Remarks

For example, one history detail table entry may contain information regarding a gas works that relates to the early history of the area. Another detail table entry relating to the same area, may contain information about a steelworks that relates to the later history of the area. Therefore the type of information stored within the history detail table includes; past use (this plays an important role in identifying contaminants associated with site use), start and finish for this site use (this allows a judgment to be made on how long contaminants may have been on site) and features associated with past uses, (this allows the system to identify hazards associated with such features), and level above ordnance datum (which can indicate whether the area has been infilled or excavated since the land use described).

Also among the detail tables at this level is the geology detail table (Table 7). This table contains any data regarding subsurface material, including information concerned with made ground, superficial geology or bedrock geology. This again allows the zones to have as many geology types as required. For example, within a zone where there are three distinct layers of material, e.g. layer one: made ground, layer two: Coal measures and layer three: Sandstone, each layer would be assigned an entry in the detail geology table. Within each table, details of the type and age of material, depth to top of layer, main characteristics and source of information are stored. The information stored within this table allows the investigator to have an understanding of the geology located within the area under investigation. This in turn allows permeabilities to be assigned to different types of geology and also allows judgments to be made regarding possible movement of contamination through the different types of geology.

It is also important to note that the stratum descriptions table within the AGS format is given the group name GEOL. This is obviously the same name as has been assigned to the geology general table described in this chapter. However, this is not seen as a problem, due to the fact that the IDs for each table do not conflict. The stratum descriptions table sits below the hole table within the AGS format, which relates to individual boreholes from exploration investigations. This means that key fields within this table are *HOLE_ID*, *GEOL_TOP* and *GEOL_BASE*. In the preliminary investigation data structure the key fields for the geology general table are; *PROJ_ID*, *ZONE_ID* and *GEOL_ID*. This means that if the AGS format is used in conjunction with the format detailed within this chapter, the two tables can sit within different levels of the data structure and not conflict.

Table 7. Geology Detail Table

GEDT	
Field Name	**Field Description**
PROJ_ID	Project Identifier
ZONE_ID	Zone Identifier
GEOL_ID	Geology General Identifier
GEDT_ID	Geology Detail Identifier
GEDT_DESC	Stratum Description
GEDT_LYNO	Layer Number
GEDT_LYDT	Depth to Top of Layer
GEDT_LYTH	Layer Thickness
GEDT_CHAR	Characteristics
GEDT_FEPT	Features Present
GEDT_SOIF	Source of Information
GEDT_REM	Remarks

Other detail tables include the services detail table (Table 8). This table includes information regarding the type of service, responsible authority, elevation, trend of service and co-ordinates of service. The information here is vital for identifying possible pathways for contaminant movement as well as ensuring that boreholes and trial pits are not excavated at the location of services.

Table 8. Services Detail Table

SEDT	
Field Name	**Field Description**
PROJ_ID	Project Identifier
ZONE_ID	Zone Identifier
SERV_ID	Services General Identifier
SEDT_ID	Services Detail Identifier
SEDT_TYPE	Type of Service
SEDT_RSAT	Responsible Authority
SEDT_ELEV	Elevation
SEDT_TRED	Trend of Service Across Zone
SEDT_STCX	Start X-Co-ordinate of Service
SEDT_STCY	Start Y-Co-ordinate of Service
SEDT_FNCX	Finish X-Co-ordinate of Service
SEDT_FNCY	Finish Y-Co-ordinate of Service
SEDT_SOIF	Source of Information
SEDT_REM	Remarks

The other two tables at this level include the vegetation detail table (Table 9) and the fauna detail table (Table 10).

Table 9. Vegetation Detail Table

VEDT	
Field Name	**Field Description**
PROJ_ID	Project Identifier
ZONE_ID	Zone Identifier
VEGE_ID	Vegetation General Identifier
VEDT_ID	Vegetation Detail Identifier
VEDT_TYPE	Type of Vegetation
VEDT_HATH	General Health of Vegetation Type
VEDT_REMH	Remarks
VEDT_LEVH	Health of Leaves
VEDT_REML	Remarks
VEDT_ROTH	Health of Roots
VEDT_REMR	Remarks
VEDT_YSRG	Young Seedling Regeneration
VEDT_REMY	Remarks
VEDT_VGDB	Vegetation Die Back
VEDT_REMD	Remarks

Both tables have been compiled in order to store information that assists in identifying likely contaminants. For example, the health of certain types of vegetation, seedling regeneration and vegetation die back can be used to identify contamination within the ground. The same is also true for fauna health as well as the abundance and diversity of certain species.

Table 10. Fauna Detail Table

FADT	
Field Name	**Field Description**
PROJ_ID	Project Identifier
ZONE_ID	Zone Identifier
FAUA_ID	Fauna General Identifier
FADT_ID	Fauna Detail Identifier
FADT_SPCE	Fauna Species
FADT_HLTH	Health of Species
FADT_HEDT	Details of Health
FADT_ABNC	Abundance of Species
FADT_DIVS	Diversity of Species
FADT_REM	Remarks

The final level within the data structure is designed to store detailed information relating to the fifth level, and these are again linked by their unique identifier. The reason for this extra level is outlined in the following example; a zone may have a number of types of geology within it, one of which may be a sandstone containing a number of faults and folds. The general geological information about the zone will be contained within the fourth level of the data structure, the detailed information about the sandstone will be within the fifth level. However, a problem of storing data regarding the structure features (folds and faults) within the layer arises at this point. It is impossible to store these features within this fifth level, as the number of structural features is variable. To overcome the problem another level has been added below the fifth level with the aim of storing such features.

Table 11. Geology Structural Features Table

STFT	
Field Name	**Field Description**
PROJ_ID	Project Identifier
ZONE_ID	Zone Identifier
GEDT_ID	Geology Detail Identifier
STFT_ID	Structural Feature Identifier
STFT_TYPE	Structural Feature Type
STFT_FTDD	Dip & Direction of Feature
STFT_FTLC	Location of Feature
STFT_FTSZ	Size of Feature
STFT_SOIF	Source of Information
STFT_REM	Remarks

Within this level sits a structural features table (Table 11), which allows the storage of data regarding the type of feature and its dip and direction. Each feature is assigned an entry in the table. Therefore, within the example outlined above, one entry may detail information about a fault within the sandstone and another about a fold. This allows the geology detail table to have as many structural feature table entries linked to it as required. The information stored at this level plays an important role in identifying possible pathways for contaminant movement.

CONCLUSION

The storage of preliminary investigation data is extremely important within the area of contaminated land. Data structures have been developed for storing all aspects of preliminary site investigation information, ranging from geological data to historical data. The data structure designed also contains the ability to store data relating to vegetation and fauna, which is a major advance over other database systems. This type of data can be particularly useful in the area of contaminated land. The data structures were implemented using the Microsoft Access Relational Database Management System.

With the preliminary investigation data stored in such a manner it allows the knowledge-based system, to use the data within its rules. The benefit of having data stored independently to the knowledge-based system also means that the data can be passed to other software and hence used in different aspects of the development of a site.

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REFERENCES

AGS 1994. Electronic transfer of geotechnical data from ground investigations, Publ. AGS/Issue 07/94, Association of Geotechnical Specialists, Camberley, Surrey.

BARRY, D. 1991. Hazards in land recycling, recycling derelict land, (Ed. Fleming G.) Thomas Telford, London, 28-63.

BRITISH STANDARD BS10175. 2001. Investigation of Potentially Contaminated sites - Code of Practice, British Standard Institution, London.

DEPARTMENT OF THE ENVIRONMENT. 1994a. A framework for assessing the impact of contaminated land on groundwater and surface water, Contaminated Land Research Report No. 1, **Vol. 1**, DoE, London.

DEPARTMENT OF THE ENVIRONMENT. 1994b. A framework for assessing the impact of contaminated land on groundwater and surface water, Contaminated Land Research Report No. 1, **Vol. 2**, DoE, London.

DEPARTMENT OF THE ENVIRONMENT. 1994c. Guidance on preliminary site inspection of contaminated land, Contaminated Land Research Report No. 2, **Vol. 1**, DoE, London.

DEPARTMENT OF THE ENVIRONMENT. 1994d. Guidance on preliminary site inspection of contaminated land, Contaminated Land Research Report No. 2, **Vol. 2**, DoE, London.

DEPARTMENT OF THE ENVIRONMENT. 1994e. Sampling strategies for contaminated land, Contaminated Land Research Report No. 4, DoE, London.

DEPARTMENT OF THE ENVIRONMENT. 1995. Industry profiles 1 - 48, DoE, London.

HARRIS, M.R., HERBERT, S.M., & SMITH, M.A. 1995, Remedial treatment for contaminated land Volume III: site investigation and assessment. Special Publication 103, Construction Industry Research and Information Association, London.

MALENKE, M. 1991. Relational database design and technology. Geotechnical Engineering Congress 1991 (Eds. Mclean F.G., Campbell D.A. & Harris D.W.), Geotechnical Special Publication, **1** (2), June 10-12, Boulder, Colorado.

MARTIN, J.C. 2001. The development of a knowledge-based system for the preliminary investigation of contaminated land. Unpublished PhD Thesis, School of Engineering, University of Durham.

YOUNG, P.J., POLLARD, S. & CROWCROFT, P. 1997. Overview: context, calculating risk and using consultants, contaminated Land and its Reclamation, (Eds. Hester R.E. & Harrison R.M.), The Royal Society of Chemistry, Cambridge, 1-24.