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Soil quality — Sampling —

Part 104: **Strategies**

Qualité du sol — Échantillonnage —

Partie 104: Stratégies

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 190, *Soil quality*, Subcommittee SC 2, *Sampling*.

This first edition of ISO 18400-104, together with ISO 18400-101, ISO 18400-102, ISO 18400-105, ISO 18400-107, ISO 18400-202, ISO 18400-203 and ISO 18400-206, cancels and replaces the first editions of ISO 10381-1:2002, ISO 10381-4:2003, ISO 10381-5:2005, ISO 10381-6:2009 and ISO 10381-8:2006, which have been structurally and technically revised.

The new ISO 18400 series is based on a modular structure and cannot be compared to the ISO 10381 series clause by clause.

A list of all parts in the ISO 18400 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is part of a series of sampling standards for soil (the role/position of the individual standards within the total investigation programme is shown in Figure 1). It provides guidance on the development of site investigation strategies in general (more specific guidance is given in other standards) and of sampling strategies [e.g. what to sample, where to sample (locations and depths) and the types of samples to take] taking into account the need to obtain representative samples and to have regard to relevant statistical principles.

Soils (and other soil materials) are composed of a mixture of mineral particles, organic matter, water, air (soil gas) and living organisms. In the case of some contaminated soils, a non-aqueous liquid phase might also be present. The solid matrix (phase), consists of particles of different size, shape and physical and chemical properties. The aim when carrying out soil sampling is usually to obtain sufficiently representative samples that can be used to characterize the properties of the whole soil entity (e.g. *in situ* soil in the form of a volume or horizon, or surface deposit such as a stockpile) or the portion considered relevant to the objectives of the investigation (e.g. <0,1 mm fraction for exposure assessment via hand-to-mouth activity). The properties of discrete entities such as individual soil particles are not addressed. As the soil as a whole cannot be analysed, soil samples are taken instead. The assumption that the results of these investigations on samples represent the total soil volume of interest is always an approximation, the reliability of which depends on additional information about the soil, the site and use of an appropriate sampling strategy. In other words, the sampling strategy should guarantee that, together with additional information (on-site observations, background information, previous investigation results, etc.), the results for the samples analysed allow a model to be developed of relevant properties of the soil volume of interest to a sufficiently reliable degree, in accordance with the investigation objectives.

Whatever the purpose of the investigation, a sound conceptual site model is required. Every property of a soil or soil material is a result of their dynamic development influenced by natural and human-induced processes such as weathering, leaching, dislocation, contamination, and many others. Without considering this, the results of any investigation of samples cannot be interpreted and evaluated properly. When spatial variability of soil properties (including contamination) is of particular interest, the conceptual site model includes what is known, or believed to be known, about the processes that led to the anticipated spatial distribution of properties.

The sampling strategy, especially when average properties are of interest, is preferably based on statistical methods, as far as practical and appropriate.

Having first defined key elements such as involved parties, objectives, properties of interest, phase of the investigation, background and site information, as well as health and safety aspects, a sampling strategy is developed that can form the basis of a sampling plan in accordance with ISO 18400-101 (the sampling plan covers a number of practical issues as well as the sampling strategy).

The appropriate sampling strategy in any particular case depends on

— the objectives of the investigation,

— the special situation and characteristics of the material to be sampled,

— the properties of interest, and

— the required degree of precision and reliability of the results.

Many other factors can also influence the design of the sampling strategy including:

— accessibility of the site as well as the sampled material;

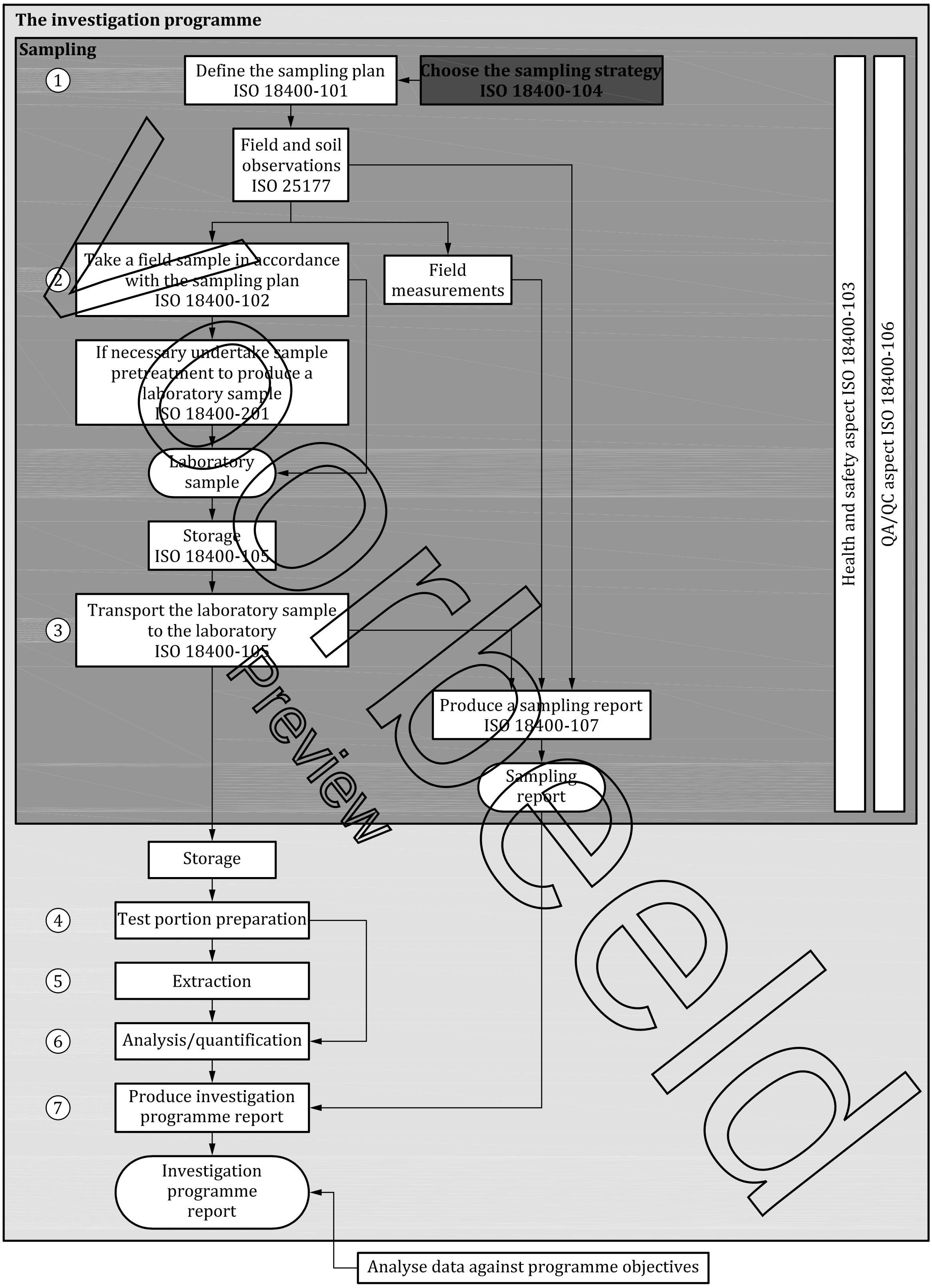
— financial, personnel, and technical resources;

— weather conditions;

— the time schedule/frame;

— legal/environmental restrictions.

Following the definition of the sampling approach, the appropriate sampling techniques are selected following the guidance in ISO 18400-102 with regard to health and safety (ISO 18400-103) and various practical considerations. The decisions made regarding sampling techniques form part of the sampling plan.



NOTE 1 The numbers in circles in Figure 1 define the key elements (1 to 7) of the investigation programme.

NOTE 2 Figure 1 displays a generic process which can be amended when necessary.

Figure 1 — Links between the essential elements of an investigation programme

Soil quality — Sampling —

Part 104: **Strategies**

1 Scope

This document gives general guidance on the development of site investigation strategies and detailed guidance on the development of sampling strategies, when collecting information on

— the average properties of soil,

— the variability of soil properties, and

— the spatial distribution of soil properties.

It is applicable to soil samples intended for chemical testing and determination of a variety of other properties (e.g. physical).

Although the main focus of this document is the collection of material (field samples) for transfer to a laboratory for testing, it is also applicable when measurements are made directly in the field.

NOTE 1 This document also provides information on the statistical principles underlying the development of appropriate sampling strategies and statistical methodologies.

NOTE 2 Guidance on other forms of related sampling activities are given in other International Standards [for soil gas (ISO 18400-204) and for biological testing purposes (ISO 18400-206)]. Guidance on sampling groundwater is provided in ISO 5667-11 and ISO 5667-22 and on sampling methods and groundwater measurements in geotechnical investigations in ISO 22475-1.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11074, *Soil quality — Vocabulary*

ISO 11464, *Soil quality — Pretreatment of samples for physico-chemical analysis*

ISO 18400-201, *Soil quality — Sampling — Part 201: Physical pretreatment in the field*

ISO 18400-202, *Soil quality — Sampling — Part 202: Preliminary investigations*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11074 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

NOTE The hierarchical approach and terms used in this document as well as the relationships between the sampling approaches and sampling patterns employed in this document are shown in Table 1.

3.1
above-ground sampling
taking samples from material that has been deposited on the ground surface

EXAMPLE Samples are taken from a stockpile (including bulk volumes of excavated soils), deposit of waste or embankment.

3.2
anthropogenic ground
deposits which have accumulated through human activity

3.3
cluster sample
composite sample (3.4) for which the *increments* (3.8) are taken over a small area around a predefined sampling point

Note 1 to entry: Sampled area is typically about 0,5 m^2 to 1,0 m^2.

Note 2 to entry: Material sampled is taken from within the same stratum or from material with the same characteristics.

3.4
composite sample
sample made of a number of increments (*cluster sample* (3.3) or *spatial composite sample* (3.22))

3.5
convenience sampling
taking samples based on accessibility, expediency, cost, efficiency, or another reason not directly concerned with sampling parameters

Note 1 to entry: The samples might be taken to a predetermined plan (locations, depths, etc.) or taken from locations and/or depths decided on site.

3.6
fill
anthropogenic ground (3.2) in which the material has been selected, placed and compacted in accordance with an engineering specification

3.7
ground
all materials below the ground surface, including natural materials (soil and rock) and anthropogenic materials

3.8
increment
material forming part of a *composite sample* (3.4) obtained by a single operation of a sampling device

Note 1 to entry: For instance, the filling of a scoop or auger.

3.9
in-ground sampling
taking samples from the ground surface and/or within the ground beneath the surface

3.10
judgemental sampling
targeted sampling
taking samples from particular zones or features of a site taking into account existing knowledge, including what is known about the history and layout of a site or a zone within a site

Note 1 to entry: Judgemental sampling could be required, for example, around underground storage tanks or pipelines where there might have been leaks, above ground storage tanks where there might have been spills, and for areas where raw materials or waste have been stored or deposited.

Note 2 to entry: Sampling locations are usually predetermined based on what is known about the target area but some locations may be selected in the field in response to on-site observations.

3.11
made ground
anthropogenic ground (3.2) comprising material placed without engineering control and/or manufactured by man in some way, such as through crushing or washing, or arising from an industrial process

3.12
macro-aggregate
soil aggregates consisting of micro-aggregates cemented together by organic matter, microbial polysaccharides, fungal hyphae, earthworm excretions and plant roots

Note 1 to entry: Generally, aggregates are >0,25 mm to 5 mm in size.

Note 2 to entry: Macro-aggregates are typically found in undisturbed soils.

3.13
micro-aggregate
soil aggregates consisting of primary particles, plant roots, and humin cemented together

Note 1 to entry: Generally, aggregates are less than 0,25 mm in size.

Note 2 to entry: Micro-aggregates are more typically found in disturbed or cultivated soils. Multiple micro-aggregates can form larger *macro-aggregates* (3.12) through microbial activity, plant root exudates and actions, fungal hyphae, and earthworm casts.

3.14
population
<soil sampling> entirety of a soil volume or mass about which information is to be sought via sampling

EXAMPLE A particular site, an *in situ* volume of soil, a stockpile, a truck load.

3.15
principal sampling situation
one of four sampling situations characterized by a combination of whether information is required on spatial distribution or average properties, with whether *in-ground sampling* (3.9) or *above-ground sampling* (3.1) is required

Note 1 to entry: The concept is illustrated in Table 2.

3.16
probabilistic sampling
taking samples to ensure that each particle or element in the *population* (3.14) has an equal chance of being part of the sample

Note 1 to entry: This means it is easy to obtain a quantifiable level of reliability (or uncertainty) in the estimated mean value and enables estimation of variability of the results for the population being tested.

[SOURCE: ISO 11074:2015, 4.2.10]

3.17
random sampling
simple random sampling
taking samples in locations selected arbitrarily within the area to be investigated

Note 1 to entry: The coordinates of the intended sampling locations are derived using pseudo-random or quasi-random numbers which can be found in tables included in manuals on statistics or generated by computer programs.

3.18
regular sampling
taking samples at the nodes of a regular pattern, such as a square or triangular grid, i.e. the sampling locations are evenly spaced

3.19
sampling pattern
set of predetermined sampling points

3.20
selective sample
sample deliberately chosen or formed based on some specific characteristic(s) of the material to be sampled

EXAMPLE Appearance, odour, particle sizes.

[SOURCE: ISO 11074:2015, 4.2.16, modified]

3.21
site investigation objective
statement regarding the information to be obtained during the investigation

3.22
spatial composite sample
composite sample (3.4) formed from small incremental point samples taken over an area (such as a field)

Note 1 to entry: The general premise is that the distribution of soil constituents is relatively homogeneous. The *increments* (3.8) may be located according to a regular grid, random, or other pattern. In agricultural/horticultural land investigations "N", "S", "W" and "X" *sampling patterns* (3.19) are commonly used. Along the outline of such a pattern, a number of samples or increments are taken which are bulked and mixed to provide one (composite) sample for analysis.

3.23
spot sample
sample from a discrete location

Note 1 to entry: Sample can be formed from one or more contiguous portions of material.

Note 2 to entry: Sample may be *disturbed* or *undisturbed*.

3.24
stratified random sampling
dividing the area to be sampled into a number of identical grid cells (strata) and taking samples arbitrarily in each cell

3.25
systematic sampling
taking samples from locations that have been pre-designated according to a geometric or other statistically derived pattern

Note 1 to entry: Systematic sampling can include a random positioning component.

Note 2 to entry: Some systematic sampling patterns are regarded as "*probabilistic*" (3.16).

Note 3 to entry: This definition is wider than the usual definition found in the literature, where systematic sampling commonly means *regular sampling* (3.18).

3.26
systematic unaligned sampling
taking samples using a *sampling pattern* (3.19) intermediate between a regular grid and *stratified random sampling* (3.24), where each row (respectively column) of the grid shows a similar pattern of unaligned points

Note 1 to entry: See Figure B.8.

4 Overall investigation strategy

4.1 General

The sampling strategy for soils and soil materials usually forms part of an overall site investigation strategy. This usually comprises a number of phases as described in 4.3.

NOTE 1 The soil sampling exercise that is being planned could be only one component of a wider investigation strategy that could also require collection of information relating to, for example, groundwater, geotechnical properties of the ground, archaeology, ecology, and soil gas and that for practical and logistical reasons a degree of integration between investigations into different aspects of the site might be required. How this can be done is outside of the scope of this document.

NOTE 2 Soils (and other soil materials) are composed of a mixture of mineral particles, organic matter, water, air (soil gas) and living organisms. In the case of some contaminated soils, a non-aqueous liquid phase might also be present. The solid matrix (phase) consists of particles of different size, shape and physical and chemical properties. The aim when carrying out soil sampling is usually to obtain sufficiently representative samples that can be used to characterize the properties of the whole soil entity (e.g. *in situ* soil in the form of a volume or horizon, or surface deposit such as a stockpile) or the portion considered relevant to the objectives of the investigation (e.g. <0,1 mm fraction for exposure assessment via hand-to-mouth activity). The properties of discrete entities such as individual soil particles are not addressed.

Sample is generally used in this document to mean the field sample. Sampling, therefore, means the collection of one or more field samples. The field sample usually equates to the laboratory sample [i.e. the material sent to the laboratory (ISO 11074:2015, 4.3.7)], although in some cases, the field sample is subjected to pretreatment in the field according to ISO 18400-201 to produce a sample of smaller size to send to the laboratory. The laboratory sample is usually subject, at least in the case of chemical analysis, to pretreatment in the laboratory (according to ISO 11464) in order to obtain a test sample. Physical and biological testing usually require a different approach and often require use of the whole of the laboratory sample. Information is provided in 6.6 and Clause 7 on the amounts of soil required primarily in the context of chemical testing but also for certain physical tests.

Table 1 — Sampling approaches and patterns

Convenience sampling	Judgemental sampling	Samples are taken from pre-designated locations							Spatial composite sampling
		Systematic sampling							
		Linear patterns	Circular patterns	Simple random sampling	Stratified random sampling	Unaligned sampling	Regular sampling		
							Rectangular grid	Non-rectangular grid	

NOTE 3 The terminology used to describe approaches to sampling and sampling patterns, etc. is not always applied consistently. Because of the variability in the use and understanding of terms related to sampling, it is important that those designing or carrying out site investigations explain what they intend to do, or have done, in ways that will be understood by non-experts and avoid reliance on specialist jargon.

The overall site investigation strategy should take into account:

a) the client's reasons for requesting the investigation to be undertaken (these should be clearly set out by the client);

b) the decisions that need to be made regarding the site or other area to be investigated;

c) the confidence required for making these decisions (this will determine the level of detail and accuracy of measurements required);

d) the findings of any investigations already carried out;

e) known data gaps and uncertainties (e.g. in the conceptual site model, see 4.4);

f) the findings of any risk assessment(s) completed to date.

A preliminary investigation (see 4.3.2) in accordance with ISO 18400-202 should always be carried out before any sampling or other intrusive investigation is carried out.

Once the preliminary investigation has been completed decisions should be made whether:

a) an exploratory and/or detailed (main) investigation is to be carried out, and in both cases, whether to carry out a single stage of sampling or two or more stages;

b) to zone the site, e.g. on the basis of past or current land use(s), intended use, or topography (if the site is zoned a separate sampling strategy will be required for each zone), see 4.2;

c) there are safety and environmental issues that could constrain the way that the sampling is carried out, see 5.9.

The objectives of the site investigation should be set before the investigation strategy is determined.

The objectives of a site investigation will vary, depending upon the stage in the process that has been reached and the underlying intentions for the land involved, but could, for example, be to provide:

— information on the pedological state of the site to be sampled;

— information on potential agricultural productivity;

— information on the physical and chemical state of the site to be sampled;

— information on contamination of the ground and groundwater;

— information on natural concentrations of potentially hazardous substances;

— the information needed to form, or further develop, a conceptual site model, including identification of potential pathways and receptors for the purposes of contamination-related risk assessment;

— support for a risk assessment;

— provide data for the design of remedial or protective works;

— provide data for re-use of soil materials (see ISO 15176) or for their disposal as waste.

As information is developed during an investigation, the impact on the objectives and the objectives themselves should be reviewed to determine whether these require modification or extension.

The formulation or refinement of a conceptual site model, see 4.4, should always be one of the investigation objectives and the model should be reviewed and revised in response to the results of the site investigation.

NOTE 4 The conceptual site model is to be no more detailed than required by the task in hand.

NOTE 5 Guidance on the investigations of particular types of site and in connection with the assessment for particular purposes is given in a number of other International Standards including: ISO 18400-205, ISO 18400-206, ISO 11504, ISO 15175, ISO 15176, ISO 15799, ISO 15800, ISO 16133, ISO 19258 and ISO 18400-203.

NOTE 6 An investigation (of potentially contaminated sites) are often carried out in one of the following contexts (see ISO 18400-203):

— in support of a proposal to develop or redevelop a site on behalf of the client (who might or might not be the site owner);

— in connection with the potential sale and purchase of a site to enable its value to be estimated, taking into account potential contaminated land liabilities and possible remediation requirements;

— to "benchmark" site conditions (e.g. contamination levels) for future reference;

— to determine whether it falls within a regulatory regime requiring remediation or some other form of response.

4.2 Zoning

Where logical and appropriate, the site should be divided into zones and separate conceptual site models and investigation strategies developed for each zone. Zoning may be based, for example, on:

— near-surface geology (e.g. made ground or natural ground);

— deeper geology;

— topography;

— probable absence or presence of contamination;

— previous, current or planned land uses;

— the nature of probable contaminants [e.g. volatile organic compounds (VOC) or inorganic compounds];

— known differences in soil types;

— observations on plant health;

— intended future use.

Zoning should be reviewed after each phase (and stage) of the investigation.

NOTE A stockpile or other above-ground deposit can be considered to be a single zone requiring separate investigation, or it can be divided into a number of zones, for example to reflect the method of formation (e.g. in layers or by end-tipping), or to reflect difference in appearance or on an arbitrary basis.

4.3 Types of investigation

4.3.1 General

Four principal phases of investigation are described in 4.3.2 to 4.3.5. The relationship between these phases and other investigation-related activities is shown in Figures 2 to 4. The person designing the overall site investigation should decide what phases of investigations are required, whether one or more of the phases should be carried out in stages, and the scope of each phase or stage of investigation.

Typically, investigations should comprise:

— a preliminary investigation (always required), see 4.3.2;

— an exploratory investigation (not necessarily required), see 4.3.3;

— a detailed investigation (required unless an exploratory investigation indicates otherwise), see 4.3.4;

— a supplementary investigation (sometimes required), see 4.3.5.