
**Soil quality — Conceptual site models
for potentially contaminated sites**

*Qualité du sol — Schémas conceptuels de sites pour les sites
potentiellement pollués*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document can be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 7, *Impact assessment*.

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 provides a definition of the conceptual site model (CSM) for contaminated sites consistent with other ISO standards related to contaminated land. It refers to ISO accepted terminology and generally accepted understanding of a CSM. Links with the ISO 18400 series of standards (*Soil quality — Sampling*) are made. It is applicable to the management of potentially contaminated sites, sites that are known to be contaminated, and also to land with naturally elevated concentrations of potentially harmful substances.

It provides general guidance on the application of CSMs, how they are developed and how they can evolve, with respect to all media, for example, air, surface water, sediments, soil, groundwater, soil gas, biota, subsoil, including buildings and other artefacts.

The CSM is a synthesis of all relevant information about a potentially contaminated site with interpretation as necessary and recognition of uncertainties. The description relies on the concept, of “source-migration pathway-receptor linkages” (sometimes termed « contaminant linkages ») that are, or might be, present.

The investigation of land potentially affected by contamination is usually performed using observations and measurements made on-site as well as by taking samples for laboratory analysis and testing. Soil and groundwater characteristics include a wide span of features, such as chemical and mineralogical composition, soil texture, the concentrations, amounts and distribution of contaminants and soil components. For practical and economic reasons, these investigations cannot cover the total volume of interest, and the on-site measurements and especially the sampling have to be limited to certain points or small areas/volumes.

Spatially limited investigations will give the best possible information if they are planned thoroughly. The questions: “what are we looking for, and what can we expect?” are essential for developing an investigation programme that is efficient and fit for purpose. The best way to start the planning of the investigation is to formulate a CSM, based on a thorough preliminary investigation (desk study and site reconnaissance in accordance with ISO 18400-202) prior to any intrusive investigation.

Therefore, a CSM is a synthesis of information about the site together with some interpretation, assumptions, and hypotheses. By testing the assumptions and hypotheses, intrusive investigations can concentrate on the essential questions and data gaps, and can be planned and carried out more efficiently. Depending on the results of the intrusive investigation, the CSM can be developed further. It can become more detailed, more reliable, and often also modified or corrected, and step by step can lose its conceptual character, although remaining a model.

In the context of potentially contaminated land, a CSM is a tool that can be developed for the planning of an investigation, for undertaking a risk assessment, and for planning remediation and aftercare of a site. It can also be used for construction or other engineering works that are planned for after remediation. A CSM can be used when conducting environmental audits and “due diligence” exercises. The degree of detail needed for the CSM can depend on the objectives of any of these tasks, and the nature, current use and possible development of the site.

When preparing a CSM the terms that are being used should be carefully defined because terms might not be understood to have the same meaning by people with different backgrounds and experience. In addition, CSMs are intended to be of use to those without a technical background.

NOTE This document follows the established convention for documents published by ISO Technical Committee 190 (TC 190) in distinguishing between “contaminant” (“substance or agent present in an environmental medium as a result of human activity – see 3.2 in this document) and pollutant (“substance or agent present in the soil (or groundwater) which, due to its properties, amount or concentration, causes adverse impacts on soil functions” - see ISO 11074:2015, 3.4.18). Hence, “contamination” and “pollution” are not considered to be the same thing. However, it is recognised that this distinction is not always made at “official” level in all jurisdictions. Even in those jurisdictions where it is recognised, it might be for some purposes but not others and the definitions of “contamination” and “pollution” used in legislation and regulations for different purposes can differ. In addition, the use of the terms is not necessarily consistent between and even within guidance documents produced by government and professional bodies.

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Soil quality — Conceptual site models for potentially contaminated sites

1 Scope

This document provides guidance on developing and using conceptual site models (CSMs) through the various phases of investigation, remediation (if required), and any subsequent construction or engineering works.

It describes what CSMs are, what they are used for and what their constituents are. It stresses the need for an iterative and dynamic approach to CSM development.

This document is intended to be used by all those involved in developing CSMs and by those who rely on using them such as regulators, landowners, developers, and the public (and other relevant parties). Ideally, this includes representatives from all phases of the investigative and remedial processes, for example, preliminary assessment, detailed investigation, baseline human health and environmental risk assessments, and feasibility study, and, any subsequent construction or engineering work.

NOTE 1 This document is applicable whenever the presence of “potentially harmful” or “hazardous” substances are present irrespective of whether they are naturally occurring or present due to human activity (i.e. are “contaminants”).

NOTE 2 Although most of the principles described for developing CSMs in this document can apply to other domains, such as groundwater resources management, the present document is specifically written for the management of potentially contaminated sites or known contaminated sites.

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*

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/>

3.1

anthropogenic ground

deposits which have accumulated through human activity

[SOURCE: ISO 11074:2015/DAmD 1:2019¹⁾]

1) Under preparation. Stage at the time of publication: ISO 11074:2015/DAmD 1:2019.

3.2

conceptual site model

synthesis of all information about a potentially contaminated site relevant to the task in hand with interpretation as necessary and recognition of uncertainties

3.3

contaminant

substance or agent present in an *environmental medium* (3.4) as a result of human activity

Note 1 to entry: There is no assumption in this definition that harm results from the presence of the contaminant.

Note 2 to entry: ISO 11074:2015, 3.4.6 defines “contaminant” as “substance or agent present in soil as a result of human activity”.

3.4

environmental medium

soil, underlying material, sediments, surface water, groundwater, soil gas, and air that can contain *contaminants* (3.2)

3.5

exposure pathway

path, route or other means, a *contaminant* (3.3) or hazardous substances from a particular source takes to a *receptor* (3.7)

Note 1 to entry: Each exposure pathway links a source to a receptor.

[SOURCE: ISO 11074:2015, 5.2.12 modified]

3.6

fill

anthropogenic ground in which the material has been selected, placed and compacted in accordance with an engineering specification

[SOURCE: ISO 11074:2015/DAmD 1:2019]

3.7

made ground

anthropogenic ground 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

[SOURCE: ISO 11074:2015/DAmD 1:2019]

3.8

migration pathway

means by which *contaminants* (3.3) or hazardous substances from a particular source of contamination can spread or distribute

Note 1 to entry: A migration pathway does not necessarily link to a receptor.

3.9

pollutant

substance or agent present in an *environmental medium* (3.3), which, due to its properties, amount or concentration, causes adverse impacts on an environmental medium

Note 1 to entry: ISO 11074:2015, 3.4.18 defines “pollutant” as “substance or agent present in the soil (or groundwater) which, due to its properties, amount or concentration, causes adverse impacts on soil functions”

3.10 receptor

defined entity that is vulnerable to the adverse effect(s) of a hazardous substance or agent

Note 1 to entry: Receptors might include persons (e.g. trespassers, current and intended users, construction workers), other organisms or complete ecosystems, environmental media or artificial construction.

[SOURCE: ISO 11074:2015, 3.3.29, modified, note added]

3.11 source

place from which a *contaminant* (3.2) or hazardous agent is released

Note 1 to entry: ISO 11074:2015, 3.3.35 defines “source” as “place from which a substance or agent is released giving rise to potential exposure to one or more *receptor*” (3.7).

4 Basics

4.1 Structure of this document

The structure of this document is shown in [Figure 1](#).

Clause 4 : Basics				
Clause 4.1 : Structure of this document				
Clause 4.2 : Principles	Clause 4.3 : Scope of a conceptual site model		Clause 4.4 : Representing and communicating a conceptual site model	
Clause 5 : Development of a conceptual site model				
Clause 5.1 : Step wise procedure				
Clause 5.2 : Step 1 - Defining the overall objectives and boundaries (both spatial and temporal)				
Clause 5.3 : Step 2 - Identifying the known and potential contaminant(s) and characterizing the source				
Clause 5.4 : Step 3 - Identifying and characterizing each known and potential contaminated medium				
Clause 5.5 : Step 4 - Identifying potential migration pathways				
Clause 5.6 : Step 5 - Identifying potential receptors, exposure pathways and points of exposure				
Clause 5.7 : Step 6 - Identifying possible foreseeable events				
Clause 6 : Conceptual site model development during site investigation				
Clause 6.1 : General	Clause 6.2 : Preliminary investigation	Clause 6.3 : Exploratory investigation (optional)	Clause 6.4 : Detailed investigation (optional)	Clause 6.5 : Supplementary investigations when required
Clause 7 : Conceptual site model for remedial and mitigation measures				
Clause 8 : Conceptual site model for construction works				
Clause 9 : Data collection and quality assurance				

Figure 1 — Content of present document and interactions between the descriptive clauses

4.2 Principles

The conceptual site model (CSM) is a synthesis of all information about a potentially contaminated site or a site known to be contaminated, relevant to the task in hand with interpretation as necessary and recognition of uncertainties.

CSMs are important aids for the development of site-specific investigation programmes, the undertaking of site risk assessments, remediation design, follow up post remediation, and if necessary for subsequent construction on those sites that have been managed to deal with contamination. It is developed following a step-by-step approach (see [Clause 5](#)). Its preparation requires judgement by the person(s) preparing and developing the model.

Once, developed, a CSM should comprise all relevant information, including:

- past and present uses (see ISO 18400-202);
- intended future uses, included where known existing configuration and or future buildings/ infrastructure (e.g. basements, crawlspace under the floor of a building);
- the geological, geomorphological, hydrogeological and hydrological settings, soil, sediments, and air (indoor air and the atmosphere) of the site and surrounding area;
- the properties of the potential contaminants (e.g. volatility solubility, toxicity) and their sources, including distribution of contamination [e.g. plume of contaminant(s)], potential migration pathways (natural and anthropogenic features such as sewer lines) and transport mechanisms;
- potential receptors of the contamination;
- possibilities of new exposure pathways and new receptors associated with the construction and completion of a new development;
- foreseeable events [e.g. potentials for flooding (rivers, sea, groundwater), rising groundwater or seawater levels, extreme weather conditions, change of use, etc.].

The aim of a CSM can be, as appropriate, to:

- present the characteristics of the site;
- identify uncertainties and data gaps and act as a basis for designing further investigations and assessments;
- provides a basis for planning remediation and mitigation measures;
- provide a systematic review of where risks might potentially occur by summarizing possible direct and indirect exposure pathways;
- facilitate as a communication tool, the overall management of potentially contaminated site, e.g. to help in the decision-making process of experts in designing and planning all required actions;
- enable experts from all disciplines, clients, members of the public and regulators to communicate effectively with one another about issues concerning a site and facilitate the decision-making process.

CSM development should start as early in the site investigation process as possible. It should be an iterative process of refinement in which the uncertainties are recognized and reduced as more information becomes available (see [Clause 6](#)). The CSM can evolve as the results of investigations become available and remediation strategies are formed. Refinement of the CSM should continue through any remediation works and protective mitigation measures (see [Clause 7](#)). The planned use of a site following any remediation cannot always be known when the CSM is first developed. The CSM is likely to require review and possible extension following construction works and additional protective mitigation measures as these confirm expected site conditions or reveal new information (see [Clause 8](#)).

Eventually, the CSM should take into account all measures whose implementation can determine the final acceptability of the project, i.e. the total compatibility of site conditions and current or planned uses.

4.3 Scope of a conceptual site model

The complexity of a CSM should be consistent with the complexity of the site and available data and the purpose for which it is developed.

The formulation of CSM should make it possible to determine the linkages between:

- the potential sources of hazardous substances (see 5.3);
- the potential migration pathways, including the various transport mechanisms in each medium and their characteristics (see 5.4 and 5.5);
- the existing and/or future receptors that must be protected (see 5.6).

A CSM should:

- be developed for a defined purpose;
- be no more complex and detailed than required by the task in hand;
- identify uncertainties in the available information and in the conclusions.

A CSM should be prepared taking into account:

- the objectives of the investigation, or the purpose of the remediation (if required) and the purpose of any subsequent construction or engineering works;
- the reason(s) for preparing the CSM, e.g. to aid risk assessment, help communicate with interested parties, to plan remedial measures, or any subsequent construction or engineering works;
- uncertainties in the available data and other information.

The concerns of environmental risk assessment are different from those of human-health risk assessment. These differences are usually sufficient to warrant separate descriptions and representations of the CSM in the human health and environmental risk assessment reports. There can be elements of the CSM that are common to both representations. However, the risk assessors should develop these together to ensure consistency.

4.4 Representing and communicating a conceptual site model

The development of a CSM helps integrate technical information from various sources so it can be used to communicate effectively.

A fully developed CSM can be seen as a mental construct of all the gathered information (see the six steps in [Clause 6](#)). The CSM or one or several aspects of the CSM can be expressed or presented using one or more of the following approaches/representations:

- a text description of the site and all relevant features and processes;
- one or more maps of the site;
- one or more tabular or matrix description;
- one or more drawings or other diagrammatic illustration;
- a series of hypotheses to which qualitative probabilities can be attached.

For example, a diagram can be used to illustrate important examined questions on a potentially contaminated site. It can also help to identify and formulate what the risks are, i.e. understanding what

the sources of contaminants, the migration pathways and receptors are. This allows an understanding of a site in a simple and schematic way.

Examples of the various representations of CSM are provided in [Annex A](#).

5 Development of a conceptual site model

5.1 Step wise procedure

Six main steps have been identified for the development of a realistic and complete conceptual site model (CSM) of a potentially contaminated site (see [Figure 2](#)). The six steps are:

- 1) defining the overall objectives and boundaries (both spatial and temporal);
- 2) identifying the known and potential contaminant(s) and characterizing the source;
- 3) identifying and characterizing each known and potential contaminated medium;
- 4) identifying potential migration pathways;
- 5) identifying receptors, exposure pathways and the points of exposure;
- 6) identifying possible foreseeable events.

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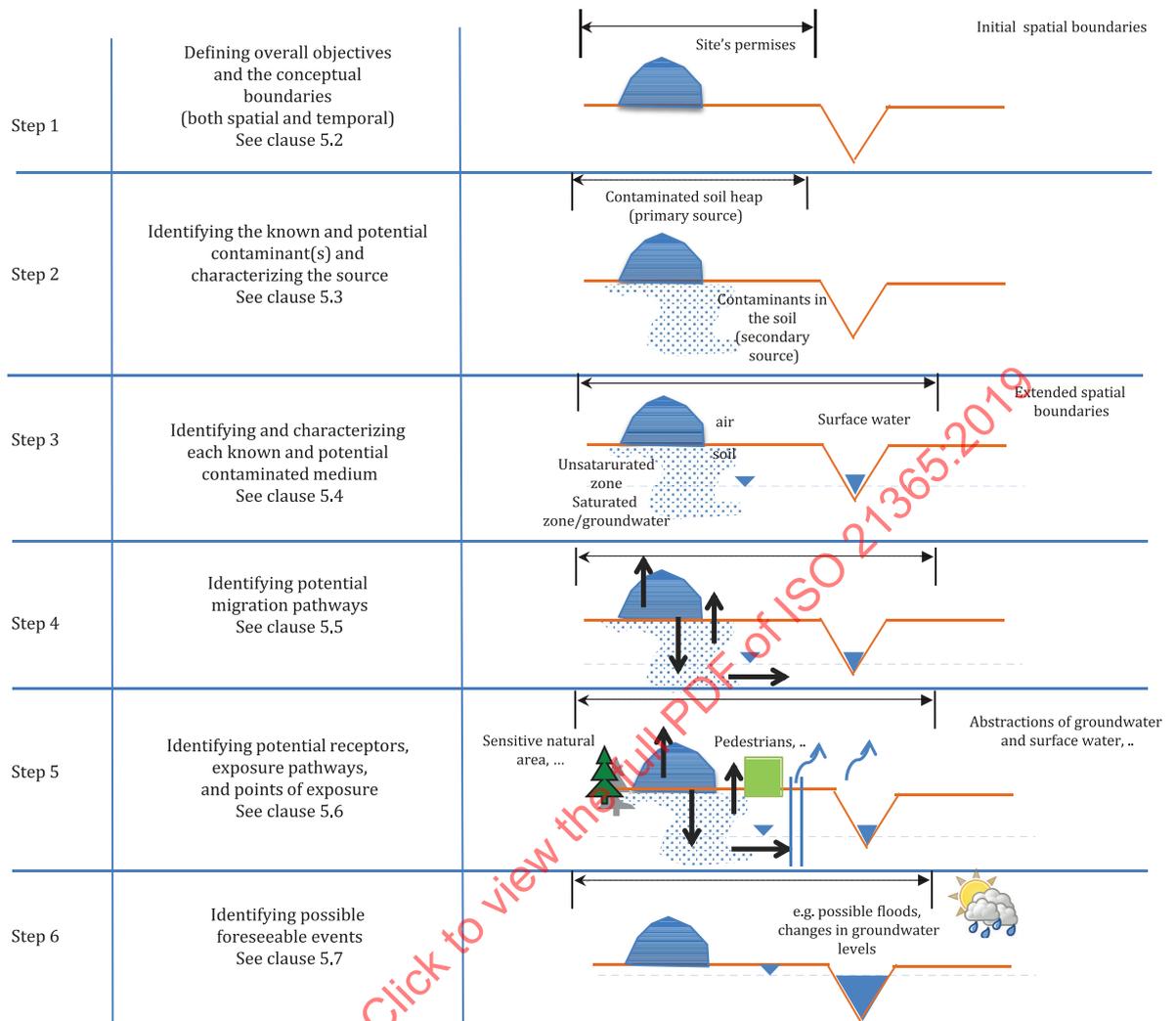


Figure 2 — Diagram illustrating the 6 steps to develop a conceptual site model (Adapted from French National guidance on developing conceptual site model^[20])

The CSM should be reviewed by re-considering the six steps again after each phase of investigation and regularly throughout the risk assessment process. Changes should be made based on the additional information that has become available. A note should be made of whether the new information has decreased or increased the model uncertainties. Further investigation should be considered if the uncertainties are too great to permit realistic risk assessment(s) to be carried out.

All the relevant information that has been gathered should be taken into consideration, whether it concerns the sources of contaminants, the migration pathways or the receptors to be protected. The analysis of conditions for media of concern (e.g. geochemistry, redox conditions) helps determine the magnitude and extent of migration pathways and help to identify the potential exposure points.

NOTE Depending on the phase of the site investigation, there are different degrees of uncertainty as to whether contaminants are present and which media are contaminated. To avoid repetition in the text, “contaminants”, “contaminated medium” or “contaminated site” refer to both potential contaminants, or potentially contaminated medium or potentially contaminated sites and to confirmed contaminants or confirmed contaminated medium or confirmed contaminated sites, as appropriate.

5.2 Step 1: Defining overall objectives and the boundaries (both spatial and temporal)

The overall objectives of the CSM should first be defined. The CSM boundaries, both spatial and temporal, should then be agreed and thereafter clearly communicated through the CSM(s).

All underlying models and assumptions should be valid within the time frame which the CSM is valid for. The changes that are likely to occur during the period of interest should be identified, for example, changes in land use, changes due to erosion, or sea-level change. If changes are likely, different versions of the CSM could be needed to cover/embrace varying conditions over time.

Attention might need to be paid to legal or other context in which the studies are to be carried out.

The defined spatial boundary should correspond to the area of the site being considered initially (e.g. site's premises, installation boundaries etc.), and if appropriate, be reviewed and encompasses a much larger area to include, for example, all the downstream areas that are affected by contaminants spreading from the site (e.g. between step 2 and step 3 in [Figure 2](#)).

A unique CSM should be developed for the site under consideration, unless there are multiple sites in proximity to one another such that it is not possible to determine the individual source or sources of contamination. Sites may be aggregated in that case. An overall CSM should then be developed for the aggregate.

Considerations should be given to whether the site should be divided into separate sub-areas, or zones for which separate CSMs is needed within the overall CSM. The separate sub-areas can be based on differing topography, ground conditions; contamination situation; and past, present and future uses (zoning of sites – see ISO 18400-104). Care should be taken that focus on separate zones does not obscure the overall picture and that the potential interactions between the zones are not overlooked in the separate CSMs.

Several “conceptual models” could also be required to cover different aspects of an investigation, for example, a biogeochemical model to cover contaminant partitioning and availability, a model of the migration pathways, a model of food chain transport or of human exposure. These types of sub-model are then be integrated into the overall CSM.

It is important that the development of the contamination situation with time is considered. This gives us information about whether contaminant levels have increased or decreased in the past and whether they are expected to increase or decrease in the future.

NOTE An example is the case of organic contaminants that degrade either biologically or chemically, where it is important to estimate the likely extent of degradation that has already taken place and that might take place in the future. Another example is the passage of a plume of contaminants, and the situation of the site relative to the passage of the plume; The question can be asked as whether the site is at the breakthrough front of the plume, in the middle of the plume or at the end of the plume.

5.3 Step 2: Identifying the known and potential contaminant(s) and characterizing the source

This step involves identifying the contaminant(s) that are or might be present at the site, and in its surroundings. A first identification is usually based on the assembled information from the preliminary investigation (desk study and site reconnaissance) prepared (see ISO 18400-202). Subsequent investigations can then be carried out to confirm the occurrence of contaminants (see [6.4](#)). Each identified contaminant must then be related to a source. Primary and secondary sources should be distinguished (see the example in [Figure 3](#)).

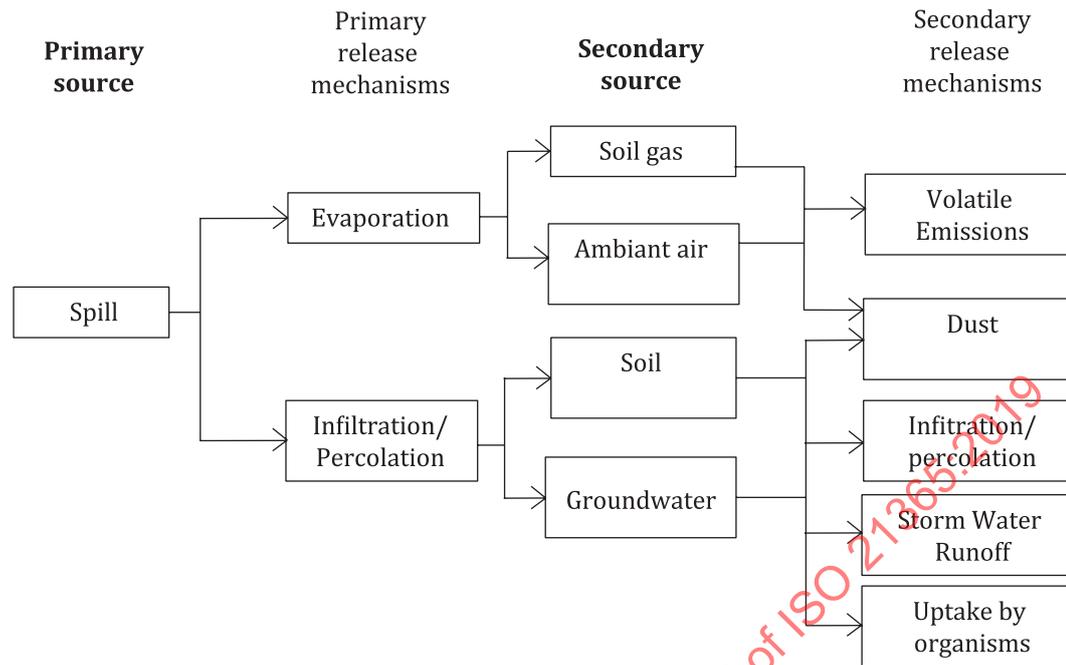


Figure 3 — Example illustrating primary and secondary sources of contaminant released from a spill (e.g. in the case of a fuel spill)

Each source should as far as possible be characterized by the following:

- its origin(s), location(s), depths, extent and relationship to the property boundaries, and accurately shown on a site map or other drawings (including a scale and direction indicator);
- its amount, the volume of the medium which is contaminated, the times of initiation, duration and rate of contaminant release from the source;
- the chemical, biological, physical, toxicological properties of the contaminant(s) that are present in the source and its concentrations in the environmental medium;
- the partitioning of contaminants between the contaminated media (for example between soil, groundwater, soil gases, free phase, surface water, sediments, biota and air).

At this step, the model should propose hypotheses on how and why the contaminant was released from the source(s). If no contaminants are found, a CSM should still be developed, documenting the reasons why contamination is not believed to be present.

Background values at local and regional scale should be sought for all contaminants found at the site. The model should include sufficient information to distinguish contamination attributable to the source(s) under consideration from naturally occurring or nearby anthropogenic sources (e.g. of diffuse contamination).

NOTE 1 This information also helps establish the extent to which contamination exceeds background. Guidance on how to establish background concentrations in soils can be found in ISO 19258.

NOTE 2 Guidance on why particular substances can be of concern and the receptors to which they could be hazardous is provided in ISO 18400-202, Annex A. Examples of associations of important contaminants with industrial uses of land are also provided.

5.4 Step 3: Identifying and characterizing each known and potential contaminated medium

This step involves identifying each known contaminated media or suspected contaminated media i.e. all environmental media or artefacts that would be contaminated by releases from the sources

identified in Step 2. Contaminants could be present, for example in soil, sediments, groundwater, surface water, soil gas, air, and biota. Contaminants can also impact buildings and other constructions, e.g. concrete foundations can become saturated with oil. Potentially contaminated media should be identified based on the information gathered during a preliminary investigation (desk top study and site reconnaissance) (see ISO 18400-202). The model should be reviewed when measurements become available regarding the presence of contaminants in the different media.

Only the relevant media should be considered for developing the CSM. The properties of the media that can influence contaminant behaviour should be determined. For example, pH, redox potential, or permeability, can influence contaminant forms, transport and toxicity.

The media that are not included in the model, however, should be identified as such and the reasons for omitting them from the CSM should be given.

5.5 Step 4: Identifying potential migration pathways

For each contaminated medium identified, contaminant migration pathways should be identified and represented and described in the CSM. The aim is to identify potential points of exposure for people or the environment, thus allowing identification of contaminant receptors.

When developing the CSM, the description of migration pathways can include:

- the mechanism of contaminant release from primary or secondary sources and the type of transport process (see examples in [Table 2](#));
- the medium in which the contaminant is transported (if the relevant environmental receptors are not located at the source);
- the transport processes operating in the contaminated medium and the important factors which determine the rates of transport.

Modelling might be required to characterize migration pathways. The quality and reliability of the results of a contaminant transport modelling study depends on the data that have been used to develop the conceptual model and to construct and refine the mathematical model. If the data are inadequate, the model results are unreliable. The data used should be site-specific and should characterize the site and area being modelled. For example, the final model should contain sufficient information to support the development of current and future exposure scenarios.

A diagram could be used to illustrate the migration pathways for all source types at a site (See Examples in [Annex A](#): A1.5; A16; A4.1; A4.2). [Table 2](#) illustrates examples of migration pathways.

Table 2 — Examples of migration pathways

Contaminated medium	Possible migration pathways and mechanism of contaminant release
Soil	<ul style="list-style-type: none"> Plant uptake Leaching by infiltrating water to the groundwater Suspension of dust Particle transport by surface runoff
Groundwater	<ul style="list-style-type: none"> Unsaturated zone to the saturated zone by infiltration and percolation Groundwater transport through aquifers by diffusion, advection, dispersion, capillary transport Groundwater transport through trenches (for water, sewage, electricity etc.) and other constructions Volatilisation to soil air Solution of free-phase contaminants into the groundwater
Surface water	<ul style="list-style-type: none"> Transport of dissolved and particulate contaminants with storm runoff in the storm water drainage system Transport of dissolved and particulate contaminants by flowing water in rivers and lakes Sedimentation of contaminants which have become associated with suspended particles Ingestion of particles by biota/uptake by or sorption to aquatic plants
Sediments	<ul style="list-style-type: none"> Bed load transport Resuspension of particles Desorption of contaminants from sediment to water Plant uptake from sediments Sediment ingestion by animals
Air	<ul style="list-style-type: none"> Gaseous phase transport through soil- air to the soil surface Transport to indoor air from soil air through building foundations Transport of soil gas through trenches (for water, sewage, electricity etc.) and other constructions Wind transport of dust and of vapours
Free phase contaminant	<ul style="list-style-type: none"> Gravity driven transport through soils and rocks Solution in groundwater, and groundwater transport Evaporation to gaseous phase followed by transport through soil air
Biotic transport	<ul style="list-style-type: none"> Uptake of contaminants by plants Sorption of contaminants to plant or animal surfaces Uptake of contaminants by animals from water or pore water Uptake of contaminants by animals as a result of food ingestion Uptake of contaminants by animals as a result of the direct ingestion of contaminated soil or sediment
NOTE 1 Adapted from French National guidance on developing conceptual site model ^[20] .	

NOTE 2 The identification of migration pathways relies on a good understanding of the physico-chemical properties of the contaminant, which determine its behaviour in the environment being investigated. The physico-chemical properties of the contaminant determine the distribution of the contaminant between different environmental media and the transport processes operating. Examples of important physico-chemical properties are the contaminant's affinity for lipids, solubility in water, density, complex-formation and sorption behaviour.

NOTE 3 The identification of migration pathways and transport processes relies also on a good understanding of the underlying geology and hydrology, on the properties of the environmental medium, the results of site investigations, and information relative to the physicochemical and behavioural characteristics of the substances under consideration (for example, the acidity and alkalinity of the environment, the oxygen status, presence of organic matter, clays or metal oxides). Once in contact with a medium, contaminants are affected by a number of physical or reactive geochemical and biological processes that can retard, concentrate, immobilize, liberate, degrade or otherwise transform the contaminants. Guidance on these parameters is given in ISO 15800 and ISO 15175.

Soil should be considered as a medium and possible migration pathway as human or environmental receptors could come into direct or indirect contact with contaminated soils. Exposure of human, environmental receptors and other receptors at different soil depths should be considered.

Groundwater is not only a potential contaminated medium, but also a possible migration pathway when identified contaminants have already come or could come into contact with the groundwater. When considering groundwater transport, the movement through the unsaturated zone and the saturated zone should be considered. Transport in aquifers can be important and the presence of down gradient springs and wells (irrigation or drinking water) should be considered. In addition, the presence of caves and fractures or other preferred flow paths should be considered as possible migration routes. Understanding the presence of artesian conditions is also important.

NOTE 4 Examples of other fate and transport phenomena for consideration include infiltration, percolation, hydrodynamic dispersion, interphase transfers of contaminants, and retardation.

Surface water and sediments should be considered as media and possible migration pathways when a body of water (river, lake, drainage ditch, etc.) is in direct contact with, or is contaminated by a source or contaminated area. Contaminated groundwater can discharge contaminants to surface water and surface runoff or storm water can transport contaminants from land to surface water. Also, under arid conditions ephemeral drainage can convey contaminants to downstream points of exposure.

Air should be considered as a medium and possible migration pathway when contaminants are in media capable of releasing gases or particulate matter to the air (for example surface soil, subsurface soil, surface water). Contaminated air can be found in the pore space of soils, in construction artefacts (for example in drainage and water pipes), in indoor spaces and outdoors. Transport of air between these different compartments could be an important migration pathway, for example the penetration of soil air into buildings. Diffusion and convection are important transport processes for contaminants in the vapour-phase, whereas particulates are transported only by air flows. Transport of soil air is highly dependent on the soil water conditions. The migration of contaminants from air to other media should be considered, for example, deposition of airborne particulates onto surface waters and soil.

Free-phase organic contaminants that are lighter than water (LNAPLs – light non-aqueous liquids) can form layers on surface waters and groundwater and migrate in this form over large distances. They can migrate upwards into the unsaturated zone due to capillary action and dissolve in the water in which they are in contact.

Free-phase organic contaminants that are denser than water (DNAPLs – dense non-aqueous liquids) are transported under gravity in free-phase until they reach an impermeable layer. Gravitational transport is often not in the direction of groundwater transport. DNAPLs can be found in pools over impermeable layers in the soil or at the surface of impermeable bedrock. Alternatively, free phase DNAPLs can penetrate into fractures in the rock. Further transport of free-phase contaminants can occur after dissolution in water with groundwater flows or after evaporation to soil air with pore-air transport.

In the soil, free-phase contaminants (both light NAPLs and DNAPLs) can be retained by adsorption to the solid phase, particularly to organic matter and also be left in the pore spaces of soils.

Transport of contaminants can also occur following uptake into biota, for example, uptake from soils into plants, and uptake from water and sediment by aquatic plants and animals. Further transport in the food chain via herbivorous animals and carnivorous animals to top consumers can occur. People can also be exposed by the consumption of plants, animal products and fish. Many organic, lipophilic contaminants found in soils or sediments can bioaccumulate and bioconcentrate in organisms such as plankton, worms, or herbivores and biomagnify throughout the food chain, leading to high

concentrations of contaminants in organisms such as carnivorous fish, mammals or birds. The movement of contaminated biota can transport contaminants.

The dynamics of transport processes should be considered. This may be particularly important in the case of the transport of a contaminant plume in groundwater or in air, when it is important to understand whether the current contaminant situation is a result of plume breakthrough, or whether the area being assessed is currently positioned in the middle of the plume, or whether the main body of the plume has already passed the site.

5.6 Step 5: Identifying potential receptors, exposure pathways and points of exposure

The aim of this step is to identify each medium to which people, the environmental and other receptors are or might become exposed, and the points of exposure.

Potential receptors include media, humans, other organisms and artefacts that are in direct contact with the source of contamination or present along the migration pathways. Potential exposure pathways to different environmental media are shown in [Table 3](#).

Receptors can be exposed to the contaminants either directly from the source or following the migration of contaminants through media. Therefore, this step involves searching for all uses of environmental media that might expose humans and the environment, directly or indirectly, to contaminants.

Groundwater and surface water could constitute water resources, and as such are receptors in their own right. The soil, sediments and waters are also the habitat for biota, and therefore should be considered as receptors with regard to environmental effects.

When human exposure is likely, exposure pathways that can be considered include soil ingestion, water ingestion, animal product consumption, vegetables ingestion/intake via plants, dust inhalation, vapour inhalation and skin contact (see ISO 15800 for further guidance).

In the case of human receptors, exposure can be direct, i.e. by the ingestion of a contaminant, e.g. by children playing in a contaminated media, or indirect e.g. by the ingestion of contaminants through consumption of water, fruits, vegetables or meat, from a contaminated environment or watered with contaminated water. [Table 4](#) highlights possible uses for the main media.

Table 3 — Potential exposure pathways and media to which exposure may occur

Receptor	Exposure pathway	Media to which exposure may occur
People	Oral ingestion	Soils, sediment, dust
	Skin contact	Soils, sediment, water, vapour, building materials
	Inhalation of vapours	Outdoor/indoor air
	Inhalation of dust	Dust
	Consumption of contaminated drinking water	Groundwater, surface water, water in the pipes due to permeation from contaminated soil sediment, groundwater
	Consumption of plants grown on contaminated soils or irrigated with contaminated water	Fruit, vegetables, wild berries, edible fungus
	Consumption of animal products from animals grazing on contaminated land or consuming fodder produced on contaminated land or contaminated groundwater	Milk and dairy products, meat, eggs
	Consumption of fish, algae, or shellfish from contaminated surface water bodies	Surface water
	External radiation from radioactive substances	Soil, sediments, buildings materials

Table 3 (continued)

Receptor	Exposure pathway	Media to which exposure may occur
Environment	Contamination of water resources	Groundwater and surface water
	Direct uptake across membranes by biota from contaminated water, soil or sediment	Groundwater and surface water, soil, sediment, soil gas, air
	Intake of contaminated water, soil or sediment as fodder or water, or unintentional intake (such as soil contamination on fodder)	Soil, sediment, water
	Food chain transport; the consumption of biota contaminated by contact with or consumption of one of the contaminated media identified	Contaminated biota

Table 4 — Examples of uses of particular of exposure media that might expose humans, environmental and other receptors

Exposure medium	Possible uses within the site/surrounding environment
Sediments	Sediment extraction/dredging Land spreading for agricultural purposes Recreational /occupational exposure (for example, drawing up anchors) Drainage of former water/marsh areas for use for housing, agriculture, industry
Soil	Soil and soil materials (as a resource) extraction/quarrying/peat cutting/soil improvers Civil engineering elements and structures being used or to be kept following the redevelopment of the site (*) Resource to be preserved for agriculture Resource to be preserved for nature conservation Basis for housing, green areas and industrial areas
Soil+Biota	Horticulture, farming, vegetable gardens Residential, commercial, recreational, industrial uses
Groundwater and surface water	Drinking water uses, food industry, farming uses, fisheries, fish farming, shell – fish farming, recreation. Resources to be preserved (quality objectives defined by national and local water management plans)
Unconfined air (atmosphere)	Inhalation by population and animals
Confined air medium (inside buildings)	Buildings being used (attendance rate on the site or in the vicinity, if the latter is concerned duration of human presence)
(*) For example, organic solvents can dissolve PVC gaskets, and drinking water distribution systems can be permeable to contaminants in the soil when the pipe materials are inappropriate.	

The continuity of the "water" medium means that a use identified at any given point should be considered to be characteristic of the entire sector. Thus, for example, one drinking water well means that the drinking water use concerns the entire aquifer under consideration.

In the case of environmental receptors, it might be necessary to compile a list of taxa representative of the major groups of species present at the site.

When considering soil being impacted by contaminants, direct exposure points are located on or near the site. When considering groundwater, the direct exposure points can be much further away (e.g. drinking water wells).

The final CSM can be illustrated using a map or diagram indicating the physical boundaries of areas within which environmental and human receptors are potentially or currently exposed to the source(s) or migration pathways (see Examples A1 and A2 in [Annex A](#)).

Separate maps or diagrams can be prepared to illustrate specific contaminants or groups of contaminants.

Once the relevant exposure media have been listed along with, their uses and possible migration pathways, the potential receptors and specific exposure points can be identified. In this way, a CSM can lead to the expression of probability of the occurrence of an adverse effect.

The potential for both current and future releases and migration of the contaminants along the migration and exposure pathways to the receptors should be determined.

5.7 Step 6: Identifying possible foreseeable events

Foreseeable events which could affect contaminant impacts or create new exposure pathways should be identified. These could include potential for flooding (rivers, sea, groundwater), rising groundwater or seawater levels, extreme weather conditions, and changes in the use of the land etc. In some cases (e.g. flooding) it might be possible to attach probabilities to an event occurring within a specific time frame.

Detailed knowledge can be required about the site in order to identify possible foreseeable impacts on contaminant behaviour, for example:

- Rising groundwater might come into contact with contaminants hitherto in the unsaturated zone or wet biodegradable material which has previously been dry (e.g. because it is under a low permeability cover). Increases in groundwater levels could arise from natural events (e.g. changes in rainfall) or reduced abstraction for potable or industrial uses. The construction of deep structures into the groundwater can also affect the local groundwater regime.
- Certain engineering works to improve ground bearing capacity or the superimposition of a covering system as part of remediation could cause settlement of the ground bringing contaminants hitherto in the unsaturated zone into the groundwater or wetting biodegradable material, which has previously been dry.
- There might be no firm plans for change use of the land in the short-term but there could be a longer-term plan or changes be foreseeable on the basis of changes on nearby land.

6 Conceptual site model development during site investigation

6.1 General

A conceptual site model (CSM) first comes into existence the moment the question is asked whether the site needs to be investigated but is usually first formalised after preliminary investigations have been completed (see [6.2](#) to [6.5](#)). The development of the CSM should continue through the execution of any remedial works and mitigation measures (see [Clause 7](#)). The CSM should also be kept under review during any subsequent construction phase as this too might lead to the discovery of unexpected contamination etc. (see [Clause 8](#)).

A proper understanding of the principles that should underlie the design of any site investigation is essential to the collection of the data and other information required for the development of a soundly based CSM. Investigations of contaminated sites should be designed in accordance with the guidance in ISO 18400-104 and ISO 18400-203, which describe the principal phases of investigation: preliminary, exploratory, detailed and supplementary (see [Annex B](#)).

The uncertainties in the CSM drive the design of the investigations. Characteristically, each phase and subsequent activity, provide, as indicated in [Annex C](#), different types and amounts of information, and might indicate a need to carry out additional field or documentary research in order to address newly

identified uncertainties. Similarly, new information might become available during any remedial or protective works, or subsequent construction or engineering works that indicate a need to update the CSM.

It is important not to forget that the CSM might also be required to inform the design of mitigation, protective or remediation works and might influence how construction works are to be carried out.

Monitoring of contaminants in different media could be required at all stages of an investigation and beyond the investigation phase. The CSM should be updated as monitoring data becomes available.

For example, monitoring of groundwater and soil gas as part of a site investigation should be carried out to enable a proper understanding of site conditions and how these vary with time. Indeed, realistic risk assessments are often not possible if this is not done. Monitoring can be required during remediation to check whether the works are having an adverse impact, e.g. by mobilizing contaminants or increasing gas flows. Post remediation monitoring aids evaluation of the effectiveness of remedial actions in reducing the exposure of human and other receptors to contaminants. Finally, monitoring can include long-term programmes of inspection to check that a cover system is working properly (e.g. assessment of vegetation cover), i.e. not just groundwater and soil gas monitoring.

NOTE 1 Groundwater and soil gas conditions can vary over comparatively short time spans (e.g. tidal influences, changes in atmospheric pressure and weather conditions), seasonally (e.g. growth and decay of vegetation causing changes in water demands, changes in rainfall amounts) and over extended time periods (e.g. degradation and dispersion of contaminants in groundwater, decay of methane and/or carbon dioxide producing materials in soil and groundwater, rising groundwater levels).

NOTE 2 Groundwater levels can also be affected by human activities such as the closure or opening of an industrial abstraction, or variable use during the year.

Those developing a CSM should liaise with those carrying out studies for other purposes, e.g. geotechnical studies, archaeological studies and ecological surveys, etc. The development of the geotechnical ground model follows a similar iterative process to the development of the CSM (see ISO 1997-2:2007, 2.1).

Information might be gathered in the course of these other studies relevant to the CSM and also those with different expertise might provide a different perspective on a piece of information. In addition, such liaison can avoid duplication of work and hence help to contain costs.

6.2 Preliminary investigation

The scope of a preliminary investigation is presented in [Annex B](#). The preliminary investigation should provide sufficient information:

- for an initial CSM to be developed;
- for initial conclusions to be drawn about potential risks to human and other receptors; and
- to determine whether there is a need for further action (e.g. field investigation – this might be intrusive or non-intrusive).

The initial CSM helps highlight data gaps, enable the setting of formal hypotheses that can be tested by investigation, and the design of any subsequent investigation including health and safety aspects and environmental protection aspects. If the hypothesis of probably uncontaminated sites is shown to be sufficiently robust it might not be necessary to carry out any further investigations.

Examples of formal contamination-related hypotheses that can be tested during a subsequent exploratory or detailed phase of investigation include:

- hypothesis of probably uncontaminated site or zone;
- hypothesis of probably contaminated site or zone;
- hypotheses relating to spatial distribution of contamination (see ISO 18400-203, Annex A).

Non-contamination related hypotheses might concern, for example, the nature and thickness of strata, depths to groundwater and groundwater flow directions etc.

6.3 Exploratory investigation

The scope of an exploratory investigation is presented in [Annex B](#). The data and information produced during an exploratory investigation are assessed to determine if the hypotheses from the preliminary investigation such as those listed in [6.2](#) are correct, and, where appropriate, to test other aspects of the CSM. This enables:

- the CSM to be updated;
- any preliminary risk assessments to be updated;
- determination of whether any further investigation, e.g. further exploratory investigation or a detailed investigation, is required; and;
- any further investigation to be designed.

6.4 Detailed investigation

The scope of a detailed investigation is presented in [Annex B](#). A detailed investigation should enable:

- a comprehensive CSM to be prepared;
- any risk assessments to be updated;
- determination of whether protective mitigation measures or remedial works are required and generalizations about the type of measures that might be appropriate;
- identification of important uncertainties and determination of whether any further investigation is required, for example to fill in information gaps and to provide information that aids the selection and design of remedial or protective works, or necessary for selection or design of construction works (e.g. the choice of the piling methods to be used and location and design of drainage systems could be influenced by the presence of contamination).

It is often beneficial for technical or other reasons to carry out detailed investigations in two or more stages with the CSM being updated on completion of each stage. Staging can often be necessary when a site is operational, or although non-operational, buildings and plants still remain on the site limiting where trial pits and boreholes can be placed. In such circumstances, sampling locations are often mainly those targeted at suspect areas (as in an exploratory investigation) and those placed where access is feasible (convenience sampling). This can leave large parts of a site not investigated. There can be large gaps in overall coverage and hence in the CSM. Failure to properly acknowledge these limitations and consequential uncertainties can lead to unjustified extrapolations and over-interpreted risk assessments.

6.5 Supplementary Investigation

The scope of a supplementary investigation is presented in [Annex B](#). A supplementary investigation of a contaminated site might be required, for example to:

- enable the CSM to be updated;
- inform a detailed quantitative risk assessment (e.g. testing bioaccessibility or establishing site specific soil-to-plant uptake factors);
- provide additional information needed to design and cost remedial works (e.g., to delineate volumes of soil requiring remediation);
- carry out specific tests to evaluate the suitability of specific remedial treatment techniques.

NOTE Each possible remediation method is likely to have specific information requirements and it is seldom possible to satisfy all these requirements during the detailed investigation. Indeed at this stage of the overall project it is unlikely that the remediation method(s), if any, to be used is known. Similarly, the future use, and hence construction needs might not be known (see also [Clauses 7](#) and [8](#)).

Reducing uncertainties in the CSM can save money, especially for example by enabling better quantification of how much material to excavate for treatment or disposal. Various studies have shown there can be an optimal amount of additional site investigation aimed at a better understanding of the variability and distribution of contamination that can save money (see for example ISO 18400-104, Annex C). The same can be true for other soil and site characteristics (e.g. thickness of anthropological ground).

7 Conceptual site model for remediation and mitigation measures

In order to prepare for remediation or mitigation, the overall conceptual site model (CSM) might have to be extended to embrace a wider range of site characteristics. Each possible remediation or mitigation measures is likely to have specific information requirements and it will not usually be possible to satisfy all these requirements during the detailed investigation so supplementary investigation could be required (see [6.5](#)).

Proper regard should be paid to the geotechnical ground model when selecting and designing remedial and protective measures. For example, the engineering properties of the ground could severely limit the choice of available options, and a failure to properly understand them could lead to adoption of measures that result in adverse impacts on the environment during execution and on completion of the works.

NOTE 1 For example, if a metre-thick clean cover system is applied to the surface of a site, this surcharge could cause settlement so that material originally present in the unsaturated zone is forced into the saturated zone so that contaminants are mobilized and/or putrescible materials begin to generate carbon dioxide and/or methane. Pore space could be reduced causing contaminated groundwater, non-aqueous liquids, and soil gas to be expelled.

Other “models”, e.g. archaeological, ecological etc. might also impose constraints on the choice and execution of remedial works and the mitigation measures.

When remediation or protective mitigation measures have been chosen, the CSM should be used to check for unwanted constraints on future uses of the site (e.g. on planned construction works).

NOTE 2 For example, if a clean cover system 1 metre thick is planned, but foundations are expected to go to 1,5 metres and water pipes have to be laid at no less than 0,8 metres, are these things that could be done without compromising the integrity of the cover system, bringing contamination to the surface, or putting the water pipes at risk?

A regular comparison should be made during the execution of remedial works and mitigation measures between what is found and what is expected and the CSM updated accordingly (see [Annex D](#)). For example, unexpected contamination might be found, a greater thickness of anthropological ground found than expected or depths to groundwater might not be as expected. A need for additional investigation might arise.

8 Conceptual site model for construction works

When a site is to be redeveloped, the planned construction activities and the form of the completed buildings (e.g. presence of basements, form and depth of foundations, amount of hard/soft landscaping) and other artefacts must be integrated into the CSM. The planned construction works can include additional specific protective mitigation measures (e.g. inclusion of gas protection, ventilation in buildings or basements etc.).

The development of the CSM should continue during the execution of the construction works (see also [Annex D](#)). The comprehensive CSM should include what is known about any remediation, mitigation measures and additional protective mitigation measures that have been carried out and take into account, any post-remediation monitoring.

If the original detailed investigation was comprehensive and the remedial works have been properly verified, there might be few uncertainties about site conditions. However, review of the available information could reveal uncertainties that need to be addressed by further investigation before construction plans can be finalized.

Further refinement can also be required several years afterwards if construction or other works occur as part of an integrated project soon after remedial or protective works have been completed or occur.

Finally, on completion of all site works, an “as built” CSM should be prepared. If there is any post-completion monitoring, e.g. for soil gas or groundwater quality, or for monitoring of protective mitigation measures, further refinement of this CSM can be required.

NOTE Reclaimed/development sites can often stand empty for an extended period whilst development plans are made and can sometimes be sold and resold several times before development occurs.

Care should be taken to pay proper regard to the geotechnical ground model and to consider possible interactions between planned construction works and completed remediation works. Failure to do so could undermine the effectiveness of the remedial works and protective mitigation measures.

Attention should also be given to any works designed to improve the engineering properties of the ground (e.g. temporary surcharging, dynamic consolidation and stabilization) and to foundation choices (e.g. displacement piles, replacement piles, stone columns) because there can be profound impacts on contamination including its dispersion in water and soil gas.

9 Data collection and Quality Assurance

Quality Assurance comprises all those measures taken to ensure that results of the investigations are “fit for purpose” including documentation, procedures to be followed, the setting of data quality objectives and reporting. For example, methods used for obtaining analytical data should be described, and sources of information should be referenced.

Quality Assurance when collecting data and developing a CSM is important. The process for looking into Quality Assurance relies on two major issues:

- 1) planning to ensure data quality is considered, by identifying quality criteria
- 2) evaluating the quality of data and information once collected to ensure it meets identified criteria

Uncertainties associated with the CSM need to be identified clearly so that efforts can be taken to reduce these uncertainties to acceptable levels. Early versions of the CSM, which are usually based on limited or incomplete information, can identify and emphasize the uncertainties that should be addressed.

NOTE ISO 18400-106 provides guidance on Quality Assurance with regards to soil sampling.

Annex A (informative)

Expressions and illustrations of conceptual site models for potentially contaminated sites

A.1 Introduction

As described in the main text, a fully developed conceptual site model (CSM) can be seen as a mental construct of all the gathered information. The CSM, or most of the time, one or several aspects of the CSM can be expressed or presented using different approaches/representations to support the narrative (and which may be combined). Indeed, it is very rare that a single illustration without explanatory text can be regarded as a sufficient representative CSM.

Approaches to illustration of aspects of conceptual site model are provided below in the follow examples:

- Examples A1: several aspects of a CSM presented as a text description, tabular format, and diagrams showing aspects of the conceptual site model at different stages of the project;
- Examples A2: several aspects of a CSM expressed using one map of the site;
- Examples A3: several aspects of a CSM expressed using a tabular (or matrix) description;
- Examples A4: several aspects of a CSM expressed using diagrammatic illustrations (or drawings);
- Examples A5: several aspects of a CSM expressed as a series of hypotheses to which qualitative probabilities as to their veracity can be attached.

NOTE All examples are for illustrative purposes only. They are not necessarily complete CSMs. Not all possible contaminant linkages are listed and each individual illustrative model does not provide information, for example, on different locations of contaminants that could lead to different contaminant linkages.

Examples A1: Several aspects of a CSM expressed using combined text description, tabular format and diagrammatic illustrations

This example presents several aspects of a CSM in a combined text description, and diagrammatic illustrations at different stages of a project.

The text description covers 1) an overview of the proposed site use, the site setting and the site history ([Table A1.1](#)), 2) the identification of sources and contaminants and initial responses to some of these (especially soil gas) ([Table A1.2](#)) and 3) a presentation of a qualitative risk assessment and the actions that are proposed to mitigate any identified potential or actual risks ([Table A1.3](#) and [Table A1.4](#)). [Figure A1.5](#) illustrates the CSM developed prior to the design of the proposed works and [Figure A1.6](#) the conceptual site model as it was expected to be on completion of the planned works.

Table A1.1 — Section 1: Project summary

Project Summary
<p>The client proposed to construct a two-way single carriageway with illumination, footpaths and provisions for cyclists to connect two existing roads to alleviate traffic pressures through a town centre.</p> <p>The route is to cross over problematic geology consisting of a large historic landfill and compressible superficial deposits. The site is adjacent to sensitive receptors including residential areas, a school and a primary river.</p> <p>The north western area of the site has a history of quarrying and infilling from the late 1800s through to the 1950s. Additionally, the south western area of the site has hosted several industrial factories; most notable an large Battery Works from 1938 to present day. The consultant adopted the road alignment which was determined as optimal so as to avoid contamination/maximize development areas.</p> <p>It was concluded that the most efficient method to break viable contaminant linkages was to remove potential migration pathways from source to end user receptors utilizing a clean cover system. Sustainability and minimal import/export of materials were key objectives. Groundwater elevations were observed to be below construction levels with evidence from previous investigations and regulatory approval that risk to controlled waters were unlikely to be exacerbated by the construction of the proposed road. To reduce costs of disposing of soil to landfill, a material management plan under UK guidance^[26] was utilized to partially recover and re use excavated soil within construction as road sub-base material.</p>

Table A1.2 — Contaminants as determined in initial screening and groundwater quantified risk assessment (GQRA)

Soil	Groundwater	Ground Gas
<ul style="list-style-type: none"> — Lead — PAHs — Asbestos <p>(above assessment criteria)</p>	<ul style="list-style-type: none"> — Groundwater was not encountered during the investigation and determined as below construction level. — Previous investigations and monitoring identified contaminants however the consultant gained regulatory confirmation that the road construction will not exacerbate or impact upon controlled water receptors. 	<ul style="list-style-type: none"> — On-site soil gas was not expected to pose a risk to the proposed development, as the highway design does not include any confined spaces (with the exception of service conduits) which could allow ground gas to accumulate. — Service conduits will be designed to vent passively. — During works site personnel will not be permitted to enter any confined spaces. Development of the surrounding area will likely require additional assessment and possible ground gas protection measures.

Table A1.3 — Plausible contaminant linkage of concern for made ground and landfill materials

Contaminant Linkage			Plausible Linkage of Concern?	Commentary and Proposed Responses
Sources	Migration Pathways	Receptors		
<p>Made Ground</p> <p>Metals (lead) -encountered towards to the south-east part of the site</p>	<p>Accidental ingestion and/or dermal contact with contaminated soil and/or leachate, inhalation of contaminated dust</p>	Human Health - Site personnel	Yes	<p>GQRA has identified contaminants of concern as above assessment criteria. Site personnel have a greater chance of coming into contact with contaminated soils. Particularly during excavation and soil recovery works.</p>
<p>Landfill Material</p> <p>PAHs and VOCs (Benzo(a)anthracene)</p>		Human Health - End users	No	

* As defined in the UK a "Secondary A" aquifer comprises permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.

Table A1.3 (continued)

Contaminant Linkage			Plausible Linkage of Concern?	Commentary and Proposed Responses
Sources	Migration Pathways	Receptors		
Benzo(b)fluoranthene, Benzo(a)pyrene and Dibenzo(a,h)anthracene)	Leaching of contaminants from made ground through infiltration and percolation of rainwater	Controlled waters, underlying Secondary A* aquifer	Yes (limited)	The development of the proposed road (hardstanding and drainage) will reduce the leachate produced from contaminated soils, and therefore reduce the impact to groundwater. Off-site sources are still likely to be predominant mechanisms of contamination to controlled waters.
		Infrastructure and services	Yes (limited)	The development of the proposed road (hardstanding and drainage) will reduce the leachate produced from contaminated soils. Infrastructure and services shall be designed to resist chemical attack and ingress.
Made Ground Asbestos (Asbestos containing materials (ACM) and loose fibres)	Inhalation (of fibres). Construction works disturbing bound material and releasing fibres	Human Health - Site personnel, end land users, and users of adjacent sites	Yes	Risk of inhalation of fibres during ground investigation and construction works. Disturbance of ACMs and dust derivatives from construction would increase risk to adjacent sites.
* As defined in the UK a "Secondary A" aquifer comprises permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.				

Table A1.4 — Plausible contaminant linkage of concern for ground gas and groundwater

Contaminant Linkage			Plausible Linkage of concern?	Commentary and Proposed Responses
Sources	Migration Pathways	Receptors		
Ground gas Ground gases (methane and carbon dioxide in the landfill areas as monitored during previous studies)	Inhalation of ground gas Accumulation of ground gas in confined spaces (asphyxiation or explosion)	Human Health - site personnel	Yes (limited)	During excavation work removal of confining strata may expose workers to volumes of pocketed gas. Protective measures during the works required. Limited linkage based on concentrations and flows observed during monitoring from previous studies.
		Human Health - end users	No	The highways design does not include confined spaces with the exception of service conduits.
		Infrastructure and services	No	Service conduits have been designed with passive venting systems.

Table A1.4 (continued)

Contaminant Linkage			Plausible Linkage of concern?	Commentary and Proposed Responses
Sources	Migration Pathways	Receptors		
Groundwater	Contact with contaminated groundwater	Human Health – site personnel	No	Groundwater is known to be consistently below the construction level and as such it is expected that construction workers will not encounter groundwater.
		Human Health – end users	No	Groundwater is known to be below construction level and as such, is expected to not rise above ground level or the final level of the road.
	Contaminants leached from the Made Ground and from off-site sources may be mobilised to greater distances through advective flow	Controlled waters (primary river), aquatic flora and fauna Infrastructure and services	No	Impacted groundwater could transport contaminants vertically and horizontally through permeable strata. However, the site works will not exacerbate this, and site work will be undertaken above the water table. Groundwater will need to be considered for surrounding developments.

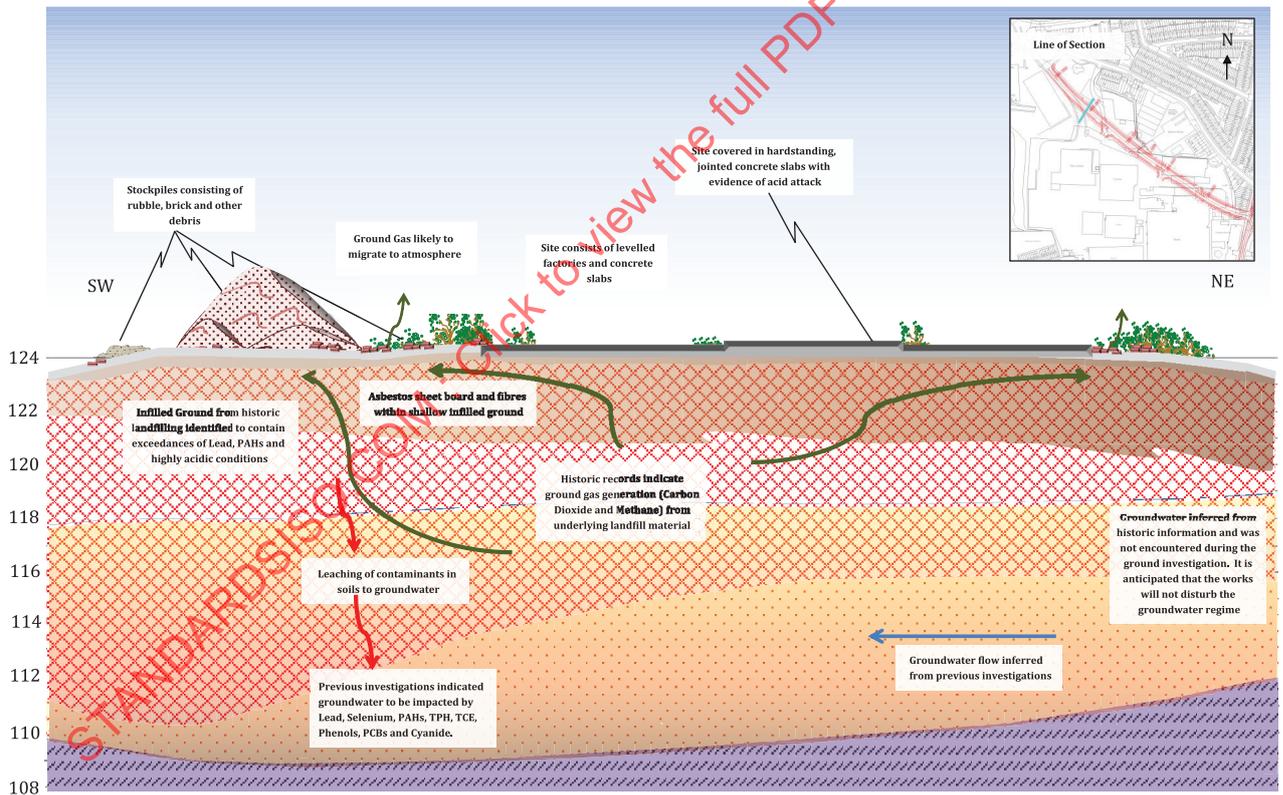


Figure A1.5 — Illustration of the CSM as it was following preliminary assessment (Adapted from original supplied by Amey Consulting)

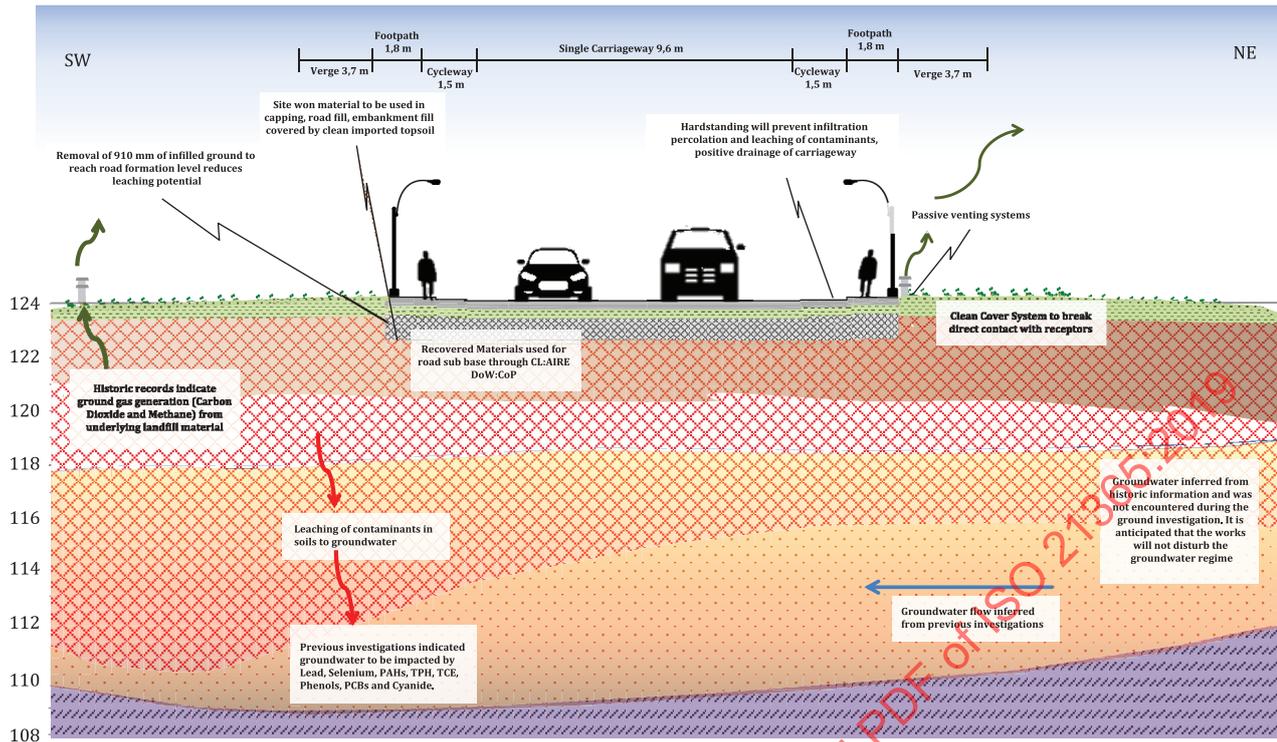
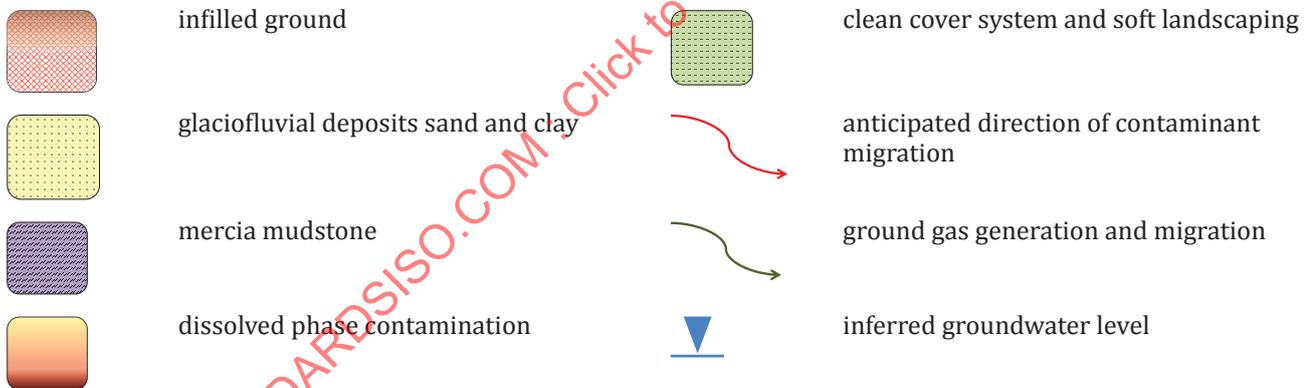


Figure A1.6 — Illustration of the CSM as it was expected to be on completion of the planned works (Adapted from original supplied by Amey Consulting)



Key for Figures A1.2 and A1.3 (Adapted from original supplied by Amey Consulting)

Examples A2: Several aspects of a CSM expressed using a map of the site and a diagrammatic illustration

Figure A2.1 provides a plan view of the source (leaking tank), main receptor (water supply borehole), and exposure pathway within the groundwater (highlighted by the groundwater flow direction) and actual risks to the nearby water supply borehole.

Figure A2.2 highlights the source and contaminants (e.g. benzene) and actual risks to the nearby water supply borehole, following an exploratory investigation and prior to the design of any remediation works.

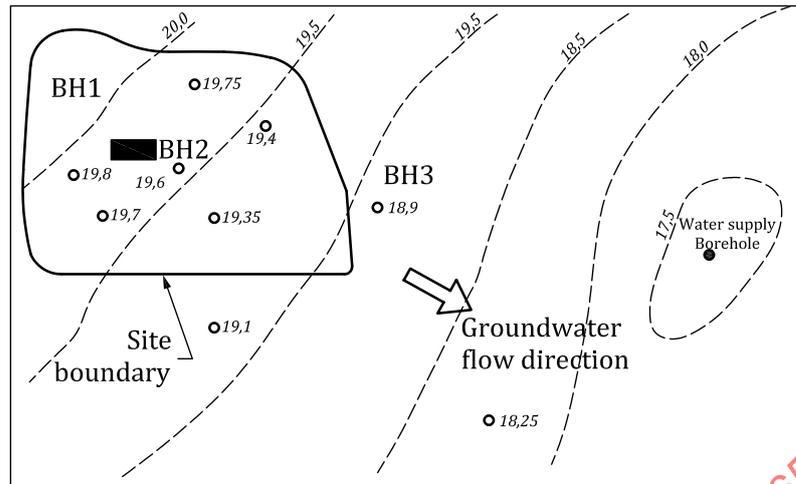


Figure A2.1 — Plan view showing aspects of a CSM in the context of a leaking storage tank - showing groundwater contours and source - migration pathway - receptor linkage (adapted from Model Procedures for the Management of Land Contamination, Contaminated Land Report 11[24])

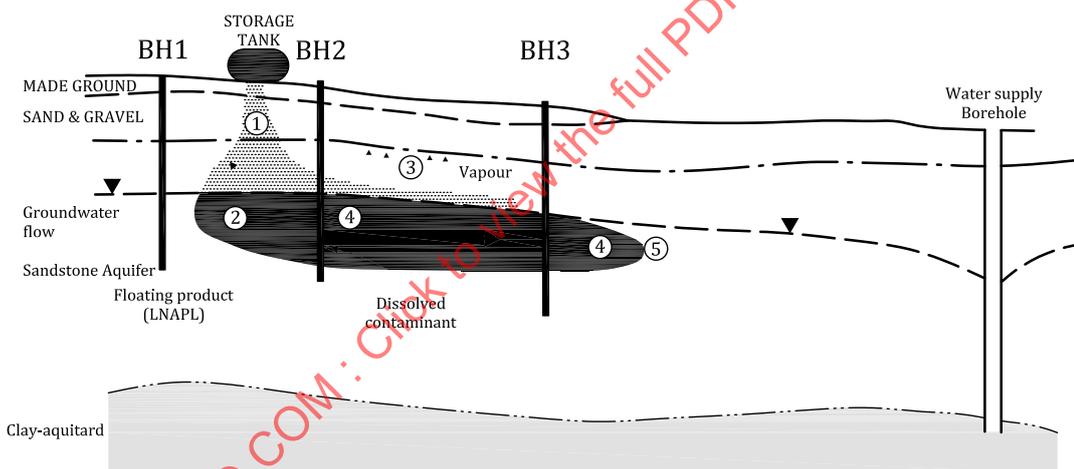


Figure A2.2 — Diagrammatic illustration of parts of a CSM in the context of a leaking storage tank- cross-section view showing source - migration pathway - receptor linkages (adapted from Model Procedures for the Management of Land Contamination, Contaminated Land Report 11[24])

Examples A3: Several aspects of a CSM expressed using tabular format

[Figure A3.1](#) illustrates in a combined diagrammatic and tabular format, possible source migration pathway receptor linkages and actual risks to identified exposed receptors from a preliminary investigation. It illustrates a fuel spill.

[Table A3.2](#) illustrates in a tabular format, possible source exposure pathway receptor linkages from a preliminary investigation.

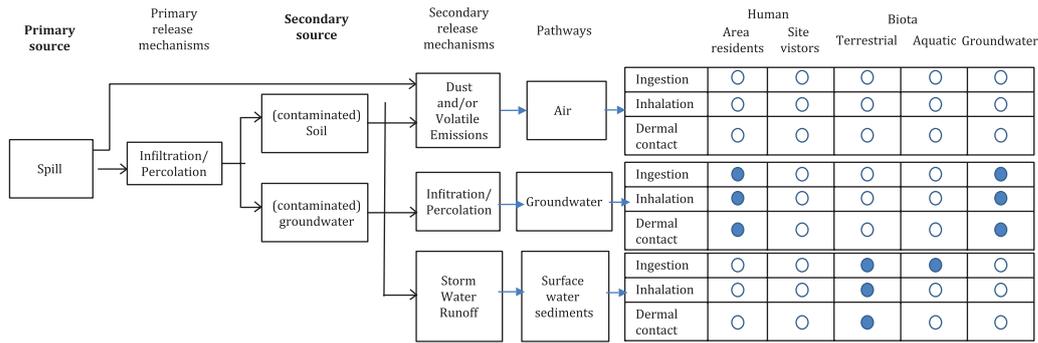


Figure A3.1 — Illustrations of parts of a CSM showing migration pathways in a tabular/matrix form (adapted from Standard Guide for Developing [18]), e.g. in the case of a fuel spill

Table A3.2 — Illustration of parts CSM showing exposure pathways in a tabular (adapted from Model Procedures for the Management of Land Contamination, Contaminated Land Report 11 [24])

Contaminant	Exposure Pathway(s)	Receptor
Metals A, B, C	Ingestion, inhalation, direct contact	Future residents, sit workers, (possibly) neighbours — Future residents
Semi-volatile, non-halogenated hydrocarbons D, E, F	— Dermal contact — Migration through made ground — Migration through sands	— Future residents — Groundwater in sand — River
Volatile halogenated hydrocarbons X, Y, Z	— Migration into buildings — Migration through made ground — ground Migration through sands	— Future residents — Groundwater in sand — River

Context: The site was formerly occupied by workshop garage and is being considered for redevelopment for residential purposes – all of the proposed dwellings will have private gardens. The site is located in an urban area with established residential properties to the south and industrial occupation on all other boundaries. The site is generally level. The site geology is made ground overlying sands overlying sandstones. A river is located approximately 200 m to the west of the site.

Examples A4: Several aspects of a CSM expressed using diagrammatic illustration (or drawings)

Figure A4.1 illustrates in a diagrammatic format, possible source migration pathway receptor linkages and actual risks to identified exposed receptors from a preliminary investigation. Figure A4.2 highlights the source, exposure pathways, and exposed receptors obtained from a preliminary investigation. Figure A4.3 illustrates in a combined diagrammatic and tabular format, potential source and released contaminant within environmental media (soil, made ground/unsaturated zone, saturated zone) in fractured rocks. It also shows actual risks to the main receptor, i.e. groundwater. This information was obtained following an exploratory investigation and prior to the design of any remediation works.

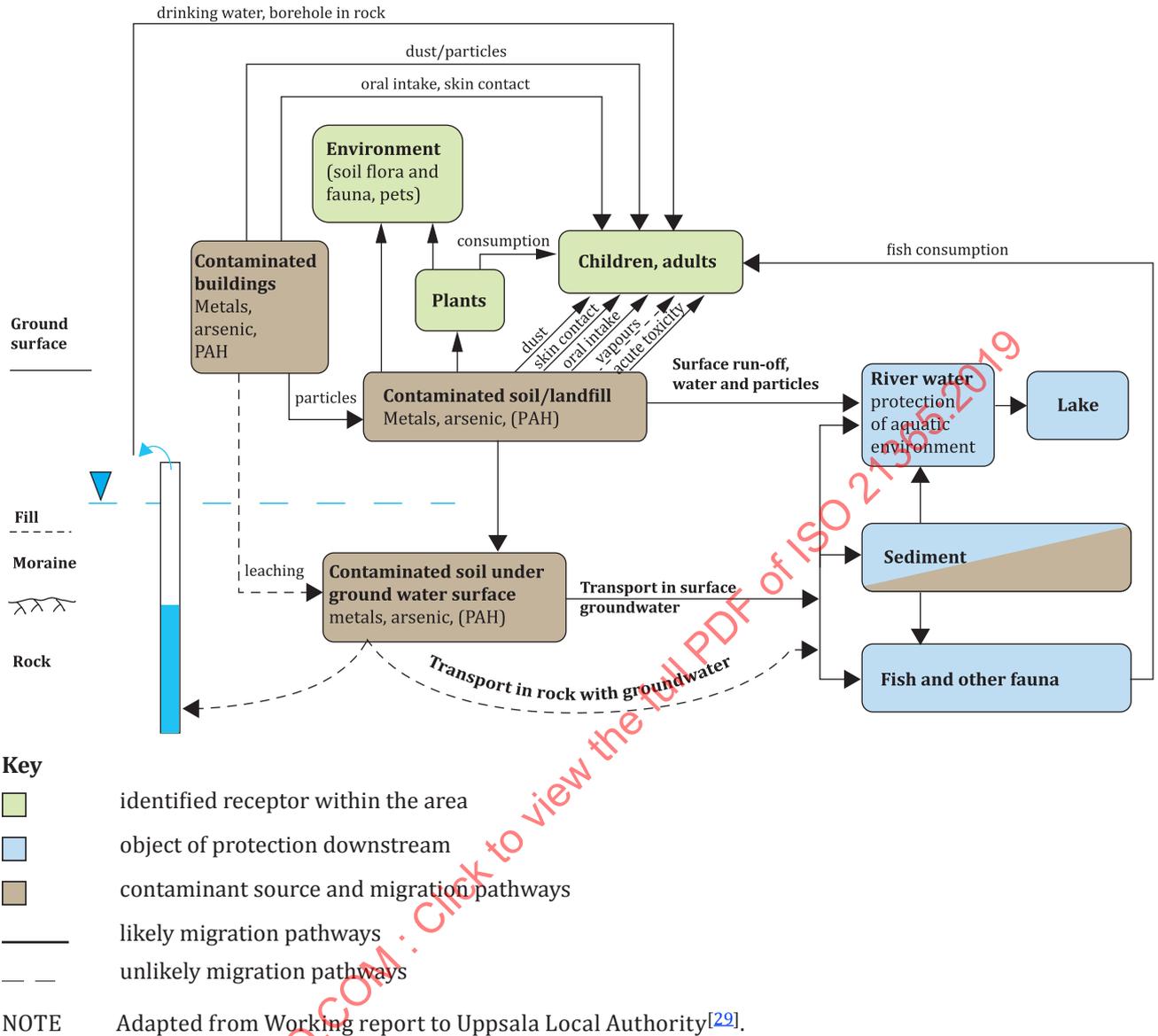


Figure A4.1 — Diagrammatic illustration of a CSM to illustrate sources, migration and exposure pathways and identified receptors

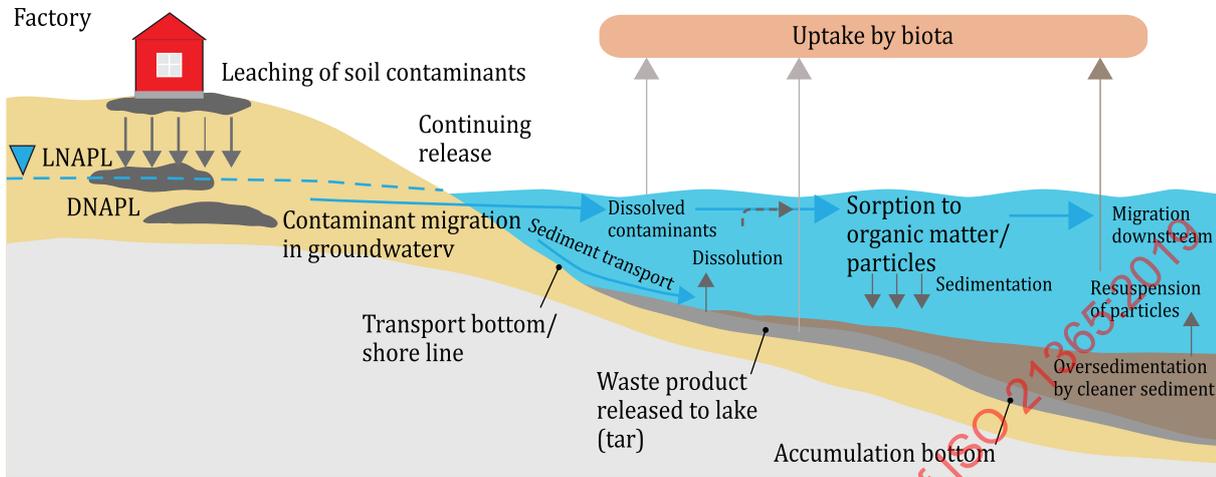


Figure A4.2 — Diagrammatic illustration of a CSM to illustrate sources, migration and exposure pathways (cross section) (adapted from Working report to Jämtland County Authority Kemakta^[30])

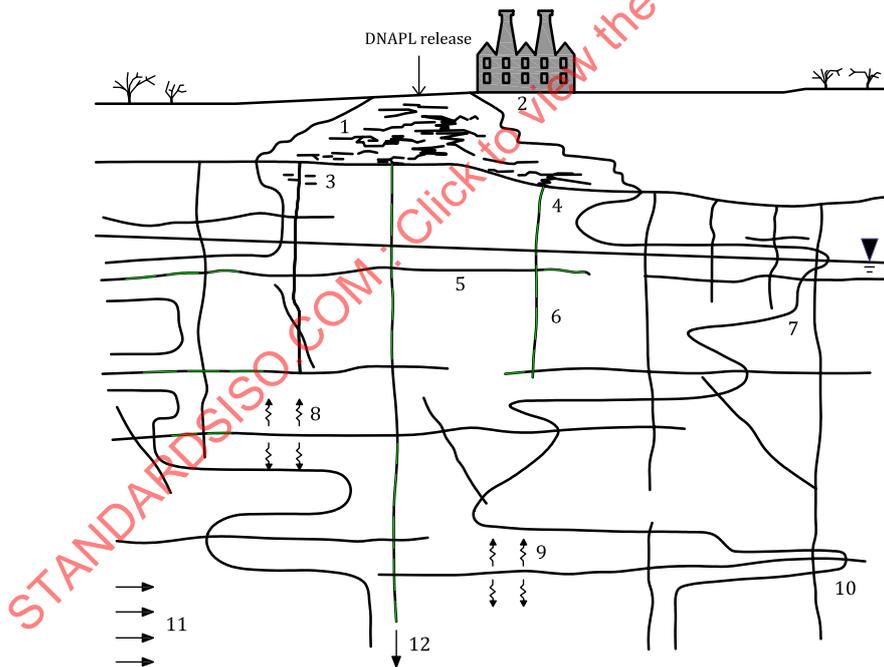


Figure A4.3 — Combined diagrammatic and tabular illustration showing parts of CSM (adapted from R&D report 133, Illustrated handbook of DNAPL transport and fate in the subsurface^[31])

Examples A5: Illustrations of parts of a CSM using a series of hypotheses to which qualitative probabilities as to their veracity can be attached

This brief example from [Table A5.1](#) to [Table A5.4](#) shows how a CSM can be presented as a series of hypotheses presented in varying detail that can be tested by further desk study or on-site investigation. The idea is to emphasize that almost all aspects of a CSM are subject to uncertainty – uncertainty that can be reduced, but not necessarily eliminated, by appropriate investigation.

The site has been in use for the manufacture of toiletries and similar products for over thirty years and is expected to continue to be so used for the foreseeable future. An assessment is to be made regarding current site conditions and hence potential liabilities, and in preparation for future small scale building or maintenance on the site. The plant covers most of the site with a peripheral road to provide access for deliveries of process materials, some by tanker, and for vehicles collecting goods for distribution. Features include bulk storage tanks for process chemicals, three electrical sub-stations, and vehicle workshops. The heating plant is currently gas-fired but was previously oil-fired. The surface drainage is mainly via deep soakaways. Part of the site is subject to surface water flooding.

Table A5.1 — Hypotheses Regarding Some Site Aspects: geological and anthropogenic context

Hypotheses	Probability of truth	Comments	Proposed response
The site is underlain by chalk	certain 100 %	Geological maps published by the national geological survey shows the site to be underlain by chalk	None needed
There are no superficial deposits	uncertain 50 % probability are present	Geological maps published by the national geological survey show superficial deposits to be absent from the whole of the site. However, glacio-fluvial surficial deposits have been found on an adjacent site contrary to the information provided by the maps	Intrusive investigation required
Made Ground is present in some areas	uncertain 80 % probability present	The site is over 30-years old and has undergone various modifications over the years	Intrusive investigation required
Fill or Made Ground is present at a depth >2 m thick in one part of the site	uncertain 95 % probability present	The level of a part of the site appears to have been raised above that of the natural topography	Intrusive investigation required Check whether the company knows what has been deposited on this part of the site and why
Fill in the form of sub-base materials etc. is present beneath the roads, hard standing areas and the solid building floors etc.	certain 100 %	Inherent component of normal construction	Intrusive investigation required Check whether the company has any records arising from in-ground maintenance works

Table A5.2 — Hypotheses Regarding Some Site Aspects: contamination

Hypotheses	Probability of truth	Comments	Proposed response
The site is contaminated	Uncertain 95 % probability some contamination present	Industrial site in use for over thirty years	Intrusive investigation required
Hydrocarbon contamination is present where there were once above-ground heating oil storage tanks	uncertain 50 % probability of presence	The area is now a car park subject to surface flooding Contamination could have been removed during construction of the car park ten years ago	Intrusive investigation required

Table A5.2 (continued)

Hypotheses	Probability of truth	Comments	Proposed response
There is localised contamination with PCBs or PCB-contaminated oil	Uncertain 20 % probability of being present	This is a standard concern where electrical sub-stations are present but in practice is seldom found. Regulations require that use of PCBs ceased many years ago and that other materials are used instead	Intrusive investigation required Check whether the company holds the records about the status of this equipment as required by regulation
Asbestos is present in the Made Ground and Fill	Uncertain 90 % probability are present	Consensus is that all Made Ground and Fill of non-natural origin should be assumed to be contaminated with asbestos or asbestos-containing materials. Natural materials disturbed during construction may also contain asbestos	
Etc.			

Table A5.3 — Principal Hypotheses Relating to Potential Presence of Contamination showing parts of CSM – part 1

Contaminant(s) hypothesised to be present	Principal hazard/reasons for concern	Hypotheses regarding presence, comments and possible responses
Petroleum hydrocarbons	Potentially harmful to human health	Present in a number of locations <i>Intrusive investigation not needed unless works are to be carried out in these areas</i>
PAHS and toxic metals	Potentially harmful to human health	Present associated with other petroleum hydrocarbons, trafficking by vehicles and breakdown of tarmacadam etc. Present in silt accumulated in soakaways and in ground around soakaways <i>Primarily of concern during maintenance operations. Some investigation of silt could be considered</i>
Sorbitol, PEG and other large volume raw materials	Generally of low toxicity to humans	Present in a number of locations <i>Intrusive investigation is not needed unless possibly if works are to be carried out in these areas</i>
Low volume raw materials and wastes including biologically active substances such as tricosan and chlorhexidine digluconate	Variable toxicity for humans	Present in silt accumulated in soakaways and in ground around soakaways <i>Primarily of concern during maintenance operations. Some investigation could be considered</i>
Asbestos-cement and other forms of asbestos in the ground	Harmful to human health through inhalation of fibres Potentially carcinogenic	Present in demolition materials and in imported fill <i>There is no direct evidence that these are present but Made Ground in all exploratory excavations and soil samples should be inspected and tested where appropriate</i>

Table A5.3 (continued)

Contaminant(s) hypothesised to be present	Principal hazard/reasons for concern	Hypotheses regarding presence, comments and possible responses
Carbon dioxide and methane And associated depleted oxygen concentrations	Carbon dioxide is toxic and an asphyxiant Methane is an asphyxiant, and is flammable and explosive Severe oxygen depletion can occur presenting a hazard in any deep excavation	Present due to degradation of petroleum hydrocarbons and other organic chemicals. Carbon dioxide can also arise from the action of acids (including acid rain) on chalk <i>Areas that might possibly be affected due to degradation of hydrocarbons are in the open parts of the site so the potential risks, if these gases are present, are likely to be low</i> <i>Any confined excavation into the chalk could be affected by elevated carbon dioxide concentrations</i> <i>Advantage should be taken of any intrusive investigations in suspect areas to determine gas concentrations</i>
Volatile organic compounds (VOCs)	Potentially harmful to human health.	<i>Some of the chemicals used on site could be classified as VOCs but at present there is no evidence for example for the use of chlorinated solvents</i> <i>Advantage should be taken of any intrusive investigations in suspect areas to determine VOC concentrations</i> <i>If evidence that such materials were used or stored in the buildings in such a way that contamination of the ground beneath the buildings might have occurred, a specialist investigation might be required</i>
Polychlorinated biphenyls (PCBs)	Potentially harmful to human health	<i>Unlikely to be present but any soil or groundwater samples taken from near the transformers should be analysed for PCBs</i>

Table A5.4 — Principal Hypotheses Relating to Potential Presence of Contamination showing parts of CSM – part 2

Contaminant(s) hypothesised to be present	Principal hazard/reasons for concern	Hypotheses regarding presence, comments and possible responses
Copper, nickel and zinc	Toxic to plants	Present in silt accumulated in soakaways and in ground around soakaways <i>Not an important consideration given the form of the development</i>
Petroleum hydrocarbons	Potential groundwater contaminants	<i>Risks to groundwater could be relatively high via the surface drainage system, otherwise probably low</i> <i>An intrusive investigation is required</i>
PAHS and toxic metals	Potential groundwater contaminants	Present in silt accumulated in soakaways and in ground around soakaways <i>The potential risks are low but some limited intrusive or other investigation could be helpful</i>
Sorbitol, PEG and other large volume raw materials	Potential groundwater contaminants	Present at are a number of locations <i>Generally the potential risks to groundwater are low but some intrusive investigation could be helpful</i>

Table A5.4 (continued)

Contaminant(s) hypothesised to be present	Principal hazard/reasons for concern	Hypotheses regarding presence, comments and possible responses
Low volume raw materials and wastes including biologically active substances such as tricosan and chlorhexidine digluconate	Potential groundwater and surface water contaminants Tricosan and chlorhexidine digluconate can have adverse effects on aquatic ecosystems	Present in silt accumulated in soakaways <i>Generally the potential risks to groundwater are low but some intrusive investigation or other forms of investigation could be helpful</i> <i>The likelihood of significant concentrations of biologically active substances reaching surface water via the groundwater is very low</i> <i>However, in the event of flooding or overflow from soakaways contaminated water or silt could enter nearby drainage ditches and hence nearby surface water</i>

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