SNOWMAN NETWORK

Knowledge for sustainable soils

Decision-Making Frameworks for the Remediation and Redevelopment of Contaminated Land

Introduction

Issues related to contaminated land are encountered all around the world, in both urban and rural environments. In a 2014 report by the Joint Research Centre (JRC) of the European Commission[1], it was estimated that there were 340,000 contaminated sites in Europe, of which only one third had been identified and 15% remediated. Around one third of Europe's soil contamination is caused by the disposal and treatment of municipal and industrial waste; metal industries, petrol stations and mining are also common sources. The most frequent contaminants are mineral oils and heavy metals. The JRC report estimated that the management of contaminated land in Europe costs around EUR 6.5 billion per year, resulting in high costs for both the private and public sectors.

In some urban areas, significant areas of brownfield land (potentially contaminated land previously used for industrial or commercial purposes) are underused. This can lead to inefficient land use, for example due to restrictions on land use or a perception that the land is not fit for use and cannot be remediated. As a result, green land grabbing due to urbanisation pressure can pose a significant threat to soils. In addition, in urban areas the process of redevelopment involves different actors (urban planners, designers, developers, surface and subsoil engineers) who do not always work together in an integrated way, to address the same opportunities and challenges. In many cases, however, improved planning and decision-making processes could enable contaminated and brownfield land to be redeveloped, allowing for more sustainable urban development.

This *Policy Brief* provides a synthesis of the analysis undertaken by two projects funded by the SNOWMAN network: the BALANCE 4P[2] and MCA[3] projects. These projects aimed at developing and demonstrating more integrated, holistic decision-making approaches to support the sustainable redevelopment and remediation of contaminated and brownfield sites. Another goal was to ensure that soil quality and function are taken into account in land redevelopment and remediation. The approaches and practical tools developed can facilitate decision-making on the redevelopment of brownfield and contaminated land, and support planners and decision-makers in planning more efficiently and taking into account the impacts of redevelopments on soil quality and function.

Main findings

Both the BALANCE 4P and MCA projects developed decision-making tools or frameworks, and used case studies to demonstrate their applicability.

- The BALANCE 4P decision process framework presents a structured framework for policy-makers to assist in their decision-making.
- The MCA project tested two tools for use by policy-makers: SCORE (Sustainable Choice OF REmediation), which provides structured, transparent support for assessing the sustainability of remediation alternatives; and SF Box, which calculates changes in soil quality based on a proposed minimum data set).

Key policy recommendations

The following key lessons for decision-makers can be drawn from the experiences of the two projects:

- A structured framework and decision-making criteria should be set for the assessment of development alternatives;
- A suitable combination of instruments should be used to assess the sustainability of the different development options;
- Sufficient time and resources must be allocated to the redevelopment project, including an identified 'process holder' to take responsibility for ensuring that soil aspects are considered in the project; and
- Full engagement with all relevant stakeholders is crucial.

Content and methodology

The **BALANCE 4P project** looked at the application and assessment of methods for designing alternative land redevelopment strategies, capable of embracing case-specific opportunities and challenges. The work was developed via three case study locations: Merwevierhavens (Rotterdam, The Netherlands), Alvat (Buggenhout, Belgium), Fixfabriken (Gothenborg, Sweden), and included workshop discussions. Alternative land use change strategies and remedial technologies were evaluated and compared with respect to their ecological, economic and social impacts. Particular consideration was given to account for gains related to soil ecosystem services. The planning context, best practice and building processes in the three case study locations were studied, and many differences were found which illustrated the fragmented information regarding planning. Nevertheless, an integrated decision process framework was developed that offers advice on how to plan and execute a process, or parts of a process, to support urban renewal and redevelopment of brownfields.

The four Ps to be taken into account include the three Ps of sustainability, namely People, Planet and Profit/Prosperity. The fourth P, Project/Process, represents the specifics of the urban development project and the interaction between stakeholders and relevant institutions during the planning and execution of an urban plan or design.

The **MCA project** aimed to demonstrate the use of multi-criteria analysis (MCA) to evaluate different management and remediation alternatives to assess their overall impact. There was a particular focus on soil function (ecosystem services and goods) and sustainability.

Rather than focusing on pure cost-benefit analysis (CBA), which can not easily capture the value of maintained soil function, MCA aimed at demonstrating a method that includes soil function and related geographical, cultural and soil use aspects of soil function into the MCA. The project involved case studies at the Hexion site (Mölndal, Sweden), Marieberg saw mill (Sweden), and a shooting range (Linz, Austria). A range of conventional and innovative remediation technologies and strategies were evaluated with respect to their impacts on soil function. The MCA project also aimed at identifying how geographical, cultural and soil use differences affect the ranking of aspects of soil function, and how differences in geographical and climate conditions affect the outcomes of different remediation scenarios.

Decision-making frameworks

The two projects developed and tested frameworks that support decision-making in appraising different options for the remediation and redevelopment of contaminated land.

The BALANCE 4P decision process framework

BALANCE 4P took a holistic approach, attempting to integrate sub-surface aspects in the process for redeveloping land, to promote more sustainable land management. The holistic approach is governed by legislation, regulation, policy, and the institutions that set the relevant planning conditions (for example related to heritage, environment, nature and water). It is important to ensure that both surface and sub-surface aspects are considered in each phase of the urban redevelopment process.

The integration of surface and subsurface aspects can be enhanced in several ways:
1) through law and regulation;
2) by policy and vision;
3) through structured knowledge exchange; and
4) in the design/construction process.

An important aspect of BALANCE 4P was to investigate tools that can enhance knowledge exchange between sectors. The tools assessed included: the SEES method (System Exploration Environment & Subsurface); the Brownfield Remit/Response (BR2) tool; and the Brownfield Opportunity Matrix; OVAM MCA (Sustainable Choice of Remediation); ecosystem services assessment (www.natuurwaardeverkenner.be); biodiversity assessment (www.biodiversiteitstoets.be); and a social impact analysis (SIA).

The developed decision process framework aims at optimising both brownfield redevelopment and land use. It is anticipated that use of such a holistic approach will result in redevelopment plans that allow for smart, cost-effective and sustainable solutions during their implementation. This is achieved by ensuring knowledge is exchanged between those working in the surface and subsurface sectors during the planning process. The approach should also enable longer-term sustainable planning with regard to the subsurface due to increased awareness that the subsurface is a resource, and the risks and possibilities associated with this. It is recognised, however, that the framework is only one part of the whole system of decision-making and planning.

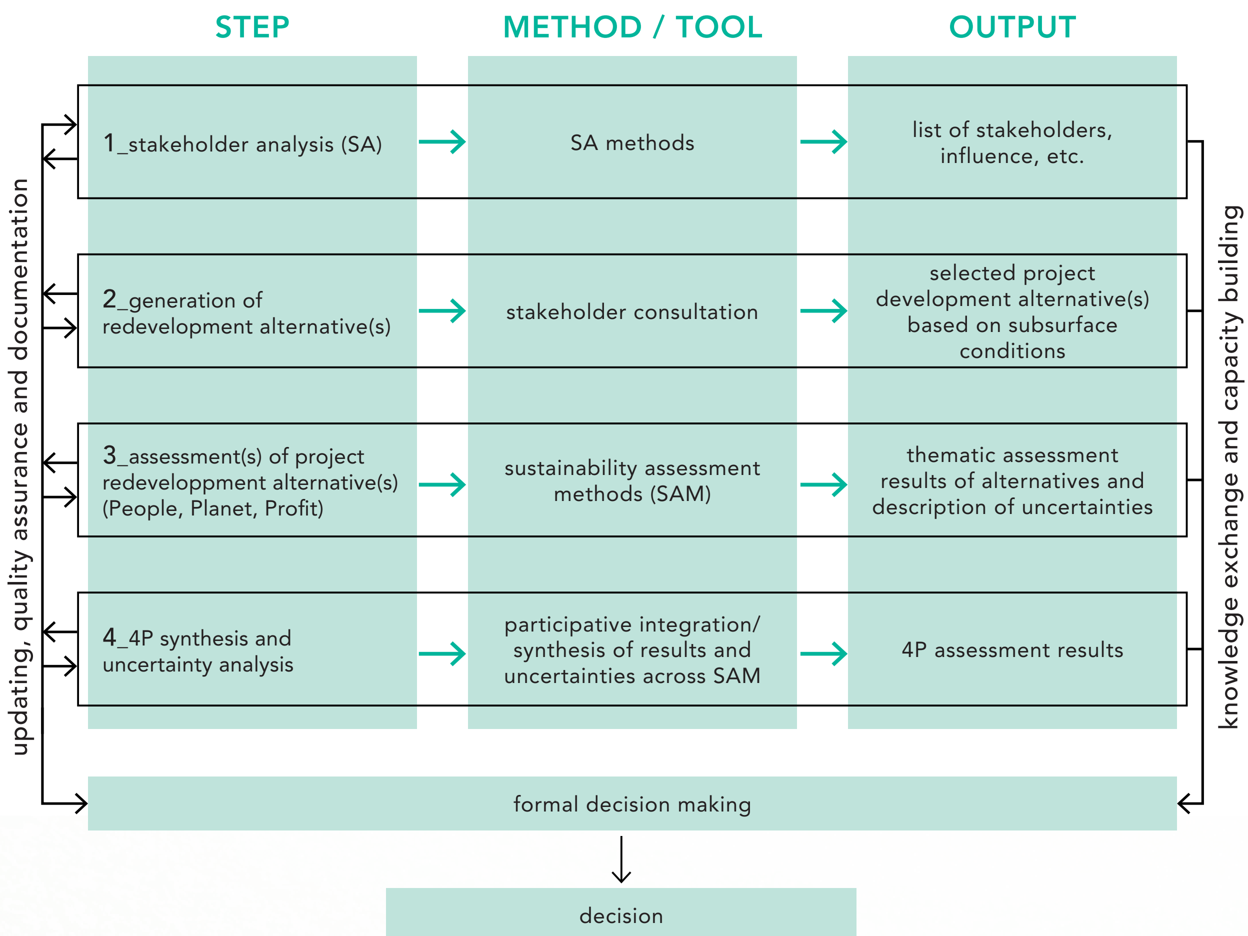

Figure 1. The BALANCE 4P decision process framework to support sustainable redevelopment of brownfields

The decision support framework aims to guide project teams who wish to implement a more holistic approach to decisions for land redevelopment. The framework includes four steps, which should be carried out iteratively:

1_Stakeholder analysis:
Identify all relevant stakeholders to take part in knowledge exchange, identify their interests and resources, determine how to involve them in the different phases of the project (e.g. inform, consult, partnership or control), and revise the stakeholder list as necessary (e.g. when new stakeholders appear or new activities are planned).

2_Generation of redevelopment alternatives:
Generate redevelopment alternatives using appropriate instruments (e.g. consultation, discussions, workshops etc), that ensures that knowledge exchange is facilitated between the surface and subsurface sectors. The generated alternatives should be revised and refined as new information becomes available (if possible).

3_Sustainability assessment of the alternatives:
Explicitly consider the three P's (People, Planet, Profit/ Prosperity) in the brownfield redevelopment Project, using assessment method(s)/tool(s) appropriate to the particular circumstances of the redevelopment (e.g. ensuring the tool is relevant, adequate resources are available for its use, and that it complies with regulatory frameworks). Ensure that relevant stakeholders are appropriately involved in the assessment. The sustainability assessment should be revised and refined as new information becomes available (if possible).

4_Synthesis of the assessment results, including uncertainty analysis:
Develop a participatory synthesis (e.g. by means of a workshop) of the results. This is proposed to be carried out as a qualitative and integrating analysis of the outcomes, in collaboration with relevant stakeholders. The synthesis may result in a ranking of redevelopment alternatives, and can be used as input for further stakeholder discussions and subsequent decision-making. Again, the analysis should ideally be revised if necessary, ideally via a new 'synthesis activity' (e.g. workshop).

The SCORE and SF Box tools

The MCA project applied the **SCORE (Sustainable Choice OF REmediation)** method which provides structured, transparent support for choosing between a set of remediation alternatives, by assessing whether each alternative will lead towards sustainable development. It allows for the integration of both quantitative and qualitative information within a comprehensive sustainability assessment. This includes a cost-benefit analysis of externalities (e.g. impacts on human health and the provision of ecosystem services), and a means for considering the effects on soil functions and services (which may otherwise be ignored) within the decision-making process. SCORE also identifies the potential for improving the sustainability of the remediation alternatives, and allows for an iterative approach so updates can be made as new information becomes available.

SCORE first identifies a set of environmental, social and economic sustainability criteria. The environmental key criteria/indicators are: soil; flora and fauna; groundwater; surface water; sediments; air; non-renewable natural resources; and non-recyclable waste. The social key criteria/indicators are: equity; health and safety; cultural heritage; local environmental quality and amenity; local participation; and local acceptance. The key economic sustainability criterion/indicator is: social profitability. The relative weight/importance of each criterion is decided. Each environmental and social criterion is then given a score, and the monetary costs and benefits in the economic domain are quantified. This allows the method to identify any trade-offs between the sustainability criteria, and also helps to distinguish between development towards weak sustainability (where some irreversible environmental, social-cultural and/or economic impacts may be neglected) and strong sustainability (where environmental, social-cultural and economic capital are maintained separately). A normalized score is calculated for each remediation alternative, taking into account the scorings and quantifications of the criteria and their relative weight/importance. This provides an overview of the positive and negative effects of the remediation alternative. An uncertainty analysis is then carried out, to help identify areas where more information is needed to achieve a more reliable sustainability appraisal.

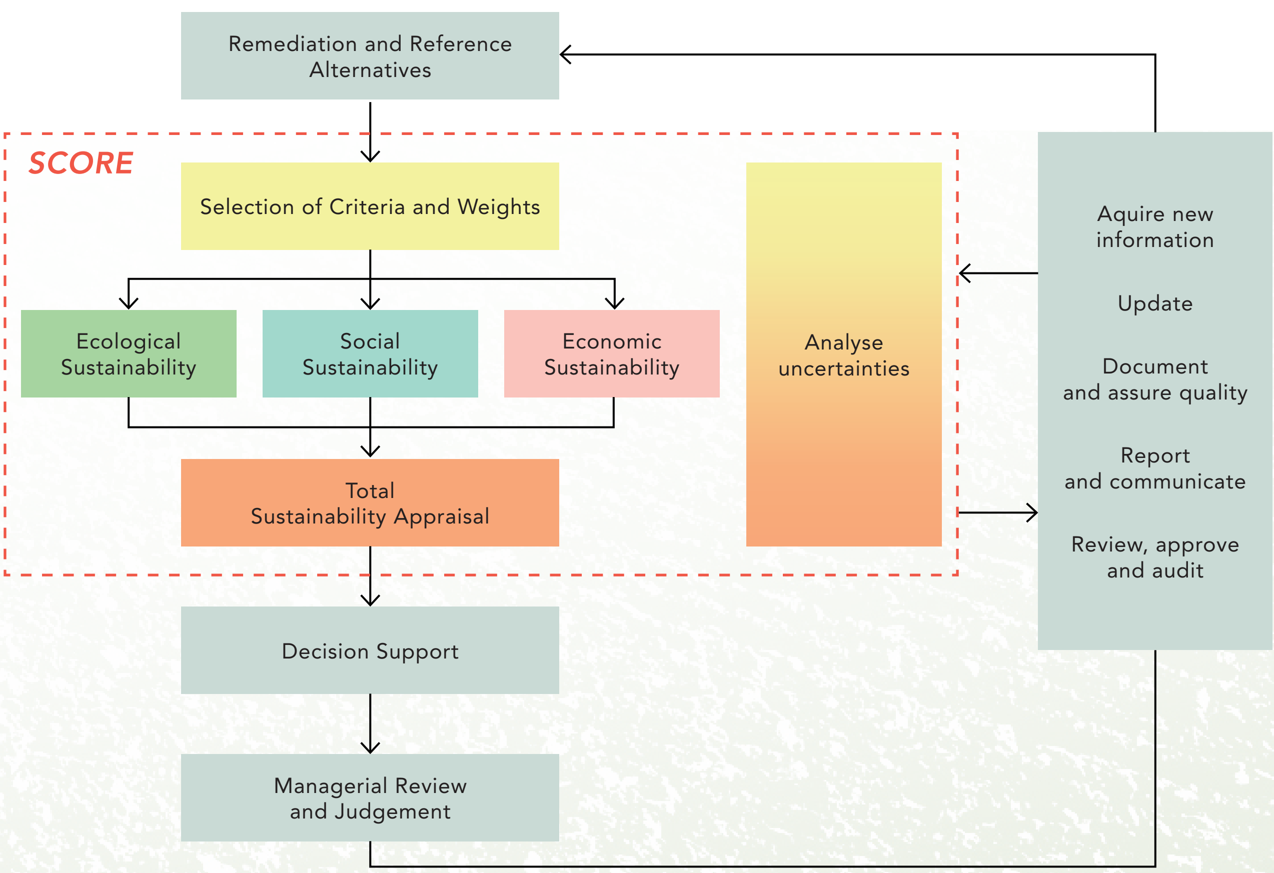

Figure 2. The SCORE (Sustainable Choice Of REmediation) framework (Rosén et al., 2013)

The MCA project also proposed the Excel-based **SF Box tool**, based on a minimum data set (MDS) that was developed to allow practitioners to assess soil functions associated with primary production, taking into account aspects of soil quality which could otherwise be ignored. The MDS includes the following soil quality indicators (SQI): soil texture; content of coarse material; available water capacity; organic matter content; potentially mineralizable nitrogen; pH value; and available phosphorus. Each SQI is given a sub-score between 0 and 1 (0 to 0.3 = poor quality, 0.31 to 0.7 = medium quality, 0.71 to 1 = good quality), then these sub-scores are averaged to provide an overall soil classification of very good (>0.85), good (0.70 to 0.85), medium (0.55 to 0.69), poor (0.40 to 0.54), or very poor (<0.40). The SF Box tool provides a simple means of inputting data to calculate the overall soil quality index, a soil class and a soil function performance. The calculated soil class and the matrix of the effects of remediation alternatives on ecological soil functions (Figure 3) can then be used as input to the MCA.

The SF Box tool could also potentially be used for soil function assessments in other types of land management projects focused on soil function, not just for remediation projects.

Soil Class of Reference Alternative	Soil Class as a result of Remediation Alternative				
	1*	2*	3*	4*	5*
1*	0	-	--	--	--
2*	+	0	-	--	--
3*	++	+	0	-	--
4*	++	++	+	0	-
5*	++	++	++	+	0

Soil Quality Classes :

1	Very Good
2	Good
3	Medium
4	Poor
5	Very Poor

Effects on Soil Functions :

++	Very positive
+	Positive
0	No effect
-	Negative
--	Very Negative

Figure 3. A suggested matrix of the effects on soil functions (modified by the MCA project after Volchko et al., 2014)

Label	No	Clay (%)	Silt (%)	Sand (%)	Grav-el (%)	Code	Name	CM (%)	CM_ Score	OM (%)	OM_ Score	AW (%)	AW_ Score	pH	pH_ Score	NH4N (mg/kg)	N_ Score	P (mg/kg)	P_ Score	Index	Performance
												Bulk den-sity				Method		Method		Method	
												1,6				St. meth-ods		Al P		Arithmetic mean	
PG1-7	1	0	2	81	17	LS	Loamy sand	17	0,78	0,8	0,07	21	0,87	8	0,04	180	0,01	44	0,76	0,42	Poor
PG1-14	2	0	2	89	9	S	Sand	9	0,96	0,7	0,07	21	0,87	7,1	0,99	180	0,01	28	0,38	0,55	Medium
PG2-2	3	0	1	93	6	S	Sand	6	0,99	1,6	0,16	22	0,90	6,5	1,00	180	0,01	34	0,53	0,60	Medium
PG2-5	4	0	1	79	20	LS	Loamy sand	20	0,70	7	0,99	24	0,93	8,2	0,01	230	0,06	20	0,21	0,48	Poor
PG2-9	5	0	2	79	19	LS	Loamy sand	19	0,73	3,2	0,52	22	0,90	6,3	0,99	220	0,04	29	0,40	0,60	Medium
PR3-1	6	0	2	88	10	S	Sand	10	0,93	3,7	0,66	22	0,90	6,4	1,00	170	0,01	43	0,74	0,71	Good
PR3-2	7	11	14	73	2	SL	Sandy loam	2	1,00	5,8	0,95	25	0,95	6,5	1,00	210	0,03	38	0,63	0,76	Good
PR3-3	8	0	3	82	15	LS	Loamy sand	15	0,83	0,6	0,06	21	0,87	6,7	1,00	170	0,01	30	0,42	0,53	Poor
PR3-4	9	0	1	84	15	LS	Loamy sand	15	0,83	1,5	0,15	22	0,90	6,1	0,89	170	0,01	24	0,28	0,51	Poor
PR3-5	10	0	2	80	18	LS	Loamy sand	18	0,76	0,8	0,07	21	0,87	6,4	1,00	170	0,01	32	0,48	0,53	Poor
PR3-6	11	11	16	70	3	SL	Sandy loam	3	1,00	6	0,96	25	0,95	5,6	0,14	210	0,03	36	0,58	0,61	Medium
PB4-2	12	0	2	77	21	LS	Loamy sand	21	0,68	5,4	0,92	24	0,93	6,5	1,00	210	0,03	25	0,31	0,65	Medium
PB4-3	13	0	2	82	16	LS	Loamy sand	16	0,81	1,5	0,15	22	0,90	6,3	0,99	180	0,01	21	0,23	0,51	Poor
PB4-5	14	0	3	80	17	LS	Loamy sand	17	0,78	3,4	0,58	22	0,90	6,2	0,95	140	0,00	32	0,48	0,62	Medium
PB4-6	15	0	5	78	16	LS	Loamy sand	16	0,80	0,9	0,08	21	0,87	5,8	0,41	180	0,01	59	0,94	0,52	Poor
PB4-7	16	3	10	83	4	LS	Loamy sand	4	1,00	4,4	0,80	25	0,95	5,9	0,60	230	0,06	37	0,60	0,67	Medium
PB4-10	17	0	1	80	19	LS	Loamy sand	19	0,73	1,2	0,11	22	0,90	6	0,77	160	0,01	27	0,35	0,48	Poor
PB4-11	18	0	5	91	4	S	Sand	4	1,00	1	0,09	21	0,87	7,5	0,60	170	0,01	39	0,65	0,54	Poor
Mean		1,4	4,1	81,6	12,8	LS	Loamy Sand	12,8	0,88	2,8	0,40	22,4	0,91	6,6	1,00	186,7	0,02	33,2	0,51	0,62	Medium
																				Soil Class	3

Figure 4. An example of an output from the SF Box tool (evaluation for the Marieberg site, Sweden)

Conclusions and lessons for decision-makers

The practical experiences of the BALANCE 4P and MCA projects provided insights into how the decision-making tools can work in real world situations, and the practical challenges that may be faced when making decisions on remediation options for specific sites. The following key lessons for decision-makers can be drawn from the experiences of the two projects:

Set a structured framework and criteria for the assessment of development alternatives:

Taking a structured approach to generate and assess alternatives for redevelopment of sites can strengthen the work of urban planners. A structured approach helps to identify how well different alternatives meet a project's political goals and visions, and also whether the project contributes to sustainable urban development. Developing site-specific criteria (and relative importance/weight) and estimating missing data may be time-consuming and should be tackled early in the remediation project process. Whilst general, basic data can usually be generated fairly easily, e.g. from documents related to previous investigations at the sites, detailed data may not be available (in particular on soil and groundwater contamination) early in the process. There may also be challenges relating to the communication and use of results (for example if information is held by different municipal and private bodies). It is therefore advisable to use qualitative or semi-quantitative analyses for sustainability assessments during the early phases of the redevelopment process, and to revise assessments when more detailed information becomes available.

Use a suitable combination of instruments to assess sustainability:

The BALANCE 4P project recognise that the redevelopment of brownfield sites deals with complex systems (especially when fully including all subsurface qualities). For this reason, a combination of instruments should be used to assess sustainability rather than attempting to cover all aspects within a single type of assessment. Along the same lines, the MCA project concluded that the effects of a remediation project on soil functions and on soil ecosystem services should be carried out following different methods. The effects on soil functions (i.e. the natural capabilities of the soil ecosystem) should be assessed using physical, chemical and biological soil quality indicators, whereas the impacts on soil ecosystem services (i.e. utilized soil functions that contribute to human well-being) should be assessed using value-related indicators, since ecosystem services are more related to the socio-economic effects of remediation.

Allocate sufficient time and resources, and identify a 'process holder':

Sufficient time and resources must be allocated to a redevelopment project to ensure that all relevant information can be compiled and made understandable for all stakeholders concerned. If soil impacts are to be taken into account adequately, it is extremely important to identify a specific person with a clear interest and responsibility for incorporating subsurface aspects into planning procedures. This 'process holder' should be responsible for knowledge exchange within each phase of the project, and for information transfer between the phases of the redevelopment process; this is a crucial role to address the issue of stakeholders and planners having limited interest in subsurface aspects.

Engage fully with stakeholders:

It is important to identify all relevant stakeholders early in the process. It is generally most effective to communicate via physical meetings that include active participation by stakeholders, for example workshops or individual interviews. The final step of the SCORE tool (i.e. assigning values) benefits from being undertaken in a group, which allows for an iterative process where each criterion and scoring is openly discussed. One method successfully used during the BALANCE 4P case studies is the System Exploration Environment and Subsurface (SEES) methodology. This method allows urban development project teams to guide discussions between various stakeholders, using a structured matrix (see Figure 5) that ensures all necessary specialists and fields are consulted, and synergies can be identified. Although some preparation is required, the SEES methodology allows planners to gain insights into the opportunities and challenges associated with subsurface qualities at the redevelopment site, and has proven effective in supporting knowledge exchange between experts in the surface and subsurface sectors.

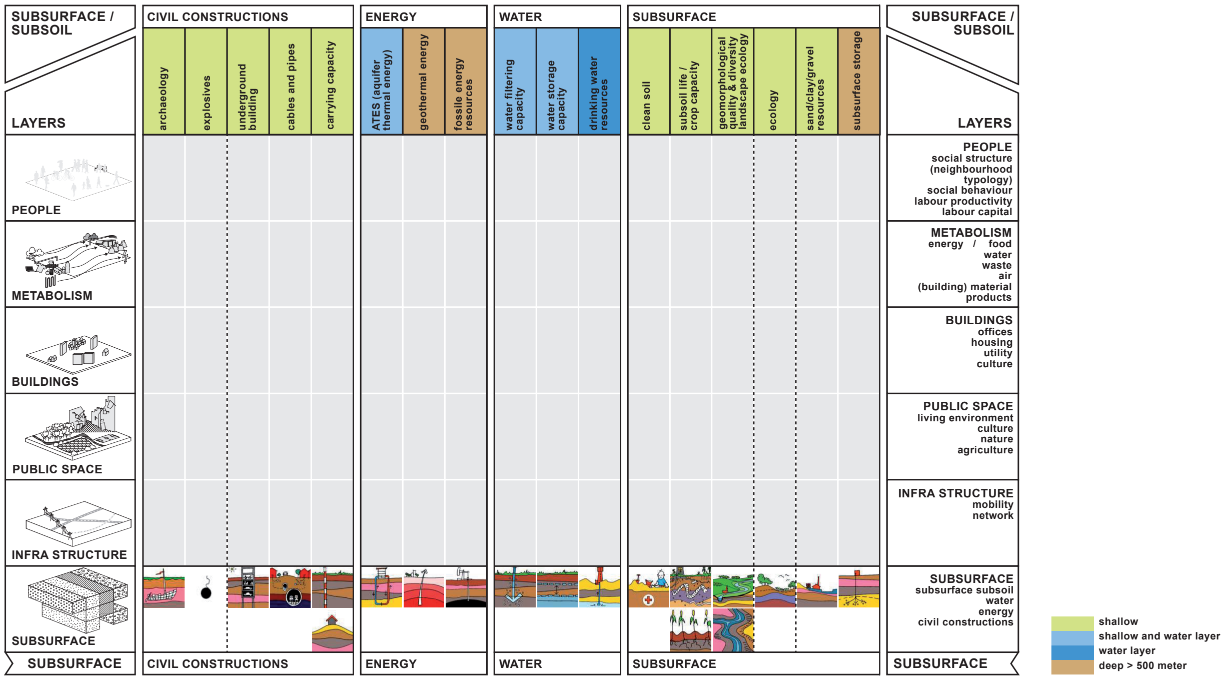

Figure 5. Figure 5 The System Exploration Environment and Subsurface (SEES) methodology matrix

About the SNOWMAN network

The SNOWMAN Network is a transnational group of research funding organizations and administrations in the field of sustainable management of soil in Europe. Acting as a Science-Policy-Practice interface, it aims to bridge the gap between knowledge demand and supply.

This policy brief is part of a series presenting the main results of the 17 European research project funded from 2006 to 2015 by the network.

More information on **www.snowmannetwork.com**.

REFERENCES :

1_ European Commission Joint Research Centre (2014). Progress in the management of contaminated sites in Europe

2_ **BALANCE 4P:** Balancing decisions for urban brownfield regeneration – people, planet, profit and processes

3_ **MCA:** Multi-criteria analysis (MCA) of remediation alternatives to access their overall impact and cost/benefit, with focus on soil function (ecosystem services and goods) and sustainability)

SNOWMAN Projects

BALANCE 4P final technical report_
http://snowmannetwork.com/?page_id=287

MCA final report_
http://snowmannetwork.com/wp-content/uploads/Final-Report-SNOWMAN-MCA-for-print-REV-SNOWMAN-141216.pdf

Full reports available at **www.snowmannetwork.com**

REDACTORS: Emma Watkins & Catherine Bowyer, Institute for European Environmental Policy

REVIEWERS: Jenny Norrman (Chalmers) , Magnus Bergknut , Yvonne Ohlsson (SGI), Esther Goidts (SPW)

GRAPHIC DESIGN: studioplay.fr

Published in 2018