Annex B

Guidance Manual for Use of Risk–based Remediation Goals for Contaminated Land Management

Hong Kong SAR Government
Environmental Protection Department
April 2007

Guidance Manual for Use of Risk-based Remediation Goals for Contaminated Land Management

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Glossary

Cancer Slope Factor (CSF) A plausible upper-bound estimate of the probability of a cancer response per unit intake of a chemical over a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. The cancer slope factor is given in units of the reciprocal of milligrams of chemical per kilogram of body weight per day $(mg/kg\text{-}day)^{-1}$.

Detection Limit (DL) The lowest amount that can be distinguished from the normal "noise" of an analytical instrument or method.

Exposure Contact of a receptor with a chemical or physical agent. Exposure is quantified as the amount of the agent at the exchange boundaries of the receptor (e.g. skin, lungs, gut) and available for absorption.

Exposure pathway	The course a toxic chemical takes from the source area to a receptor. Each exposure pathway includes a source or release from a source, a point of exposure, and an exposure route. If the exposure point is not at the source, a transport medium is also involved.
Exposure route	The mechanism by which a receptor inhales, consumes, absorbs, or otherwise takes in a toxic chemical at an exposure point.
Groundwater	Means any water beneath the earth's surface in the zone of saturation.
Hazard quotient	Ratio of the intake to the reference dose.
Intake	A measure of exposure expressed as the mass of a substance in contact with the exchange boundary per unit body weight per unit time (e.g. mg/kg-day). Also termed the normalized exposure rate; equivalent to administered dose.
Integrated Risk Information System (IRIS)	An US EPA database containing verified reference doses (RfDs) and cancer slope factors (CSFs) and up-to-date health risk and US EPA regulatory information for numerous chemicals.
Non-aqueous Phase Liquid (NAPL)	Chemicals that are insoluble or only slightly soluble in water that exist as a separate liquid phase.
Pathway	The route a toxic chemical takes to go from a source to a receptor.
Quality assurance/ Quality control documentation	Results of test run by the laboratory to verify the precision and accuracy of analytical tests and equipment.
Receptor	Any person that is or may be affected by a release of toxic chemicals.
Reference Dose (RfD)	An estimate of a daily exposure level for the human population including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime, or portion of a lifetime. The RfD is given in units of milligrams of chemical per kilogram of body weight per day.
Release	Means any spilling, leaking, pouring, emitting, emptying, discharging, injecting, pumping, escaping, leaching, dumping, or disposing of a toxic chemical into the environment (including the abandonment or discarding of barrels, containers, and other closed receptacles containing hazardous wastes or hazardous constituents).

Remediation	An action, including removal, chemical, physical, or biological treatment of soil, groundwater, or other environmental media, intended to restore or improve the land condition impacted by chemical contamination.
Risk assessment	An analysis of the potential for adverse effects caused by a toxic chemical at a site and to determine the need for remedial action or to develop cleanup levels where remedial action is required.
Site	Defined by the likely physical distribution of the toxic chemicals from a source area. A site could be an entire property or facility, a defined area or portion of a facility or property, or multiple facilities or properties.
Soil	Means any unconsolidated mineral and organic matter overlying bedrock that has been subjected to and influenced by geologic and other environmental factors, excluding sediment.
Soil saturation limit	The contaminant concentration in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water and saturation of soil pore air have been reached.
Source	Presence of a toxic chemical at or below the ground surface at a hazardous concentration.
Toxicity value	A numerical expression of a substance's dose-response relationship that is used in risk assessments. The most common toxicity values used are reference doses (RfD) for noncarcinogenic effects and cancer slope factors (CSFs) for carcinogenic effects.
Water table	Means the upper elevation of the surface of the saturated zone.
Zone of saturation	Means any part of the earth's crust in which all voids are filled with water.

Abbreviations

ASTM	American Society for Testing and Materials
CAP	Contamination Assessment Plan
CAR	Contamination Assessment Report
COC	Chemical of Concern
CSF	Cancer Slope Factor
DQO	Data Quality Objective
DL	Detection Limit
HEAST	Health Effects Assessment Summary Table
IRIS	Integrated Risk Information System
NAPL	Non-aqueous Phase Liquid
RAP	Remedial Action Plan
$RBRG_{soil}$	Risk-Based Remediation Goal for soil
$RBRG_{gw}$	Risk-Based Remediation Goal for groundwater
RfD	Reference Dose
SI	Site Investigation
SVOC	Semi-volatile Organic Chemical
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Chemical

Section 1
INTRODUCTION

1.1 The Problem of Contaminated Land

Contaminated land is caused by spillage, leakage or disposal of toxic chemicals to the ground. Soil at or below the ground surface and sometimes groundwater may be contaminated depending on the subsurface conditions. Contaminated land is a health concern if the public is exposed to toxic chemicals through the impacted soil or groundwater. In Hong Kong, examples of industrial or commercial activities that may potentially cause land contamination include boatyards, petrol filling stations, vehicle repair/maintenance or dismantling workshops, metal or mechanical workshops or oil installations etc. (Figures 1.1, 1.2 and 1.3). The potentially-polluting activities generally involve (i) underground oil or chemical storage in tanks that may leak due to corrosion, or (ii) operations that may cause spillage of chemicals. Ground surface condition is also a factor affecting the severity of contamination. Spillage over bare soil results in more serious contamination than that over a capped surface.

Before a contaminated site is re-developed or handed back from a tenant/purchaser/allocatee to the Government, it is necessary to assess the level of contamination by collecting soil and groundwater samples for laboratory analyses. If contamination is above an acceptable level, defined by a set of standards or remediation goals, remediation is required to render the site safe for future use.

1.2 Replacement of Dutch B Levels with Risk-Based Remediation Goals (RBRGs)

Historically, Hong Kong has no locally-derived contaminated land standards. The existing standards based on Dutch B levels of the Netherlands, referenced in the Practice Note for Professional Persons for Contaminated Land Assessment and Remediation (issued by EPD in 1994) have been used up to the present.

Contaminated land standards specifically derived for Hong Kong are necessary to replace the Dutch B levels for three reasons. Firstly, the Dutch government has already developed a new set of risk-based standards to replace the Dutch B levels. Secondly, the Dutch B levels were developed to protect the people and environment in the Netherlands only which means that they are not entirely suitable for Hong Kong. Thirdly, the world-wide practice is for each country to develop country specific standards based on a risk assessment approach to suit their local environmental conditions and community needs. This risk approach means that decisions on defining a site as contaminated, and hence the level of remediation required, are made based on the potential risks to receptors and the intended land use.

To bring Hong Kong in line with the international practice and to replace the Dutch B levels, a set of locally-derived contaminated land standards, the Risk-based Remediation Goals (RBRGs), has been developed for 4 types of land use in Hong Kong to protect the local human receptors. This Guidance Manual explains the risk-based approach and guides users in applying the RBRGs to their contaminated sites.

1.3 Risk-Based Approach for Contaminated Land Management

The RBRGs were developed using a risk-based approach which means that decisions on contaminated soil and groundwater remediation will be based on the nature and extent of the potential risks that are posed to human receptors as a result of exposure to chemicals in the soil and/or groundwater. This approach acknowledges that there are some low levels of exposure to the contaminants that will pose minimal risks to the receptors. RBRGs have been developed as threshold contaminant concentrations, below which hazards or risks to human health arising from exposure to soil and/or groundwater are considered minimal. These target hazard and risk levels will be quantified in subsequent chapters of this document. Remediation of contaminated soil or groundwater that poses such minimal risks would not be necessary for the protection of public health. When concentrations of soil or groundwater are detected above the RBRGs, cleanup will be required. The risk-based approach also facilitates the use of Hong Kong data in respect of typical working schedules, soil conditions, meteorological conditions, typical building designs, etc. to suit local conditions. This approach provides a specifically relevant and technically defensible framework for the assessment of contaminated sites as well as promotes cost-effective remediation in Hong Kong.

1.4 Scope and Structure of this Guidance Manual

This *Guidance Manual for Use of Risk-Based Remediation Goals for Contaminated Land Management* (Guidance Manual) introduces the background of RBRGs and presents instructions for comparison of soil and groundwater data to the RBRGs. Included in this guidance are RBRGs for soil and groundwater protective of human health for 54 chemicals of concern.

The Guidance Manual is organized as follows:

Section 1 – Introduction
Section 2 – Development of RBRGs
Section 3 – Application of RBRGs in Land Contamination Assessment
Section 4 – Record Keeping and Reporting
Section 5 – General Reference

Detailed information (e.g. exposure parameters, site assumptions, toxicity information, chemical properties) on the derivation of the RBRGs is provided in the *Background Document on Development of Risk-Based Remediation Goals for Contaminated Land Management* (Background Document).

Figure 1.1 – Boatyards

Figure 1.2 – Petrol Filling Stations

Figure 1.3 – Car Repair / Dismantling Workshops

Section 2
DEVELOPMENT OF RBRGs

2.1 Risk-based Approach

Managing contaminated land using the risk-based approach involves taking the source-pathway-receptor into consideration before making decisions on the assessment and remediation of contaminated land. This involves construction of a conceptual site model (CSM), which is the qualitative description of the ways in which receptors can be exposed to site contamination, and is developed to provide an overall understanding of the site. For exposure to be considered possible, some mechanism ('pathway') must exist by which contamination from a given source can reach a given receptor. Such complete 'source-pathway-receptor' exposure mechanisms are commonly termed 'pollutant linkages'.

The term exposure pathway is used to describe a potentially complete source-pathway-receptor linkage, i.e. where a chemical in the environment has a means by which it can reach a human receptor. There are different exposure pathways for different types of land use which represent different physical settings. Also, the ways in which people come into contact with contaminated soil and/or groundwater, including the intensity and frequency of contact, are largely dependent on the type of land use. It was therefore necessary to identify the relevant land use scenarios in Hong Kong and develop a set of RBRGs for each land use.

2.2 Development Process

The RBRGs were developed based on the principles in risk assessment calculation which can be expressed as:

Exposure Concentrations **x** Exposure Factors **x** Toxicity = Risk

Where:

X	times or multiply by
Exposure Concentrations	Chemical concentrations that people are exposed to, i.e. RBRGs
Exposure Factors	Describe how people are exposed to the chemicals
Toxicity	Level of toxicity of the chemicals
Risk	Level of health risk acceptable to the public

As shown, RBRGs can be determined based on the risk assessment technique provided that the risk level, toxicity level and exposure factors are known.

RBRGs are concentrations in soil and groundwater protective of human health. The RBRG development process consisted of the following key steps:

- Identify the chemicals of concern (COCs) for Hong Kong.
- Define the different types of land use where these chemicals may be found.
- Identify the human receptors who could come into contact with these chemicals at contaminated sites.

- Identify the exposure pathways through which the receptors could come in contact with these chemicals at contaminated sites.

- Identify the equations, models, and toxicity information that could be used to develop RBRGs to protect the receptors exposed to COCs.

- Collect information specific to Hong Kong on land use, building design, site conditions, and people's behavior, to develop RBRGs protective of human health.

Relevant overseas methodologies were used in establishing the RBRGs with input of local data as far as possible, resulting in standards more suited to the Hong Kong conditions. The RBRGs were locally derived using established methods and the risk-based approach and are more objective, consistent, and scientifically defensible while at the same time able to ensure a satisfactory level of protection to the public.

For certain chemicals, the calculated RBRGs are higher than the concentrations where a separate, non-aqueous phase may be present in soil or groundwater. Chemicals that exist in this form, referred to as non-aqueous phase liquid (NAPL), can be difficult to locate, contain, or treat and require special consideration. Screening criteria were developed for NAPL in soil and groundwater that must be considered along with RBRGs to determine whether a site requires further action. The development of NAPL screening criteria is also discussed in the following sections.

2.2.1 Chemicals of Concern

RBRGs have been developed for 54 COCs which were selected on the basis that either they are known to occur in the Hong Kong environment, or are in use locally.

The COCs are grouped into the following chemical classes:

- Volatile organic chemicals (VOCs) – 13 chemicals
- Semi-volatile organic chemicals (SVOCs) – 19 chemicals
- Metals – 15 chemicals
- Dioxins and Polychlorinated Biphenyls (PCBs) – 2 chemicals
- Petroleum carbon ranges – 3 groups
- Other inorganic compounds – 1 chemical
- Organometallics – 1 chemical

Soil and groundwater collected at sites contaminated with petroleum should be analyzed using a method that can fractionate the material into categories based on carbon numbers. Whilst toxicity values are generally not provided for Total Petroleum Hydrocarbons (TPH) as a whole, toxicity information is available for individual petroleum carbon fractions. Therefore, RBRGs have been developed for three separate hydrocarbon ranges as follows:

- C6-C8 (Carbon numbers from 6 to 8)
- C9-C16 (Carbon numbers from 9 to 16)
- C17-C35 (Carbon numbers from 17 to 35)

Note that the list of 54 COCs was compiled to the best of EPD's knowledge on what may reasonably be found in contaminated sites in Hong Kong.

In practice, the number and types of chemicals to be analyzed should not be dictated by the 54 COCs, but by the past and present chemical usage/storage activities on-site. Users of this Guidance Manual are advised to select only those COCs from the RBRG list that are relevant to their sites for laboratory testing. On the other hand, if a study of the past and present uses of a site reveals that there may be COCs specific to the site that are not in the list of 54, those specific COCs should be included in the test programme even though they do not appear in the RBRG list.

For any COC outside the list of 54, the user should propose, with justifications, the appropriate standard/remediation goal to be set for agreement with EPD.

2.2.2 Land Use Scenarios

RBRGs were developed for four different land use scenarios reflecting the typical physical settings in Hong Kong under which people could be exposed to contaminated soil and groundwater. Sets of RBRGs have been developed to protect workers at industrial sites, the public visiting public parks, and residents in urban and rural areas. Separate sets of RBRGs have been developed according to different land uses, because it has been shown that the ways in which people come into contact with contaminated soil and/or groundwater, including the intensity and frequency of their contact, are largely dependent on the type of land use. A description of each land use scenario is as follows:

1. **Urban residential –** Sites located in an urban area where main activities involve habitation by individuals. The typical physical setting is a high rise residential building situated in a housing estate that has amenity facilities such as landscaped yards and children playground. The receptors are residents who stay indoors most of the time except for a short period each day, during which they are outdoors and have the chance of being in direct contact with soil at landscaping or play areas within the estate.

2. **Rural residential –** Sites located in a rural area where main activities involve habitation by individuals. These sites typically have village-type houses or low rise residential blocks surrounded by open space. The receptors are rural residents who stay at home and spend some time each day outdoor on activities such as gardening or light sports. Degree of contact with soil under the rural setting is more than that of the urban setting both in terms of the intensity and frequency of contact.

3. **Industrial –** Any site where activities involve manufacturing, chemical or petrochemical processing, storage of raw materials, transport operations, energy production or transmission etc. Receptors include those at sites where part of the operation is carried out directly on land and the workers are more likely to be exposed to soil than those working in multi-storey factory buildings.

4. **Public parks –** Receptors include individuals and families who frequent parks and play areas where there is contact with soil present in lawns, walkways, gardens and play areas. Parks are considered to be predominantly hard covered with limited areas of predominantly landscaped soil. Furthermore, public parks are not considered to have buildings present on them.

2.2.3 Identification of Exposure Pathways

For each land use, consideration was given to ways in which contact with chemicals could occur. The term exposure pathway is used to describe the course a chemical takes from its source area to reach an individual. Each exposure pathway has the following components:

- A source
- A release and transport mechanism (if exposure occurs away from the source)
- A point or location of exposure
- An exposure route by which the chemical enters the human body (the skin, inhalation, ingestion)

For the four land use categories, it was assumed that exposure could occur in two ways:

- by direct contact with soil (see explanation below) and/or
- by inhalation of vapors if volatile chemicals migrate from soil or groundwater into the air of a building constructed on top of residual contamination.

Thus, there are two combinations of exposure pathways:

- **Soil –** includes direct contact through dermal contact and incidental ingestion of soil, as well as inhalation of particulates and volatile emissions in the ambient air from surface soil and inhalation of subsurface soil contamination in residential or industrial buildings.
- **Groundwater –** includes inhalation of volatiles from subsurface groundwater in residential or industrial buildings.

RBRGs were developed to be protective of each of these two exposure pathways, however, not all exposure pathways are relevant to all land use categories. For example, public parks are open space areas with good ventilation. They do not generally have occupied buildings in which indoor air could be impacted by the underlying soil. The exposure pathway of indoor air impact therefore would not be applicable to public parks.

The following four different types of RBRGs, have been developed for the land use categories that are marked with ✓:

	Type of RBRG	Soil					Groundwater
	Pathway	Ingestion of surface soil	Dermal contact with surface soil	Volatiles from surface soil	Particulates from surface soil	Subsurface volatiles indoor	Volatiles indoor from groundwater
Land Use Scenario	Urban Residential	✓	✓	✓	✓	✓	✓
	Rural Residential	✓	✓	✓	✓	✓	✓
	Industrial	✓	✓	✓	✓	✓	✓
	Public Parks	✓	✓	✓	✓		

Compared to other developed countries, the only significant land use/pathway combination not recommended for Hong Kong is ingestion of contaminated groundwater as drinking water. The elimination is based on the fact that groundwater is generally not used for potable purposes in Hong Kong and this situation is unlikely to change in the future.

2.2.4 Cancer and Non-Cancer Toxicity

Chemicals are classified as to whether they exhibit cancer and/or non-cancer health effects. Chemicals are also classified as to whether they are associated with health effects via one or more routes of exposure, e.g., ingestion, dermal and/or inhalation exposures. Toxicity indices, including cancer slope factors (CSFs) and reference doses (RfDs) (protective of non-cancer effects) are necessary to develop RBRGs.

In general, RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of adverse effects during a lifetime. The CSF is a measure of the cancer potency of a chemical. Conservatism and safety factors are built into both RfDs and CSFs to account for the fact that many of these values are based on animal, rather than human studies.

Toxicity indices for RBRG development were derived from a number of sources including the US Environmental Protection Agency's (EPA) Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEASTs), US Department of Energy's Risk Assessment Information System (RAIS), the World Health Organisation (WHO) publications, the UK and the Netherlands contaminated land guidance documents. Values published on the RAIS were assessed for reliability before being used for RBRG development.

RBRGs protective of cancer health effects and non-cancer health effects are calculated separately. In the event that a chemical was associated with both cancer and non-cancer health effects, both a cancer-based RBRG and a noncancer-based RBRG were developed. The lower of these two RBRGs was selected as the final RBRG.

RBRGs protective of the cancer endpoint were based on an excess life time cancer risk of one in a million (10^{-6}). RBRGs protective of noncancer endpoints were based on a hazard quotient of 1.0. A hazard quotient of 1.0 signifies that the derived RBRG, which is the environmental concentration, is equal to the reference dose (RfD) concentration. This concentration is the level at which no adverse effects are expected. In most cases, the RfD incorporates a safety factor so that with a hazard quotient of 1.0, a margin of safety would exist.

2.2.5 Non-Aqueous Phase Liquid (NAPL)

NAPL is a general term that refers to any organic liquid present in the environment as a separate distinct phase. The liquid may consist of a single pure chemical (e.g., benzene) or a complex mixture of chemicals (e.g., gasoline).

Two categories of NAPL are recognized: (1) dense non-aqueous phase liquids (DNAPLs) which are heavier than water; and (2) light non-aqueous phase liquids (LNAPLs) which are lighter than water. Examples of DNAPLs include PCBs, trichloroethylene and tetrachloroethylene. Examples of LNAPLs include gasoline, jet fuel, and toluene. LNAPLs released into soil in sufficient quantities may migrate vertically through the soil and eventually encounter the groundwater zone where the NAPL displaces water. DNAPLs released into the soil in sufficient quantities may penetrate deep into the soil with movement below the groundwater table.

Chemicals in this state can be difficult to locate, contain, or treat, and require special consideration for the following reasons:

- Released LNAPLs and DNAPLs can migrate vertically through the subsurface due to gravity, or laterally due to capillary suction. Given a large enough release, LNAPL will encounter the groundwater zone where it spreads laterally and begins to dissolve into groundwater. Once the surface LNAPL release ceases, subsurface spreading of LNAPL slows as the forces driving migration dissipate. However the dissolved phase may begin to migrate down gradient. Any such movement in the LNAPL plume can result in a significant expansion of the contaminated area and could result in imminent hazards or chronic risks to underground structures (e.g., sewers, basements) or to nearby surface waters and associated aquatic resources. DNAPLs can proceed below the groundwater table, and their flow may be enhanced by the presence of fractures in the soil or bedrock.

- When such NAPLs accumulate, they become pockets of essentially neat (i.e., undiluted) chemicals and could present a significant health threat (imminent hazard as well as chronic risk) to exposed receptors. Direct exposure to pockets of NAPLs could involve significantly greater exposures/uptakes than would be associated with similar organic chemicals that are present as sorbates on soil or solutes in groundwater.

- Pockets of NAPLs can act as long-term sources of contamination to the nearby environment via volatilization and dissolution. Vapors from volatilization may migrate to ambient air or to underground structures. Solutes from dissolution will migrate to groundwater. Such pockets of NAPL are not commonly depleted rapidly by such volatilization/dissolution, nor by degradation, so that the material acts as a source of pollution for many years or decades.

For these reasons, screening criteria (soil saturation limits, C_{sat}) were developed for NAPLs in soil and water solubility limits for NAPL in groundwater for the more mobile organic chemicals. These criteria must be considered in addition to RBRGs to determine whether a site requires further action.

2.3 Risk-Based Remediation Goal Tables

RBRGs for Soil and Soil Saturation Limits (Table 2.1) and RBRGs for Groundwater and Solubility Limits (Table 2.2) present the remediation goals for soil and groundwater respectively. Each table presents a list of the COCs and RBRGs for the relevant land use categories. Detected concentrations of COCs in soil and/or groundwater are to be compared to their respective RBRGs for the appropriate land use category. COCs for which no groundwater RBRGs are provided were lacking either the appropriate toxicity values or physical/chemical property values necessary to calculate the RBRGs, or they were not considered to be volatile (i.e. volatile chemicals are those with Henry's Law Constant $>10^{-5}$).

Table 2.1 presents the soil saturation limits (C_{sat}) for the more mobile organic chemicals (with molecular weight less than 200 g/mol). C_{sat} is the concentration at which a chemical can, in theory, be present in the environment as NAPL. Table 2.2 presents the Solubility Limits for organic chemicals in groundwater. Solubility Limits were only calculated for those COCs with Henry's Law Constant $>10^{-5}$. For these chemicals, detected concentrations must be compared to both the RBRG and C_{sat}/Solubility Limits to determine whether further action is required at the site. The C_{sat} and Solubility Limits serve as trigger levels indicating the potential for NAPL to be present. The issue of NAPL is of less concern for chemicals with molecular weights greater than 200 g/mol as chemicals with higher molecular weights are considered to be less mobile.

A non risk-based 'ceiling limit' is given as 10^4 mg/kg for soil and 10^4 mg/L for groundwater for the relatively less toxic inorganic, volatile and semi-volatile contaminants.

Instruction for comparing site data to RBRGs and C_{sat}/Solubility Limits is presented in Section 3.

2.4 Limitation on the Use of RBRGs

The RBRGs have been developed in consideration of environmental conditions, activities and building designs typical in Hong Kong. Conservative yet realistic assumptions have also been made on the degree of exposures that can occur to residents, workers and the public but only the common, important and complete exposure pathways have been included in the derivation of the RBRGs. **Users of this Manual must familiarize themselves with the assumptions behind the derivation of these RBRGs before adopting them for their sites of concern. In particular, they must satisfy themselves that all exposure pathways important to their sites of concern have been considered in the derivation of the RBRGs in this manual.** An example of unusual activity which may lead to exposure pathway not considered in the derivation of the RBRGs in this manual is the extraction of groundwater from within the site or locations close to the site for beneficial use, such as for drinking or irrigation. Where such exposure pathways exist, the user needs to conduct separate assessment on the risks posed through such pathways. There are standards for drinking water in Hong Kong and these must be adhered to.

The users should note that ecological receptors are not specifically covered by the RBRGs. The reasons being that the brownfield sites in Hong Kong are primarily former industrial or in some cases commercial premises. Today these sites will be re-developed for residential, commercial or government/institutional use. It is highly unlikely that a contaminated site in Hong Kong will be re-developed for agricultural uses or into a nature conservation area. In the rare event that protection of ecological resources becomes necessary at a particular site, a focused ecological risk assessment may need to be carried out to assess the ecological risks, in addition to applying the RBRGs.

There is chance that a contaminated site will be re-developed into a public park. RBRGs were derived for this land use to protect the park users (see Section 2.2.2). No remediation standards were set to protect landscaping plants which are the major ecological receptors in a public park. The reason for this is that uncontaminated off-site soil with suitable soil characteristics, instead of the original site soil, is normally used for planting. The imported soil is then mixed with soil conditioners and fertilizers to make it suitable for planting use. Project proponents also have the choice to plant more hardy landscaping plants that are resistant to contamination.

It will be necessary for those investigating contaminated land to build a conceptual model that describes the sources of contamination, the potential receptors and the pathways by which one may reach the other. In rare circumstances where significant ecology receptors are potentially impacted or where groundwater abstractions, surface water quality or other receptors are potentially at risk then the RBRGs will not be protective of these receptors. Site investigators will need to undertake a more detailed risk assessment that selects different, more appropriate criteria such as drinking water guidelines to protect groundwater abstractions. It is envisaged that this circumstance will be rare in Hong Kong and site investigators will need to have their risk assessments reviewed and approved by EPD.

Table 2.1
Risk-Based Remediation Goals (RBRGs) for Soil & Soil Saturation Limit

Chemical	Risk-Based Remediation Goals for Soil				
	Urban Residential (mg/kg)	Rural Residential (mg/kg)	Industrial (mg/kg)	Public Parks (mg/kg)	Soil Saturation Limit (Csat) (mg/kg)
VOCs					
Acetone	9.59E+03	4.26E+03	1.00E+04*	1.00E+04*	***
Benzene	7.04E-01	2.79E-01	9.21E+00	4.22E+01	3.36E+02
Bromodichloromethane	3.17E-01	1.29E-01	2.85E+00	1.34E+01	1.03E+03
2-Butanone	1.00E+04*	1.00E+04*	1.00E+04*	1.00E+04*	***
Chloroform	1.32E-01	5.29E-02	1.54E+00	2.53E+02	1.10E+03
Ethylbenzene	7.09E+02	2.98E+02	8.24E+03	1.00E+04*	1.38E+02
Methyl tert-Butyl Ether	6.88E+00	2.80E+00	7.01E+01	5.05E+02	2.38E+03
Methylene Chloride	1.30E+00	5.29E-01	1.39E+01	1.28E+02	9.21E+02
Styrene	3.22E+03	1.54E+03	1.00E+04*	1.00E+04*	4.97E+02
Tetrachloroethene	1.01E-01	4.44E-02	7.77E-01	1.84E+00	9.71E+01
Toluene	1.44E+03	7.05E+02	1.00E+04*	1.00E+04*	2.35E+02
Trichloroethene	5.23E-01	2.11E-01	5.68E+00	6.94E+01	4.88E+02
Xylenes (Total)	9.50E+01	3.68E+01	1.23E+03	1.00E+04*	1.50E+02
SVOCs					
Acenaphthene	3.51E+03	3.28E+03	1.00E+04*	1.00E+04*	6.02E+01
Acenaphthylene	2.34E+03	1.51E+03	1.00E+04*	1.00E+04*	1.98E+01
Anthracene	1.00E+04*	1.00E+04*	1.00E+04*	1.00E+04*	2.56E+00
Benzo(a)anthracene	1.20E+01	1.14E+01	9.18E+01	3.83E+01	
Benzo(a)pyrene	1.20E+00	1.14E+00	9.18E+00	3.83E+00	
Benzo(b)fluoranthene	9.88E+00	1.01E+01	1.78E+01	2.04E+01	
Benzo(g,h,i)perylene	1.80E+03	1.71E+03	1.00E+04*	5.74E+03	
Benzo(k)fluoranthene	1.20E+02	1.14E+02	9.18E+02	3.83E+02	
bis-(2-Ethylhexyl)phthalate	3.00E+01	2.80E+01	9.18E+01	9.42E+01	
Chrysene	8.71E+02	9.19E+02	1.14E+03	1.54E+03	
Dibenzo(a,h)anthracene	1.20E+00	1.14E+00	9.18E+00	3.83E+00	
Fluoranthene	2.40E+03	2.27E+03	1.00E+04*	7.62E+03	
Fluorene	2.38E+03	2.25E+03	1.00E+04*	7.45E+03	5.47E+01
Hexachlorobenzene	2.43E-01	2.20E-01	5.82E-01	7.13E-01	
Indeno(1,2,3-cd)pyrene	1.20E+01	1.14E+01	9.18E+01	3.83E+01	
Naphthalene	1.82E+02	8.56E+01	4.53E+02	9.14E+02	1.25E+02
Phenanthrene	1.00E+04*	1.00E+04*	1.00E+04*	1.00E+04*	2.80E+01
Phenol	1.00E+04*	1.00E+04*	1.00E+04*	1.00E+04*	7.26E+03
Pyrene	1.80E+03	1.71E+03	1.00E+04*	5.72E+03	
Metals					
Antimony	2.95E+01	2.91E+01	2.61E+02	9.79E+01	
Arsenic	2.21E+01	2.18E+01	1.96E+02	7.35E+01	
Barium	1.00E+04*	1.00E+04*	1.00E+04*	1.00E+04*	
Cadmium	7.38E+01	7.28E+01	6.53E+02	2.45E+02	
Chromium III	1.00E+04*	1.00E+04*	1.00E+04*	1.00E+04*	
Chromium VI	2.21E+02	2.18E+02	1.96E+03	7.35E+02	
Cobalt	1.48E+03	1.46E+03	1.00E+04*	4.90E+03	
Copper	2.95E+03	2.91E+03	1.00E+04*	9.79E+03	
Lead	2.58E+02	2.55E+02	2.29E+03	8.57E+02	
Manganese	1.00E+04*	1.00E+04*	1.00E+04*	1.00E+04*	
Mercury	1.10E+01	6.52E+00	3.84E+01	4.56E+01	
Molybdenum	3.69E+02	3.64E+02	3.26E+03	1.22E+03	
Nickel	1.48E+03	1.46E+03	1.00E+04*	4.90E+03	
Tin	1.00E+04*	1.00E+04*	1.00E+04*	1.00E+04*	
Zinc	1.00E+04*	1.00E+04*	1.00E+04*	1.00E+04*	
Dioxins / PCBs					
Dioxins (I-TEQ)	1.00E-03	1.00E-03	5.00E-03	1.00E-03	
PCBs	2.36E-01	2.26E-01	7.48E-01	7.56E-01	
Petroleum Carbon Ranges					
C6 - C8	1.41E+03	5.45E+02	1.00E+04*	1.00E+04*	1.00E+03
C9 - C16	2.24E+03	1.33E+03	1.00E+04*	1.00E+04*	3.00E+03
C17 - C35	1.00E+04*	1.00E+04*	1.00E+04*	1.00E+04*	5.00E+03
Other Inorganic Compounds					
Cyanide, free	1.48E+03	1.46E+03	1.00E+04*	4.90E+03	
Organometallics					
TBTO	2.21E+01	2.18E+01	1.96E+02	7.35E+01	

Notes:
(1) For Dioxins, the cleanup levels in USEPA Office of Solid Waste and Emergency Response (OSWER) Directive of 1998 have been adopted. The OSWER Directive value of 1 ppb for residential use has been applied to the scenarios of "Urban Residential", "Rural Residential", and "Public Parks", while the low end of the range of values for industrial, 5 ppb, has been applied to the scenario of "Industrial".
(2) Soil saturation limits for petroleum carbon ranges taken from the Canada-Wide Standards for Petroleum Hydrocarbons in Soil, CCME 2000.
(3) * indicates a 'ceiling limit' concentration.
(4) *** indicates that the Csat value exceeds the 'ceiling limit' therefore the RBRG applies.

Table 2.2
Risk-Based Remediation Goals (RBRGs) for Groundwater and Solubility Limit

Chemical	Risk-Based Remediation Goals for Groundwater			
	Urban Residential (mg/L)	Rural Residential (mg/L)	Industrial (mg/L)	100% Water Solubility (mg/L)
VOCs				
Acetone	1.00E+04*	1.00E+04*	1.00E+04*	***
Benzene	3.86E+00	1.49E+00	5.40E+01	1.75E+03
Bromodichloromethane	2.22E+00	8.71E-01	2.62E+01	6.74E+03
2-Butanone	1.00E+04*	1.00E+04*	1.00E+04*	***
Chloroform	9.56E-01	3.82E-01	1.13E+01	7.92E+03
Ethylbenzene	1.02E+03	3.91E+02	1.00E+04*	1.69E+02
Methyl tert-Butyl Ether	1.53E+02	6.11E+01	1.81E+03	***
Methylene Chloride	1.90E+01	7.59E+00	2.24E+02	***
Styrene	3.02E+03	1.16E+03	1.00E+04*	3.10E+02
Tetrachloroethene	2.50E-01	9.96E-02	2.95E+00	2.00E+02
Toluene	5.11E+03	1.97E+03	1.00E+04*	5.26E+02
Trichloroethene	1.21E+00	4.81E-01	1.42E+01	1.10E+03
Xylenes (Total)	1.12E+02	4.33E+01	1.57E+03	1.75E+02
SVOCs				
Acenaphthene	1.00E+04*	7.09E+03	1.00E+04*	4.24E+00
Acenaphthylene	1.41E+03	5.42E+02	1.00E+04*	3.93E+00
Anthracene	1.00E+04*	1.00E+04*	1.00E+04*	4.34E-02
Benzo(a)anthracene				
Benzo(a)pyrene				
Benzo(b)fluoranthene	5.39E-01	2.03E-01	7.53E+00	1.50E-03
Benzo(g,h,i)perylene				
Benzo(k)fluoranthene				
bis-(2-Ethylhexyl)phthalate				
Chrysene	5.81E+01	2.19E+01	8.12E+02	1.60E-03
Dibenzo(a,h)anthracene				
Fluoranthene	1.00E+04*	1.00E+04*	1.00E+04*	2.06E-01
Fluorene	1.00E+04*	1.00E+04*	1.00E+04*	1.98E+00
Hexachlorobenzene	5.89E-02	2.34E-02	6.95E-01	6.20E+00
Indeno(1,2,3-cd)pyrene				
Naphthalene	6.17E+01	2.37E+01	8.62E+02	3.10E+01
Phenanthrene	1.00E+04*	1.00E+04*	1.00E+04*	1.00E+00
Phenol				
Pyrene	1.00E+04*	1.00E+04*	1.00E+04*	1.35E-01
Metals				
Antimony				
Arsenic				
Barium				
Cadmium				
Chromium III				
Chromium VI				
Cobalt				
Copper				
Lead				
Manganese				
Mercury	4.86E-01	1.84E-01	6.79E+00	
Molybdenum				
Nickel				
Tin				
Zinc				
Dioxins / PCBs				
Dioxins (I-TEQ)				
PCBs	4.33E-01	1.71E-01	5.11E+00	3.10E-02
Petroleum Carbon Ranges				
C6 - C8	8.22E+01	3.17E+01	1.15E+03	5.23E+00
C9 - C16	7.14E+02	2.76E+02	9.98E+03	2.80E+00
C17 - C35	1.28E+01	4.93E+00	1.78E+02	2.80E+00
Other Inorganic Compounds				
Cyanide, free				
Organometallics				
TBTO				

Notes:

(1) Blank indicates that RBRG could not be calculated because the toxicity or physical / chemical values were unavailable, or the condition of Henry's Law Constant>10^{-5} was not met for the inhalation pathway.

(2) Water solubilities for Petroleum Carbon Range aliphatic C9-C16 and greater than C16 generally are considered to be effectively zero and therefore the aromatic solubility for C9-C16 is used.

(3) * indicates a 'ceiling limit' concentration.

(4) *** indicates that the solubility limit exceeds the 'ceiling limit' therefore the RBRG applies.

Section 3
APPLICATION OF RBRGs IN LAND CONTAMINATION ASSESSMENT

The normal contamination assessment practice in Hong Kong is illustrated in Figure 3.1. RBRGs should be used in place of the Dutch B levels to determine the need for future action and remediation at a contaminated site, during the preparation of Contamination Assessment Plan (CAP), Contamination Assessment Report (CAR) and Remedial Action Plan (RAP). Implementation of the RBRGs and an assessment of the RBRGs to chemical concentrations detected on a site should be undertaken by a competent specialist consultant.

Figure 3.2 presents the steps in the application of RBRGs in contamination investigation. The primary information required includes: (1) knowledge of the past, current and future land uses at a site; and (2) sufficient analytical data on the concentrations of COCs in the site's soil and groundwater.

3.1 Steps for Applying RBRGs in Contaminated Land Assessment

Figure 3.2 presents the following six steps in contamination assessment:

Step 1: Identify land use and select COCs

Step 2: Assess laboratory data for COCs

Step 3: Compare maximum detected concentrations to RBRGs and NAPL trigger criteria

Step 4: Point-by-point comparison

Step 5: Establish whether NAPL is present

Step 6: Incorporate results into CAR

Once information has been compiled through the steps above, it can be summarized and reported on Standard Forms 3.1 through 3.5, which are introduced in the steps below and in Section 4 of this Guidance Manual.

User instruction is provided as follows.

Step 1: Identify Land Use and Select COCs
The first step is to identify the past, current and future land uses of a property. This information is typically compiled as part of the initial site appraisal (see Figure 3.1). Past and current land use information is important for developing a list of potential COCs and for assessing the potential presence of NAPL-related chemicals at the site. During initial site appraisal, it is important to identify past and present site activities that have potential to cause contamination and to make an inventory of the chemicals manufactured, stored, used and disposed of. COCs for a site should be selected on the basis of the information collected during the initial site appraisal and not necessarily bound by the 54 COCs in Tables 2.1 and 2.2.

Standard Form 3.1 can be used to summarize the past, current and anticipated future uses of a property.

If past usage of a site was different from the current use, all past operations and site conditions, back to the time the affected property was pre-industrial, are to be provided. Maps of layout of former operations, if available, should be attached to this standard form to illustrate the past site conditions. The type of business/facility/site, the names of the landowners, and a description of the primary products or process associated with each past use should also be specified. The number of years the business was in operation, or if the site was not in use, the number of years the property was in that condition should be indicated.

Current use information of the site, including maps showing the present layout of the site, the type of facility or business, a description of the business operations and primary products or processes, and the name of the landowner should be provided. If the site is presently vacant, this should be indicated on the standard form as well. If there is evidence that site-related contamination has migrated beyond property boundaries to downgradient properties, the types of land use at the affected properties should be indicated.

The land use classifications for any future use of the property, e.g., urban residential, rural residential, industrial or public parks should be clearly stated. Site contamination data should be compared to the RBRGs developed for the future land use reported for the site as the applicability of each set of RBRGs is dependent on land use. In the event that the future land use is unknown, the most stringent set of RBRGs should be adopted as the cleanup standards so that the site will be suitable for all use after remediation. If a site is to be excavated after remediation and the excavated soil will be re-used off-site, the most stringent set of RBRGs should be adopted. As it is usually very difficult to control the exact location in which the soil will finally be re-used, adopting the most stringent RBRGs will ensure that the destination site of the soil, wherever that may be, will be suitable for all land uses after being filled.

For any future land use categories falling outside the four categories described in Section 2, the user of this manual needs to compare the exposure characteristics of his/her site with those described for the four categories and identify one category that most closely matches the exposure characteristics of his/her particular site in question. The RBRGs for the category that is most similar to the user's site are the applicable RBRGs for his/her site of concern. For example, if a school site has exposure characteristics most similar to that of the "urban residential" category, the RBRGs specified for the "urban residential" category should be adopted for the school site.

When applying the RBRGs to a commercial land use scenario, a case-by-case judgment is appropriate because there are many different forms of commercial use. For example, a commercial use of a single storey building located in a rural area will likely resemble the rural residential setting, and thus the RBRGs for rural residential will apply. If a commercial use is within an urban residential building, then the RBRGs for urban residential will probably apply.

Step 2: Assess Laboratory Data for COCs

Following site investigation (Part II of Figure 3.1), a check must be made that the data collected from the site present a reasonably reliable description of the soil and groundwater contamination. Standard quality control/quality assurance (QA/QC) field procedures must be adopted during sampling and storage/transport of the samples to the laboratory. Such QA/QC procedures will ensure sample integrity and reduce the potential for cross-contamination and sample errors (e.g. erroneous concentrations of phthalates which are commonly found in plastic sampling products).

Laboratory analytical data should be reviewed to check that basic quality assurance and quality control protocols were followed. Any unusual problems reported by the laboratory to have prevented attainment of a detection limit less than the RBRG should be reported. For example, it may be difficult for a laboratory to quantify the individual constituents present in a sample contaminated with high concentrations of petroleum products. In these cases, special measures, such as sample dilution, can be employed by laboratories to maintain the lowest possible detection limits. In general, analytical data with detection limits that exceed RBRGs are considered invalid for use in assessment.

All detected chemicals must be compared to their respective RBRGs. If a chemical is reported in a quality control sample analyzed by the laboratory, i.e., a "blank", or is suspected to be a laboratory contaminant, this information should be recorded in the CAR document.

All laboratory test methods must be accredited by the Hong Kong Laboratory Accreditation Scheme (HOKLAS) or one of its Mutual Recognition Arrangement partners.

Step 3: Compare Maximum Detected Concentrations to RBRGs and NAPL Trigger Criteria
The CAR document should include data summary tables for soil and/or groundwater. Standard Forms 3.2 and 3.3 can be used for this purpose. All detected chemicals are to be listed by chemical category, e.g., volatile organic chemicals, semi-volatile organic chemicals, etc. Additional statistics and information should include the following:

- Frequency of Detection – the number of times a chemical was detected divided by total number of samples collected and analyzed for that parameter.

- Range of Detected Concentration – the minimum and maximum detected concentrations for each chemical.

- Range of Detection Limits – the minimum and maximum detection limits reported by the laboratory for each chemical.

- Analytical Method - reference for the method used to analyze each chemical.

- Land Use Category - list the relevant land use categories.

- RBRG – list the lowest of the appropriate RBRG(s) from Table 2.1 for soil and Table 2.2 for groundwater for all the land use categories applicable for the site. If there is no RBRG in Tables 2.1 or 2.2 for a COC found at a site, the user of this manual should propose for EPD's agreement a suitable remediation goal for the COC.

- C_{sat} or Solubility – for the soil and groundwater data summary (Standard Form 3.2 and 3.3), list the soil saturation or solubility limit from Table 2.1 and Table 2.2.

Step 4: Point-by-Point Comparison
A point-by-point comparison must also be presented. A point-by-point comparison involves tabulation of all sample numbers, concentrations, locations, and depths of all samples. Checks are to be placed in the appropriate columns on Standard Forms 3.4 and 3.5 for samples that exceed the soil RBRG or C_{sat} (Standard Form 3.4) and the groundwater RBRG or Solubility Limit (Standard Form 3.5). A site figure is to be submitted indicating the distribution of contamination for samples that exceed an RBRG or NAPL trigger criterion.

Step 5: Establish whether NAPL is Present
If maximum detected chemical concentrations in soil exceed the C_{sat} or the maximum detected chemical concentrations in groundwater exceed the Solubility Limit, additional assessment is required to determine whether NAPL may be present.

C_{sat} and Solubility Limits represent the initial NAPL screen for soil in unsaturated subsurface zones and groundwater, respectively. The decision on whether or not the soil or groundwater at a site contains NAPL or other non-natural free liquids will likely require professional judgement and a weight-of-evidence approach to balance out potentially conflicting information. The evidence may include information on the historic land use activities at the site, soil boring logs (visual evidence and/or hydrocarbon vapor readings), as well as soil, groundwater and soil vapor concentrations of various chemicals. An industry “rule of thumb” for groundwater DNAPL contamination is that DNAPL may be present where groundwater concentrations have been observed in excess of 1 % of the effective solubility of the compound detected. This is an approximation and should be considered as an indicator of the likely presence of DNAPL, it should be used in conjunction with the site specific details listed above.

Field observations are considered in determining the potential occurrence of NAPL. Records should be kept to indicate whether any of the following three field conditions was observed during sample collection:

1. Stained, unnaturally colored, or wet soil above the water table. The presence of NAPL may be obvious based on visual evidence of liquids in the soil, especially if the appearance is of a colored (or opaque) liquid or of a viscous liquid.

2. Petroleum or solvent odors in soil or groundwater samples.

3. Presence of sheen on water samples or bailer, or oily residual on soil samples or split spoon sampler.

If any of the above field conditions was observed, NAPL is likely to be present and remediation is required. In this instance the rules below are likely to apply (> indicates ‘greater than’ and < indicates ‘less than’), situations may vary on a site by site basis:

1. Site concentration > RBRG and
   Site concentration > C_{sat} or water solubility

If the field assessment indicates no trace of NAPL then the remediation goal will be the RBRG . If the field assessment indicates NAPL as present, then NAPL removal will be necessary and the lower of the RBRG or C_{sat} or water solubility will be the clean-up criteria.

2. Site concentration < RBRG but
   Site concentration > C_{sat} or water solubility

If the field assessment indicates no trace of NAPL then remediation is not required. If the field assessment indicates NAPL as present, then NAPL removal will be necessary and the lower of the RBRG or C_{sat} or water solubility will be the clean-up criteria.

3. Site concentration < RBRG and
   Site concentration < C_{sat} or water solubility

If the field assessment indicates no trace of NAPL then remediation is not required. If the field assessment indicates NAPL as present, then NAPL removal will be necessary and the lower of the RBRG or C_{sat} or water solubility will be the clean-up criteria.

4. Site concentration > RBRG but
   Site concentration < C_{sat} or water solubility

If the field assessment indicates no trace of NAPL then the remediation goal will be the RBRG. If the field assessment indicates NAPL as present, then NAPL removal will be necessary and the lower of the RBRG or C_{sat} or water solubility will be the clean-up criteria.

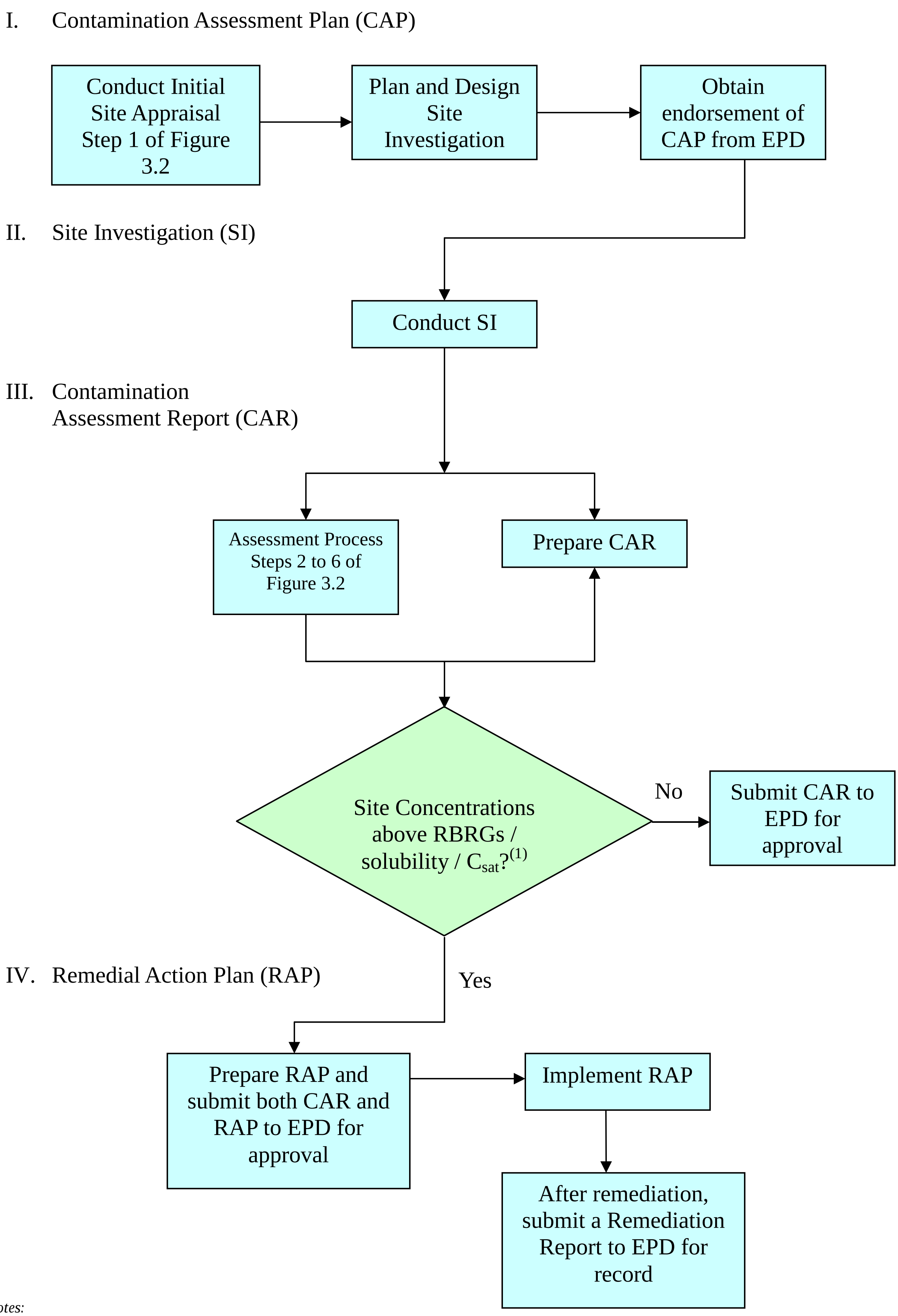
Step 6: Incorporate Results into CAR

The contamination assessment results, presented in Standard Forms 3.1 through 3.5 (or other similar format), should be included in the CAR along with recommendations for further actions The presence of the following conditions indicates that contamination exists and remedial action is required at the site:

- Any detected chemical concentration in soil or groundwater exceeds an RBRG;

- Any detected chemical concentration in soil exceeds a NAPL trigger criterion and other evidence suggests that NAPL is of concern.

Figure 3.1 – Land Contamination Assessment and Preparation of CAP, CAR and RAP



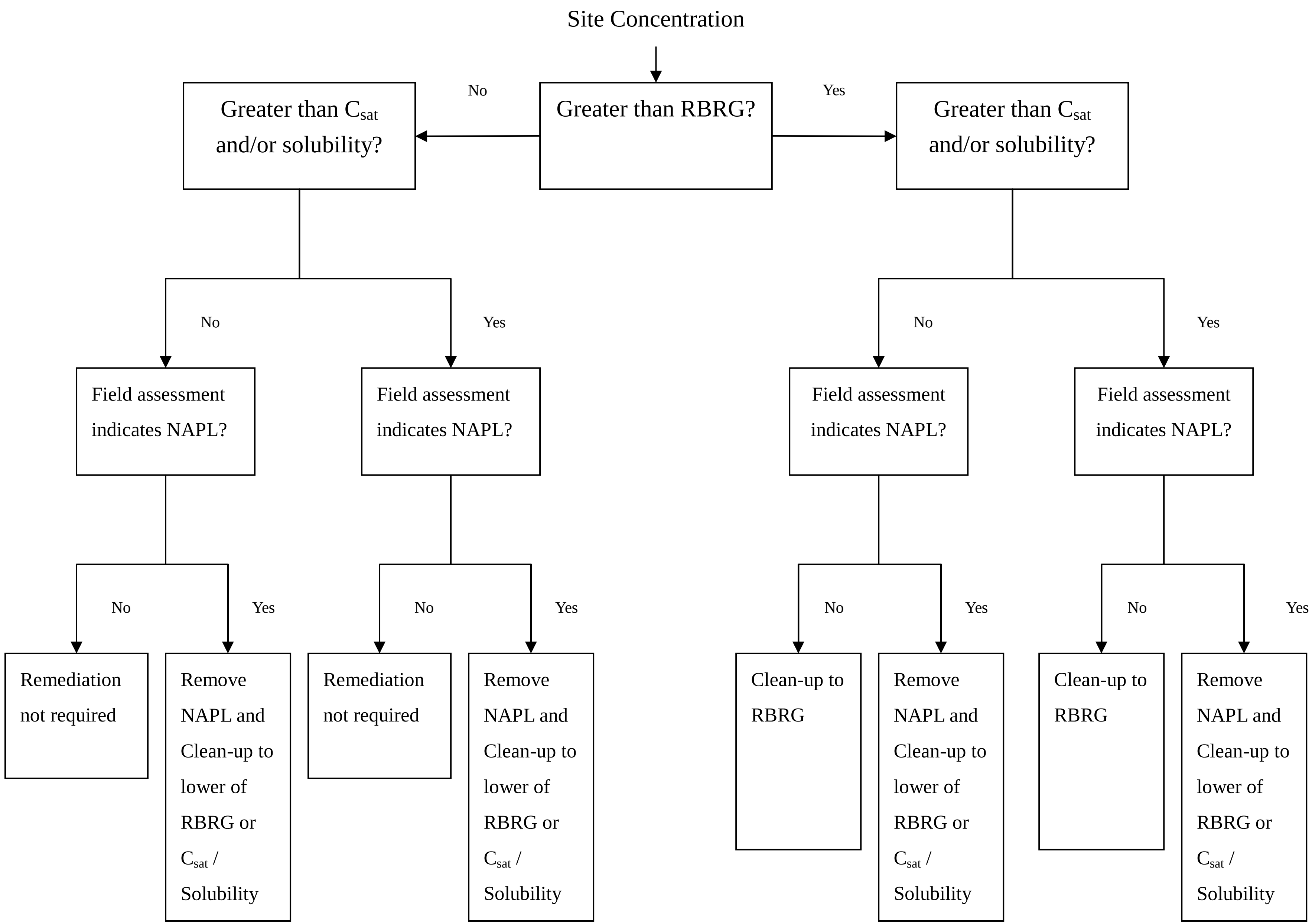
Notes:

1. Refer to Figure 3.3 for NAPL assessment flowchart.

Figure 3.2 – Land Contamination Assessment Process: Input and Reporting Requirements

Step	Necessary Information	Prepare Standard Form
1. Identify land use and select COCs	• Past land uses and activities • Current use of site and activities • Future use of site and expected activities • Maps and aerial photos of historic, current and future (if available) site layout and operations • COC selection based on past and current activities • Previous Site Investigation reports, if available	• Form 3.1 – Summary of On-Site Land Use
2. Assess laboratory data for COCs	• Soil and groundwater analytical data with detection limits less than RBRGs • Soil and groundwater COC concentrations to be representative of vertical and horizontal extent of contamination • Basic QA/QC evaluation of laboratory data noting spurious results or other reported problems	
3. Compare maximum detected concentrations to RBRGs and NAPL trigger criteria	• Sample concentrations reported as mass/mass (soil) and mass/volume (water) • Comparison of maximum concentrations in soil samples to RBRG and C_{sat} • Comparison of maximum concentrations in groundwater samples to RBRG and solubility limits	• Form 3.2 – Soil Data Summary and Comparison to RBRGs and C_{sat} • Form 3.3 – Groundwater Data Summary and Comparison to RBRGs and Solubility Limits
4. Point-by-point comparison	• Point-by-point tabulation of all chemicals, sample numbers, locations, and depths and indicate any exceedance of the soil RBRG and C_{sat} • Point-by-point tabulation of all chemicals, sample numbers, locations, and depths and indicate any exceedance of the groundwater RBRG and solubility limits	• Form 3.4 –Soil Sample Concentrations and Exceedances of RBRG and C_{sat} • Form 3.5 - Groundwater Sample Concentrations and Exceedances of RBRG and Solubility Limits
5. Establish whether NAPL is present	• Record of field observations including visual and odour evidence of NAPL plus field instrument readings.	
6. Incorporate results into CAR	• Conclusions regarding need for remediation • Discussion of information gaps and uncertainties, if applicable	• CAR

Figure 3.3 – NAPL Assessment Flowchart



Standard Form 3.1 - Summary of On-Site Land Use

Property Name ____

Current Use

Type of facility/business	On-site property land use	Date began[1]	Description of business process/primary products	Owner or Occupier	Approximate size of on-site property	Off-site property affected ? ___Yes ___No

Past Use

Are past uses different from current uses? ____Yes ____No If Yes, complete this section.

Complete this table with each different operation, use, or status of the on-site property. Include all operations back to pre-commercial or pre-industrial time if this information is necessary to characterize the site. Specify the status of the property at each stage, including times it may have been vacant. Start with the most recent use and list in chronological order backwards through time.

Type of facility/business	On-site property land use	Date began[2]	Date ended[3]	Description of business process/primary products	Owner or Occupier	Approximate size of on-site property (if different from current size)	Off-site property affected ? ___Yes ___No

Future Use

Are future uses different from current uses? ____Yes ____No If Yes, complete this section.

Type of facility/business	On-site property land use[4]	Description of business process/primary products	Owner or Occupier	Approximate size of on-site property

[1] Specify the approximate year in which the current use of the on-site property began.
[2] Specify the approximate year in which the past use of the on-site property began.
[3] Specify the approximate year in which the past use of the on-site property ended.
[4] Specify all applicable land use including urban residential, rural residential, industrial or public parks

Standard Form 3.2
Soil Data Summary and Comparison to RBRGs and C_{Sat}

Chemical	Frequency of Detection[1] (x/y)	Range of Detected Concentration[2]	Range of Detection Limit[3]	Analytical Method	Relevant Land Use Categories	Lowest RBRG(s) (mg/kg)	C_{sat} (mg/kg)	Maximum Detected Concentration Exceeds (check if applicable)	
								RBRG	C_{sat}
Volatile Organic Chemicals (List)									
Semi-Volatile Organic Chemicals (List)									
Metals (List)									
Dioxins/PCBs (List)									
Petroleum Carbon Ranges (List)									
Other Inorganic Compounds (List)									
Organometallics (List)									

1. x = number of samples in which chemical was found above the detection limit
   y = number of samples analyzed for chemical
2. Give minimum and maximum detected values
3. Give minimum and maximum detection limits

Standard Form 3.3
Groundwater Data Summary and Comparison to RBRGs and Solubility Limits

Chemical	Frequency of Detection[1] (x/y)	Range of Detected Concentration[2]	Range of Detection Limit[3]	Analytical Method	Relevant Land Use Categories	Lowest RBRG(s) (mg/L)	Solubility Limit (mg/L)	Maximum Detected Concentration Exceeds RBRG (check if applicable)	
								RBRG	Solubility
Volatile Organic Chemicals (List)									
Semi-Volatile Organic Chemicals (List)									
Metals (List)									
Dioxins/PCBs (List)									
Petroleum Carbon Ranges (List)									
Other Inorganic Compounds (List)									
Organometallics (List)									

1. x= number of samples in which chemical was found above the detection limit
   y=number of samples analyzed for chemical
2. Give minimum and maximum detected values
3. Give minimum and maximum detection limits

Standard Form 3.4
Soil Sample Concentrations and Exceedances of RBRGs and C_{sat}

Chemical	List Samples		Concentration	Check if RBRG Exceeded	Check if C_{sat} Exceeded	Approximate size of Affected Area
	Sample Number	Sample Depth				
Volatile Organic Chemicals (List)						
Semi-Volatile Organic Chemicals (List)						
Metals (List)						
Dioxins/PCBs (List)						
Petroleum Carbon Ranges (List)						
Other Inorganic Compounds (List)						
Organometallics (List)						

Standard Form 3.5
Groundwater Sample Concentrations and Exceedances of RBRGs and Solubility Limits

Chemical	List Samples		Concentration	Check if RBRG Exceeded	Check if Solubility Limit Exceeded	Approximate size of Affected Area
	Sample Number	Sample Depth				
Volatile Organic Chemicals (List)						
Semi-Volatile Organic Chemicals (List)						
Metals (List)						
Dioxins/PCBs (List)						
Petroleum Carbon Ranges (List)						
Other Inorganic Compounds (List)						
Organometallics (List)						

Section 4
RECORD KEEPING AND REPORTING

As a final step in the assessment process, the user should record in the CAR all the results mentioned in Section 3 for EPD's approval.

Standard Forms 3.1 through 3.5 are provided as templates for summarizing the information necessary to complete the contamination assessment. Reproduced copies of these forms, or similar forms containing the same information, are to be included in the CAR along with a narrative to describe their contents. The following Standard Forms have been included in this manual:

- Standard Form 3.1 – Summary of On-Site Land Use
- Standard Form 3.2 – Soil Data Summary and Comparison to RBRGs and C_{sat}
- Standard Form 3.3 – Groundwater Data Summary and Comparison to RBRGs and Solubility Limits
- Standard Form 3.4 – Soil Sample Concentrations and Exceedances of RBRG and C_{sat}
- Standard Form 3.5 – Groundwater Sample Concentrations and Exceedances of RBRG and Solubility Limits

Instructions for completing these forms are provided in Section 3. This information is to be submitted as part of the CAR, along with conclusions regarding the need for further action, or a determination of "no further action".

The following support documentation must be maintained by the project proponents and should be submitted to EPD when required:

- Field and Laboratory Data Package – Copies of field records and laboratory analytical reports for all media samples.
- Chain-of-custody documentation.
- Quality assurance/quality control documentation.

Laboratory reports must include the following information: name and address of the laboratory, name and address of client, project name, sample results, detection limits, sample ID number, lab ID number, sample matrix, date and time of sample collection, date of receipt of sample, date of sample preparation and extraction, date of analysis, preparation and analytical method numbers, method quantitation limits, analytical results, signature of laboratory personnel and issue date.

Chain-of-custody documentation must include: affected property name, address, and regulatory identification number, name of person who collected the samples, date of sample collection, type of analyses requested, sample matrix, sample ID number and sampling location, sample preservation method(s), date(s) and time(s) of transfer to other person, date and time received by the laboratory, signatures of collectors, the laboratory, and any intermediary persons, laboratory-assigned job number and sample numbers, and any other pertinent log-in information.

Quality control documentation should include any other information necessary to convey the results of the analyses and a brief summary to document that the data meet the project objectives. The project data quality objectives (DQOs) for media samples should be included in an appendix of the support documentation.

Section 5
GENERAL REFERENCE

ASTM, 1995. *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.* American Society for Testing and Materials (November, 1995).

ASTM, 2000. *Standard Guide for Risk-Based Corrective Action.* American Society for Testing and Materials (ASTM, November 2000).

CCME, 1996. *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines.* Canadian Council of Ministers of the Environment (March 1996).

CCME, 2000. *Canada-Wide Standards for Petroleum Hydrocarbons (PHCs) in Soil: Scientific Rationale - Supporting Technical Document.* Canadian Council of Ministers of the Environment (CCME, December 2000).

US EPA, 1992a. *Estimating Potential for Occurrence of DNAPL at Superfund Sites.* Office of Solid Waste and Emergency Response, US Environmental Protection Agency, R.S. Kerr Environmental Research Laboratory, Houston, Texas, USA (1992).