Geotechnical & Geoenvironmental Site Investigation

Guide 11

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Frigga Kruse, M.Sc., PIFA
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What is a Site Investigation?

In *A Client's Guide to Site Investigation* the AGS (Association of Geotechnical and Geoenvironmental Specialists) states that adequate site investigation is of importance to the civil engineer for the successful completion of any building project,

> *'The design of a structure which is economical and safe to construct, is durable and has low maintenance costs, depends upon an adequate understanding of the nature of the ground. This understanding comes from an appreciation of the distribution of the materials in the ground, and their properties and behaviour under various influences and constraints during the construction and lifetime of the structure. An adequate and properly structured site investigation is therefore an essential part of any civil engineering or building project.'*

A site investigation simply is the process of the collection of information, the appraisal of data, assessment, and reporting without which the hazards in the ground beneath the site cannot be known.

What comprises a Site Investigation?

The AGS realises that,

> *'the approach adopted for a particular site investigation, its extent and the techniques used will all depend upon the site-specific circumstances, and the experience and judgment of those involved. There is no single way to carry out an investigation, and inevitably different advisors will adopt different approaches for any particular project. However, it is usual for the site investigation to be a phased exercise.'*

Figure 1: JCB excavating test pit and cable percussion rig in foreground.

For the purposes of this article, the site-specific circumstances encountered will be land-based residential, commercial and industrial developments at any scale as well as the occasional highway or pipeline project, and the experience of those involved will be my own after having worked as an engineering geologist and field archaeologist for a UK-based firm in recent years. There is no point to discuss rotary drilling and rock core in much detail as this barely affects archaeology.

No matter what the approach to a project, it invariably adheres to the BS 5930:1999 'Code of practice for site investigations' and the BS 10175:2001 'Investigation of potentially contaminated sites – Code of practice'. The approach normally involves a Phase 1 desk study and site reconnaissance that includes the collection of information from maps, published documents, utility records, anecdotal evidence, aerial photographs, and walkover surveys, to reduce the risk of unpleasant surprises during the Phase 2 intrusive ground investigation. The Phase 2 ground investigation is usually undertaken using trial pits, boreholes, penetration tests, laboratory tests, and occasionally geophysical methods. The intrusive investigation is usually followed by the production of either factual or interpretative reports to clarify particular technical requirements and provide design and construction information to be incorporated into the design report.

However, depending on the size of a project, other contractors may prefer to follow an initial Phase 2 investigation with a more detailed Phase 3 investigation to arrive at recommendations for the design report and continue with a Phase 4 investigation to continually re-assess the assumed ground model during the actual construction period.

Phase 1 – Desk Study and Site Reconnaissance

Phase 1 starts with searching readily available archives and databases to produce a desk study report that firstly introduces the site setting:

- Site location;
- Site description;
- Site walkover;
- Geological setting;
- Hydrogeological setting;
- Hydrological setting.

Furthermore, the report outlines the results of environmental searches such as:

- Waste treatment and disposal sites;
- Air pollution controls;
- Radioactive substances;
- Pollution incidents;
- Discharge consents;
- Green Belt areas;
- Designated sites;
- Nitrate vulnerable zones;
- Geological constraints;
- Coal mining report;
- Radon report.

Earlier uses and state of the site such as underground mining, opencast mining, quarry operations, waste tips and landfills, industrial sites as well as ancient monuments and ecology should be discerned from:

- All available OS maps;
- Recent changes;
- Contemporary trade directory entries.

Firstly, the gathered information is used to clarify geological constraints and hazards such as:

- Slopes (landslides);
- Swelling and shrinking clays (heave or subsidence);
- Soluble rock (subsidence);
- Compressible or collapsible ground (excessive or uneven settlement);
- Running sand (problems with excavations, tunnelling; problems with irrigation, surface water disposal);
- Radon (naturally occurring radioactive gas that causes lung cancer);
- Methane and carbon dioxide (asphyxiants and explosive);
- Groundwater (flooding);
- Underground mining (stability).

Secondly, the gathered information is used to derive a conceptual site model of potentially contaminated land where a pollutant linkage between source and receptors such as humans, vegetation, water, and building materials may exist.

Once all available information has been assessed and it is found that geological and environmental conditions need to be quantified, recommendations for further work commonly include the commissioning of a Phase 2 intrusive ground investigation.

Phase 2 – Intrusive Ground Investigation

The selection of ground investigation methods depends firstly on the characteristics of the ground, the objectives, and the technical requirements, but may be influenced by the character of the site, equipment, personnel, and costs.

Trial pitting, window sample boreholes and light cable percussion boreholes are commonly used to recover soil samples. The following are summarized method statements for each.

Trial Pitting

Figure 2: Engineer marking samples from test pit.

Using a complete set of service drawings, the engineer marks out and CAT scans all trial pit positions to avoid local underground and overhead services.

A JCB 3CX with a 2ft toothed bucket, and occasionally a breaker to open hardstanding, positions itself adjacent to the first trial pit.

Topsoil and turfs are stripped and stored separately from other excavated material and reused at the surface when reinstating.

Jar samples are taken of the topsoil. Bulk samples are to be taken to enhance the soil profile, i.e. either every metre or, if more frequent, at every stratum change.

The trial pits are excavated to an agreed depth of maximal about 4.5m, or until the sides become unstable, an obstruction is encountered, or bedrock is reached.

Following water strike, the flow and level are recorded over a 20-minute period. Water samples are taken following a water strike.

When the trial pit is complete, the engineer records and photographs all details regarding the trial pit.

The trial pit is to be backfilled in reverse order, to which it was excavated and compacted to reduce later settlement.

All steps are carried out for the remaining trial pits before the JCB is removed from site. Any damage to the site shall be reinstated on the way out.

Window Sampling and Cable Percussive Boring

A window sampler is best suited for dry cohesive soils and can take a continuous sequence of sample tubes, usually 1m long and of variable diameter, down to a maximum depth of about 8m.

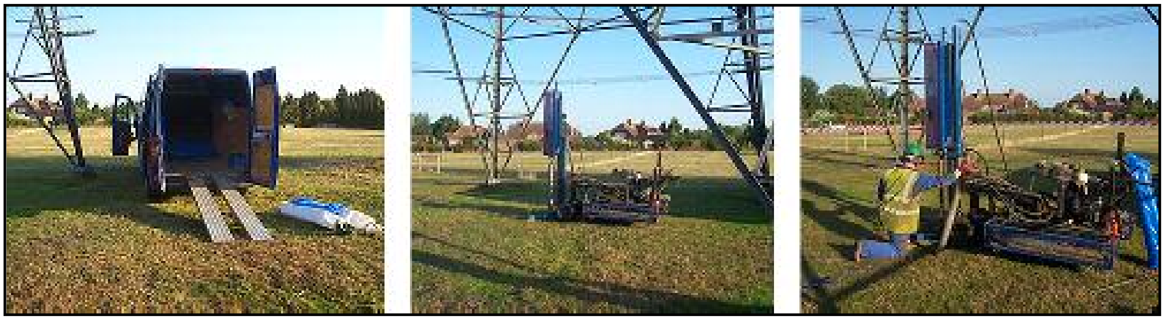

Figure 3: Window Sampler at work – Note the ability to be used even beneath a pylon.

Light cable percussion boring normally uses a mobile rig specially designed for ground work and suitable for recovering disturbed soil and weak rock samples to depths of about 60m.

Using a complete set of service drawings, the engineer marks out and CAT scans all borehole positions to avoid local underground and overhead services.

The engineer gives the drilling crew instructions, detailing sampling, chiselling and installation requirements, and the rig is erected over the first borehole position.

The drilling crew hand excavates an inspection pit to 1.20m BGL to clear for buried services and surface obstructions after which drilling commences.

The borehole is terminated at an agreed depth, or at an obstruction or bedrock, and a decision for rotary drilling, installation or grouting is issued.

Where piezometer or standpipe are required the engineer instructs the driller as to the make up of the installation.

The driller shall backfill the boreholes with the bentonite/cement grout mix.

The rig is dismantled and the borehole site is made safe and tidy. All excess spoil to be bagged and removed from site and disposed to the appropriate landfill site.

The steps are repeated for all boreholes until complete, and the rig and equipment are removed from site.

Sampling Ground and Groundwater

The BS 5930:1999 identifies four main types of sampling:

a) *taking disturbed samples from excavating equipment and the drill tool in the course of excavation or boring;*
b) *drive sampling, in which a tube or split tube sampler having a sharp cutting edge at its lower end is forced into the ground, either by a static thrust or by dynamic impact;*
c) *rotary sampling, in which a tube with a cutter at its lower end is rotated into the ground, thereby producing a core sample;*
d) *taking block samples specially cut by hand from a trial pit, shaft or heading.*

Disturbed samples from the trial pits and cable percussion boreholes are usually placed in 0.5l plastic jars or 30l bulk bags. Sampling instructions for trial pits require taking a jar sample of the topsoil, jar and bulk samples at 0.5m, and jar and bulk samples at every metre to represent the soil profile. If strata changes are more frequent, jar and bulk samples need to be taken at every change. Sampling instructions for cable percussion boreholes require two bulk samples to be taken from the inspection pit, to carry out alternating SPT tests (see in-situ testing) and U100 sampling at every metre between ground level and 5.0m, to carry out alternating SPT tests and U100 sampling at every 1.5m between 5.0m and termination depth, and to retain jar samples over the SPT range as well as bulk samples from every metre.

Figure 4: Cable Percussive Boring Rig

If hydrocarbon contamination is encountered in any trial pit or borehole this must be sampled in 1l amber glass jars and small glass vials.

Continuous tube samples obtained by window sampler are often of sufficient quality to enable the ground structure within the sample to be examined. Samples to be tested for physical and chemical properties are removed from the tube and placed in plastic or amber jars.

Rotary sampling is not discussed further, and this particular firm rarely has a need to block sample.

The BS states that, 'the simplest method of determining groundwater level is by observation in an excavation or borehole'. The JCB bucket may be able to collect enough groundwater to sample using a 1l plastic bottle, and drillers may be able to extract water while sinking the borehole. Trial pits are usually backfilled without an installation, but drillers are often instructed to install a standpipe with a perforated end section surrounded or wrapped by a filter, which is sealed to the ground at an agreed depth, or a standpipe piezometer consisting of a pipe with a porous element at the end. Over a period of time groundwater levels can be measured by dropping a dipmeter from the top of the pipe which beeps on contact with water. Groundwater can be sampled using balers and filling the water into 1l plastic bottles.

In-situ Tests in Trial Pits and Boreholes

a) Density of the ground

The engineer usually carries a hand-held vane or penetrometer to make an assessment of soil strength. The cruciform vane is forced into cohesive soil samples at half-metre intervals (either in-situ or in spoil) and rotated, and the torque required can be read off a scale and is directly related to the shear strength of the soil. Similarly, a hand-held penetrometer is pressed downward into a cohesive sample and a numerical value relates to soil strength is read off.

A mexicone measures the bearing pressure in granular soils, but readings can only be taken safely from in-situ soils within the first 1.2m after which it becomes unsafe to enter the trial pit. Continued excavation beneath this depth disturbs the sand or gravel and destroys the structure, rendering the use of the mexicone futile.

In boreholes, soil consistency and relative density are usually assessed using standard penetration testing (SPT) where a sample tube is driven into the ground at the temporary bottom of the borehole and the number of blows from a standard weight falling from a standard distance is indicative of consistency and density. Vane tests can be carried out, but are not as common.

b) Permeability of the ground

Soil permeability, a measure of the rate of water flow, can be tested in trial pits, using soakaway tests where a known volume of the pit is filled with water and the falling water level is measured over a logarithmic time period.

In boreholes, a variety of tests is available, ranging from the simple, which can nevertheless be used to investigate complex situations, to the sophisticated; the interpretation of data is crucial.

c) Others

There are a large number of other tests, which are of no real importance to archaeologists and have therefore not been mentioned.

Laboratory Tests on Samples

Figure 5: Sample storage - bulk samples and tubs.

a) Sample storage and inspection facilities

The BS 5930:1999 recognizes the need of a geotechnical laboratory for good facilities to handle, store and inspect the soil samples. All samples that arrive at the facilities are registered.

Samples are kept safe from damage and deterioration, and placed in purpose-made containers to prevent moisture loss and stored in purpose-made racks until they are no longer needed. Then they are disposed of, usually with aid of a skip to be transported to an appropriate waste site.

b) Visual examination and description of laboratory samples

The description of samples and photographic recording is done prior to any laboratory testing during which a large part if not all of the sample may be lost.

The correct order of descriptive terms for logging soil samples is given below.

c) Tests on soil

The BS 5930:1999 (Code of Practice for Site Investigations) summarizes the purposes of laboratory testing to be to describe and classify the samples, to investigate the fundamental behaviour of the soils in order to determine the most appropriate method to be used in the analysis, and to obtain soil parameters relevant to the technical objectives of the investigation.

The laboratory tests for soils commonly carried out include:

- Moisture content, which read in conjunction with liquid and plastic limits gives an indication of undrained strength;
- Liquid and plastic limits to classify fine grained soil and the fine fraction of mixed soils;
- Particle size distribution to give the relative proportions of gravel, sand, silt and clay;
- Organic matter which may interfere with the hydration of Portland cement;

- Mass loss of ignition which measures the organic content in soil, particularly peat;
- Sulfate content which assesses the aggressiveness of the soil or groundwater to buried concrete;
- pH value which is usually carried out in conjunction with sulfate contents tests;
- California bearing ration (CBR) used for the design of flexible pavements;
- Soil strength tests such as triaxial compression, unconfined compression and vane shear;
- Soil deformation tests;
- Soil permeability tests.

Tests on rocks are outside the scope of this article.

Description of Soils

Figure 6: Sample storage

The description of soils in geotechnical and geoenvironmental investigations is carried out according to BS 5930:1999 and forms an important part of ground investigation, the results of which may be required long after the disposal of the samples.

A standard description contains the following:

a) mass characteristics comprising state and structure:
   1) density/compactness/field strength;
   2) discontinuities;
   3) bedding;
b) material characteristics comprising nature and state
   1) colour;
   2) composite soil types: particle grading and composition; shape and size;
   3) principle soil type (name in capitals), based on grading and plasticity shape;
c) stratum name: geological formation, age and type of deposit; classification (optional)

Hence, boulder clay is more typically described as 'stiff/very stiff brown grey sandy slightly gravelly CLAY. Gravel is subangular to rounded fine to coarse of sandstone, mudstone, coal. Occasional rounded cobbles of sandstone'.

Descriptions of rock are outside the scope of this article.

Report

After the samples are disposed of the report will be the only record of the site investigation.

A descriptive report usually contains an introduction, descriptions of the site, the underlying geology, and the fieldwork as well as details of the trial pit and borehole logs, followed by the incidence and behaviour of groundwater, the location of the boreholes, and the results of the laboratory tests.

The BS 5930:1999 states that for trial pitting the following information should be recorded in the log:

a) A description of each stratum together with its thickness. One advantage of trial pitting over boring it the opportunity to examine in-situ the variability of the strata and strata boundaries. Where these are not variable, a simple diagrammatic borehole log type presentation of a) and b) is acceptable with a comment about the uniformity around the pit. Where the ground is variable a sketch of one or more faces to show the variability should be presented.
b) The depth of each change of stratum
c) The depth and position of each sample, including the lateral and vertical extent of larger samples such as bulks or blocks.
d) The depth and position of each test and the nature of the test.
e) The dates of excavation and logging;
f) Details of equipment in use, including excavator type, bucket size, shoring and pumps.
g) A record of groundwater conditions, including levels and estimated quantities.
h) A record of the ease of excavation of the strata.
i) A record of the stability of the sides of the excavation.
j) Comment on the weather conditions.
k) A record of depth range examined in-situ or logged on arisings.
l) Details of any instrumentation installed and method of backfilling.
m) A sketch plan showing dimensions and orientation of pit, face reference numbers and location of landmarks

Trial pit photographic records should include one or more faces and the spoil heap; all photographs should include a suitable and legible reference board. Artificial or flash lighting is normally required.

For light cable percussion boring the following information should be recorded in the log:

a) a description of each stratum together with its thickness;
b) the depth and level of each change of stratum;

c) the depth of the top and bottom of each tube sample, or bulk sample and its type and the depth of each small disturbed sample;
d) the depth at the top and bottom of each borehole test and the nature of the test;
e) where standard penetration tests are being recorded, tests should be distinguished and should include all incremental blow counts and penetrations;
f) the date when each section was bored;
g) details of tools in use, including sizes;
h) water levels (including changes) and related casing depths at all samples, tests and water inflows;
i) a record of each water strike, including rate of rise of water level, depth of water in the borehole at start and finish, depth of water at the time of each test or sample and depth of casing when each observation was made;
j) a record of water added to facilitate boring;
k) where observation wells or piezometers have been installed, their depths should be given, together with details of the installation, preferably in the form of a diagram, and often on a separate record sheet;
l) water levels in observation wells measured subsequent to the completion of the borehole; these may be recorded separately.

Information that should be included on a rotary core log is outside the scope of this article.

The descriptive report can be extended using a summary of ground conditions and parameters, listing ground types, stratigraphy, borehole sections, ground parameters, groundwater and chemical conditions.

The final stage is an engineering interpretation based on information related to the project usually supplied by the designer and the ground parameters selected from the summary of ground conditions report. The engineer making the analysis prepares recommendations concerning spread foundations, piles, retaining walls, basements, ground anchorages, chemical attack, pavement design, slope stability, mining subsidence, tunnels and underground works, safety of neighbouring structure, monitoring of movements, embankments, and drainage.

Contaminated sites

Different Phases of Investigation

Contaminated sites are dealt with in BS 10175:2001. As mentioned before, a Phase 1 desk study is carried out to provide information on past and current uses of the site and the surrounding area, and the nature of any hazards and physical constraints. It identifies potential sources, pathways and receptors of contamination and produces a conceptual model of the nature and extent of potential contamination.

Where potential contamination and a pathway to receptors exist, the conceptual model must be tested by a Phase 2 intrusive ground investigation.

The results of the ground investigation and subsequent chemical testing clarify if a supplementary investigation needs to be carried out to delineate particular areas of contamination and address technical matters concerning remediation.

Geoenvironmental assessment has become a crucial part of overall site investigation and is often complex and complicated. Hence, this article will only summarise the information which can be gained through trial pitting and the sinking of boreholes as mentioned above.

Trial Pits and Trenches

In the UK, contamination is usually tied up in made ground and the material leached from the made ground into the natural. Where the anthropological and affected natural strata are not very deep, an intrusive geoenvironmental investigation may occasionally entail the use of hand-dug pits only. But more often, geoenvironmental sampling is done simultaneously with geotechnical sampling during the mechanical excavation of trial pits.

The BS 10175:2001 lists the following advantages of an investigation using trial pits:

- detailed examination of ground conditions in 3-D;
- easily obtained discrete samples and bulk samples;
- rapid and inexpensive;
- collection of disturbed samples possible;
- applicable to wide range of ground conditions;
- combined geoenvironmental and geotechnical investigation possible;
- photography possible.

The disadvantages, however, include:

- investigation limited to a depth of about 4.5m;
- material exposed to air, risk of chemical changes, risk of loss of volatiles;
- not suitable for sampling below water;
- greater potential for damage to site than boreholes;
- generates more waste than boreholes;

- potential escape of contamination to air/water;
- possible need for inert material to backfill.

Window Sampling


Figure 7: Window sample

In addition to the recovery of continuous, fairly undisturbed samples and the possibility to install a series of measuring devices, the BS 10175:2001 lists the following advantages of window samplers:

- less potential of adverse effects of H&S;
- depth range to 10m, fast, portable;
- enables groundwater sampling.

However, the disadvantages include:

- limited opportunity to inspect strata;
- relatively small sample volumes and poor sample recovery in granular material;
- compression of strata such as peat;
- cannot penetrate obstructions;
- can cause smearing of hole walls;
- holes cannot be cased and could open pathways.

Light Cable Percussion Boreholes

The advantages of cable percussion boreholes have been discussed above, and with regards to contamination sampling they allow for:

- integrated sampling for contamination, geotechnical and gas/water sampling and the installation of groundwater and ground gas monitoring pipes.

However, they are much less discreet, more costly and time-consuming, allow for less visual inspection and smaller sample volumes than trial pits. The technique can cause disturbance of the samples and loss of contaminants as well as the potential contamination of underlying aquifers. Waste from boreholes needs to be disposed of, and samples from standing water can be cross-contaminated and not representative.

On-site Testing

Groundwater levels are frequently measured on site: in trial pits prior to being backfilled, and in boreholes while being sunk as well as in standpipes and piezometers, where these were installed following borehole completion and repeatedly monitored. Water chemistry is not usually assessed on site.

Ground gas testing in trial pits is usually futile as volatiles disperse quickly into the atmosphere. Also, ground gas is not normally detected while boreholes are being sunk. It is more common that the engineer carries out a series of site visits over a period of time to monitor ground gas levels from the installed standpipes.

In addition to testing for oxygen, carbon dioxide, carbon monoxide, hydrogen sulphate and nitrogen with a basic gas meter, flame ionization detectors (FIDs) and flammable gas detectors may be used to detect gases such as methane, and photo-ionization detectors (PIDs) respond to compounds such as chlorinated hydrocarbons or aromatics.

Off-site Testing

The requirements of a geoenvironmental investigation are continuously under review, and chemical suites to be tested in soils, water or leachates may vary according to current guidance values and available detection limits.

A standard chemical suite of a metal screen (As, B, Cd, Cr, Cu, Pb, Hg, Ni, Se, Zn), PAH (USEPA 16), pH, phenol (total), cyanide (total), organic matter content and TPH ($C_{7\text{-}9}$, $C_{10\text{-}14}$, $C_{15\text{-}36}$) has been found to meet most planning requirements.

Furthermore, where a Phase 1 desk study causes suspicion, tests can prove the presence of BTEX, VOCs, SVOCs, PCBs, asbestos, or any other contaminants. However, there may not always be a guidance value to compare detected levels to.

Report

A factual geoenvironmental investigation report normally contains the objectives and methodology for the on-site investigation and on-site observations. It outlines which samples have undergone what type of analysis and the analytical results are included.

Obviously, there can be an interpretative geoenvironmental report, the proverbial can of worms. Keeping the conceptual model of potential contaminants, pathways and receptors in mind, actual analytical results are compared to current guideline values to identify actual contamination and actual receptors. A remediation strategy can then be suggested to be carried out prior to the development which will make use of the recommendations of the interpretative geotechnical report.

Implications for Archaeology

The Definition of Site Investigation

From an archaeologist's point of view, the above definition of site investigation is incomplete. Although the geotechnical and geoenvironmental components have been taken into consideration, an 'adequate understanding of the nature of the ground' must entail information about potential archaeology. From an ecologist's point of view, the definition would still be incomplete, but I will not go as far as to say that I have any knowledge of badger surveys and the like. The comment is only meant as a reminder to think outside the box.

Figure 8: Engineer supervising test pit excavation.

Geotechnical, geoenvironmental and archaeological investigations are all requirements of the planning process which is much talked and written about and will not be discussed here. Within the planning framework, geotechnical firms seldom encounter unwilling clients while archaeologists are often confronted with the 'did you put it there' undertone. That is because developers would like to see their building spring up as soon as possible and are only too happy to fork out for a ground conditions survey if it means their building is not going to sink into the mud or slide down the hill. Geoenvironmental investigations have become a necessary evil, and are usually tolerated as long as no contamination is actually found. If contamination is found the person reporting back to the client may also receive the 'did you put it there' treatment. For the developer, having to remediate environmental contamination is like having to fund an archaeological investigation. It is surprising how quickly attitudes change for the better if you can offer a combined investigation of all three elements.

The obstacle that hinders a combined investigation is not the overall process of collecting information, appraising data, and assess and report, since this is very similar for geotechnical firms as well as archaeological contractors. The problem lies with education. Civil engineers often know little about geology and archaeology, and geologists and archaeologists often know little about each other. Even so-called geoarchaeologists are seldom subjected to the commercial reality of trial pitting, and will have no knowledge of geotechnical and geoenvironmental recording and reporting. A larger firm with larger projects may employ geologists and archaeologists to work on projects together and create good communication within the firm and with councils and clients, but a small firm undertaking much trial pitting will be hard pressed to find a single person capable of undertaking trial pitting with an emphasis on archaeology as well as small archaeological projects.

It is easier and commercially feasible to teach an archaeologist the basics of trial pitting, borehole supervision and geological logging than it is to teach a geologist the ins and outs of commercial archaeology. A geologist may be able to carry out a desk-based assessment, but beyond that a working knowledge of archaeology can only be gained through a degree or years of voluntary experience in the field.

Phase 1

A Phase 1 desk study and an archaeological desk-based assessment are similar in that they start with the searching of readily available archives and databases to firstly gather information about the site setting. After that the archives and databases approached differ substantially.

Geotechnical and geoenvironmental researchers will concentrate on geology, topography and contaminative land use within a few hundred meters of the site. It is unusual for former industries to be so contaminative that a larger radius and therefore the concept of landscape need to be considered. As such the concept and particularly the scale of an archaeological landscape are alien.

However, a geotechnical desk study may touch on archaeological remains, but only if these are shown on any edition of the OS map and are either on the site or within the immediate surroundings. Geotechnical researchers are not required to search earlier maps or any of the archaeological databases. Thus, only former or present upstanding remains in a very limited space are noted. From a geotechnical point of view, you could be within a few hundred meters of Stonehenge without thinking too much about it. Those are considerations of the planning archaeologist and any desk-based assessment required by them to be carried out by an archaeological researcher.

However, a geotechnical and geoenvironmental desk study may hold a wealth of industrial archaeological information and point to aspects of the ground that may lead to problems during archaeological site work such as instability and contamination.

Phase 2 – Intrusive Ground Investigation

Geotechnical and geoenvironmental site instructions do not normally contain any mention of potential archaeology. Neither the geotechnical engineer nor the drilling crews will have had any archaeological training and will not be looking for nor recognize any archaeology, unless it takes the form of buried structures. Where buried structures are encountered, these are often assumed to be fairly recent, and no attempt will be made to date them more accurately. If a watching brief is not commissioned, any geotechnical intrusive work can potentially be disastrous for any previously undetected archaeology.

Trial Pitting

a) Positioning

Geotechnical and geoenvironmental trial pits are not positioned in the same way as archaeological trial trenches. Trial pits are placed in order to observe the underlying geology, to discover any deviations, and to target potentially contaminated areas. The description, testing, reporting and interpreting of ground conditions to design foundations would be useless if these ground conditions were then changed and made worse by a 4m-deep backfilled trial pit in the middle of the proposed structure. Hence, trial pits are positioned away from the proposed development. Often they are not surveyed; few are marked on plans by a single central six-figure grid reference and usually lack any orientation.

Trial trenches, on the other hand, are usually positioned where the intrusive works for the proposed development will take place. Placing them elsewhere would mean no prior knowledge of the type, extent and condition of any archaeology affected by the groundworks and would render the exercise entirely pointless. Archaeological trenches are properly tied into the national grid.

Figure 9: Test pit showing soil profiles.

Figure 10: Deep test pit

Hence, a combined geotechnical and archaeological investigation would have to pay careful attention to the positioning of every exploratory trench. Ideally, it would lie partly on unaffected ground and partly within the proposed foundations, so that the archaeological investigation can be carried out within the whole trench and be followed by the geotechnical investigation by machine in the unaffected ground. The trench would be tied into the national grid.

b) Plant

Geotechnically, the typical choice of JCB is a 3CX with a 2ft toothed bucket capable of being driven to the site, digging through harder ground and moving boulders. Archaeologically, higher costs may arise from using a low loader to deliver a tracked 360 excavator for greater mobility whilst digging more slowly with a toothless bucket. In addition it would be advisable to use a plant operator with some archaeological experience.

c) Method

The excavation of a geotechnical trial pit is done rapidly with little regard to the subtleties of archaeological deposits. The operator may be fairly careful within the upper horizons to avoid damage to underground services, but the entire trial pit is usually dug in a few minutes, and sampling occurs according to possible contamination and changes in the natural strata. Geotechnical trial pits are never 1.0m x 1.0m with flat sides and base. Their dimensions are dictated by the movements of the JCB, and the length and width created by the circular motion of the arm and bucket are commonly 2.5m x 0.8m to give rise to a depth of 4.0m. The backfilling of the trial pit occurs equally rapidly unless the client requests particular attention.

Window Sampling and Cable Percussive Boring

a) Positioning

Boreholes affect a much smaller area than trial pits and create less damage to both the ground beneath the proposed structure and any potential archaeology. They can be positioned anywhere on site. If surveyed, a single six-figure grid reference locates the borehole very accurately.

b) Method

The inspection pit to 1.2m may be of interest to archaeologists since excavated layers are visible, but as already mentioned, drilling crews have very little archaeological knowledge and are not expected to look for archaeological deposits. Thus, the pit is dug quickly, with thin archaeological layers simply noted as made ground until thick enough to warrant an individual description, and sampling is limited to a bulk bag between ground level and 0.5m and a bulk bag between 0.5m and 1.2m. The inspection pit is not photographed. There is a lot of scope for cross contamination and loss of information.

Sampling

Trial pitting allows for fairly strata-specific sampling, because the geotechnical engineer can see the strata changing. That does not apply to cable percussive boreholes. The drilling crew usually follows a specific sampling strategy, regardless of strata changes since these are not immediately visible. Therefore, it is common that drillers take different types of sample at approximately every meter. The samples alone do not convey where the strata change, but a driller can drop a tape down the borehole and note this information in the driller’s logs.

In-situ Tests and Laboratory Tests

These tests are mentioned for completion’s sake with little application to archaeology.

However, laboratory technicians handle much of the soil samples, usually starting by taking out coarse fragments. These coarse fragments are never reported back to be archaeological. Technicians usually have little knowledge of geology, archaeology and legal obligations; hence if archaeological artifacts are even recognized as such they possibly end up in the bin or in a pocket.

Description of Soils

The description of soils occurs according to BS 5930:1999 which ensures that factors regarding the geotechnical and geoenvironmental nature of the soils are effectively stated. To the geotechnical engineer there is nothing more annoying than the wrong term or the wrong word order, because the proper usage creates a picture of the stratum recognizable across a whole site and in reports.

Unfortunately, the BS is not adhered to as strictly in archaeology. Much emphasis is still placed on the correct colour (which has almost no meaning in engineering terms), and words like loam and pebble are outdated. Often the geology of gravel is not stated. There is scope within the BS to adequately describe archaeological soils.

Despite this scope, geotechnical logs often do not pay the necessary attention to archaeological detail. On one hand, geotechnical engineers do not have the time to do so, and often do not bother with layers so thin that they will not affect the proposed structure; on the other hand, geotechnical engineers are not aware that simply stating the presence, disappearance, and absence of obviously modern rubbish such as plastic from a layer can give an indication of date. Geotechnical engineers have more geological training than archaeologists to recognize different lithologies, but they lack the skill to tell worked lithics and flints, and many a piece may go completely undetected. In addition, archaeology would profit from the inclusion of descriptive terms for the boundary between horizons (which could only be seen in trial pits) and an indication of moisture within layers.

Report

As seen above, a factual geotechnical and geoenvironmental site investigation report holds a wealth of information directly applicable to archaeology. Unfortunately archaeologists will find that these reports are very difficult to get hold of.

Geotechnical and geoenvironmental firms simply have no legal obligation to make their findings in any way public. The soil is not seen as a non-renewable resource in need of protection, and geotechnical engineers do not have to approach the council about every trial pit dug and every borehole drilled. That would be commercially infeasible. Since trial pits and boreholes do not destroy the soil resource as such, there is no need for ‘preservation by record’.

Therefore, geotechnical and geoenvironmental reports do not usually enter the public domain. The information unearthed by geotechnical engineers belongs to the clients. The geotechnical firm itself cannot be approached to disclose information, and since no database exists of what investigation has been carried out where it is impossible to directly approach the right client to voluntarily disclose information or even sell it.

The reason why geotechnical firms are not pressing to create the same public databases as archaeologists is that they profit from the information not being readily available. A client may commission a firm to carry out a site investigation on a particular site, but then the client pulls out. The information is not made public, so when the next developer comes along he may commission the same firm to carry out the same site investigation, the firm being paid twice. One commonly hears a drilling crew say that they know where they're going - they were only there last year.

Since the geotechnical firm has no obligation to disclose information, but an archaeologist still does, a combined project would have to present at least two reports: an archaeological one which publishes all available archaeological information but withholds all geotechnical data, and a geotechnical one which belongs entirely to the client.

In-house archaeologists within geotechnical firms, however, are in a position to use information not readily available to anyone else, and this information will lead to a better archaeological approach with regards to a specific site.

Contaminated Sites

The excavating and drilling methods employed on potentially contaminated sites are essentially the same employed for geotechnical reasons, and as such it makes sense to combine the two investigations.

However, the results of a geoenvironmental investigation are of little more use to archaeologists other than to inform about Health & Safety aspects of a proposed excavation (if the results are known in advance), or to add to the knowledge of industrial processes on site.

References

1. AGS (2004) *A Client's Guide to Site Investigation*, AGS Information Sheet, AGS, Beckenham, Kent.

2. British Standards Institute: BS 5930 '*Code of Practice for Site Investigations*', BSI, 1999.

3. British Standards Institute: BS 10175 '*Code of Practice for the Investigation of Potentially Contaminated Sites*', BSI, 2001.