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A decision support system for water cycle management in new developments: user scenarios for consideration of sustainability imperatives

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ABSTRACT

The Water Cycle Management for New Developments (WaND) project aims to support the delivery of integrated, sustainable water management for new developments by provision of tools and guidelines for project design, implementation and management. WaND is a research consortium of more than 30 researchers and around 25 professional stakeholders, and deals with the provision of water, stormwater and wastewater services.

This paper aims to simulate the practical use of 'Flexiframe' – a browser-based user interface to WaND output and decision support. Two stakeholder groups are considered here: planners and developers. The potential application of Flexiframe for stakeholders is illustrated based on case studies conducted within the WaND project. Existing decision making processes are used as a template for routes through the portal for each professional group. At each stage relevant links and targeted decision support tools developed within WaND for the specialist user are referenced. The practical use of Flexiframe for user groups is demonstrated based on assumptions of requirements. A project assessment tool within Flexiframe enables wider consideration of the relative sustainability of decisions at strategic level. Its use is demonstrated in simulated stakeholder group discussions.

Two user scenarios are considered that illustrate potential consequences of decisions for technical, economic, social and environmental aspects of a new UK housing development. The potential output of the tool is illustrated based on the results of interviews and workshops with professional stakeholders and the WaND consortium.

The paper demonstrates the practical application of the Flexiframe decision support tool; how it encourages communication between professional domains, its explicit incorporation of sustainability principles into decision making and its educational value. The tool's fulfilment of requirements of stakeholders consulted at the start of the project is considered, as is its potential future development.

Key words: Decision support, Integration, Accessibility, Assessment

1 INTRODUCTION

The Water Cycle Management for New Developments (WaND) project is funded by the Engineering and Physical Sciences Research Council (EPSRC) as part of its Sustainable Urban Environments (SUE) initiative. WaND is a research consortium of more than 30 researchers and around 25 professional stakeholders, and deals with the provision of water, stormwater and wastewater services. The project aims to support the delivery of integrated, sustainable water management for new developments by provision of tools and guidelines for project design, implementation and management. The WaND project began in 2003 and will complete in 2007.

This paper describes work carried out within WaND that aims to provide a flexible and adaptable framework to guide decision makers, actors and other stakeholders to better understand sustainability, and to support the making of more sustainable decisions for water/wastewater systems.

An IT-based graphical user interface (GUI) or portal - 'Flexiframe' has been developed to allow access to WaND output and decision support for individuals and groups concerned with water/wastewater management. Four stakeholder groups are targeted for decision support within Flexiframe: planners, developers, water service providers and lay persons. The potential application of Flexiframe for two of the stakeholder groups is illustrated based on case studies conducted within the WaND project.

Existing decision making processes are used as a template in the form of decision webs for routes through the portal for each stakeholder group. At each stage relevant links and targeted decision support tools developed within WaND for the specialist user are referenced. The practical use of Flexiframe for each group is demonstrated based on assumptions of requirements. A project assessment tool within Flexiframe enables wider group consideration of the relative sustainability of decisions at strategic level and its use is demonstrated in simulated stakeholder group discussions.

Two user scenarios are considered that illustrate potential consequences of decisions for technical, economic, social and environmental aspects of a new development based on WaND consortium case studies. The potential use of selected WaND outputs is demonstrated on the results of interviews and workshops with professional stakeholders and the WaND consortium.

The paper demonstrates a small proportion of the practical applications of the Flexiframe decision support tool; how it encourages communication between professional domains, its explicit incorporation of sustainability principles into

decision making and its educational value. The tool's fulfilment of requirements of stakeholders consulted at the start of the project is considered, as is its potential future development.

2 THE PORTAL: 'FLEXIFRAME'

2.1 Stakeholder requirements

The views of stakeholders and potential end-users of Flexiframe have informed its appearance and usability. A great number of stakeholders are associated with water cycle management for new developments, but for the purposes of development of Flexiframe, four key stakeholder groups were chosen: planners, developers, water service providers and potential householders. This range of stakeholders with differing background knowledge and different potential reasons for using Flexiframe were chosen in order to ensure its flexibility and ease of use. The tool is intended to be accessible and easy to use for each stakeholder, whilst providing access to rigorous and robust scientific data and decision support. The interaction of the chosen stakeholders in the decision making process for water cycle management in new developments is illustrated within Flexiframe and provides a framework on to which the needs of other actors and stakeholders can be appended in future development of the tool. It is hoped that it will encourage understanding and communication between sectors by giving an overview of the issues affecting each group

The needs of stakeholders were determined by: semi-structured interviews with appropriate professionals and non-specialists; information from the web; from published documentation, and during workshops with stakeholders and researchers. This information was structured in the form of ontologies (defining terms used to describe and represent an area of knowledge) that form the basic composition of the framework (Mounce et al., 2006).

A scoping study carried out with Glasgow City Council (Bordorley & Smith, unpublished) indicated that Flexiframe should:

- be standard and structured process, utilisable from the outset of a project
- deal with and process both qualitative and quantitative data and information
- be flexible enough to allow the use of finer detail as the project becomes more detailed and specific
- be usable as an effective and simple education and awareness-raising tool, for both lay persons and a range of professional groups
- be readily accessible as regards how the outcomes are presented.
- include enough inherent flexibility to ensure project-appropriateness
- be more pragmatic than 'academic' in nature

It was felt that the output should be in electronic format with provision for non-IT users, be visually appealing and understandable and should contain a tiered suite of different tools for a range of project types and sizes. The requirements of potential end-users have been fully taken into account in the development of Flexiframe.

2.2 Portal architecture

A browser prototype has been developed to address the design of the portal using a multimedia authoring package (Macrovision). The environment allows a full range of interactivity, automation, internal and web hyperlinking, launching of external applications, database connectivity and delivery on CD or as a website. A browser-based implementation allows supporting content to be synchronized with the inferencing process (the navigation through the decision web). Text, hyperlinks or graphical details from policy, procedure or reports can be keyed to the steps presented by the intelligent portal. This architecture facilitates the user to browse through the decisions web, to identify the appropriate decision process and to utilise relevant WaND consortium output.

Data acquired by the WaND consortium has been encoded within and across knowledge domains as ontologies. Ontologies are used within the portal to define a common vocabulary and structure of information space for researchers and domain experts in which to exchange and share knowledge.

The Portal forms an access point for research output from WaND and for other information relevant to stakeholders. The aim of the portal is to allow appropriate and targeted support relating to the design and implementation of project assessment. The Portal allows access to a decision support toolbox for risk-based planning and outline design for integrated water systems for new developments, including an optioneering tool. It also allows access to other software such as a demand forecasting tool, as well as GIS or spreadsheet models. It allows access to reports of case studies involving water management stakeholders and sociological perspectives on innovative water management solutions. Finally, the Portal also includes links to websites relevant to stakeholders.

Figure 1 shows the opening page of the portal, the links on that page lead to the following:

About

- An overview-an overview of the portal and its use
- A quick link to the toolbox; access to decision support tools developed within WaND
- A glossary of terms used within the portal

- Access to an ontology of project elements through a topic map browser

WaND

- The route to a description of each work package and all WP specific outputs.

Stakeholders

- A decision web with links to resources (internal and external to the consortium) for decision makers

Sustainability

- An overview of sustainability information and links to tools for sustainability assessment

Case Studies

- Information from the WaND consortium as applied to a case studies.

Figure 1: opening page of the WaND portal

Continuing extension of the portal is an iterative process throughout the WaND project, and it retains the flexibility for future refinement following user feedback (Mounce et al., 2006).

2.3 WaND outputs

Outputs from the WaND project include decision support, tools, reports and recommendations. Tables 1 to 3 illustrate some of the outputs accessible by Flexiframe.

Table 1: Examples of WaND decision support outputs

Work area	Example of output	Research organisation
The WaND toolbox (e.g. Makropoulos et al., 2006, [1 & 2])	A common decisional platform to integrate information on sustainable practices for urban water management and tools to evaluate these practices	University of Exeter
Integrated Modelling and Advanced Decision Support (e.g. Morley et al., 2004)	Integrated modelling tools to support the planning of integrated sustainable urban resource management practices under future scenarios	University of Exeter and SUE collaborators
Project Assessment Tool (e.g. Hurley et al., 2006)	Tool for use in collaborative decision-making between stakeholders. The tool aims to be user-friendly and has an easily interpretable visual outcome. It is intended for use in aiding the decision-making process rather than providing a definitive assessment.	University of Sheffield
Decision mapping	Flow charts of decision making for particular case studies are incorporated in the portal.	University of Abertay, Dundee

Table 2: Examples of WaND tools

Work area	Example of output	Research organisation
Water Supply	A suite of prototype forecasting tools for different water conservation and land management strategies and scenarios	University of Leeds
Stormwater	A suite of models that quantify the hydraulic and water quality performance characteristics of different surface drainage systems	HR Wallingford / CEH

Wastewater collection	Results of research into use of small sewer technology based on new low-energy, low-water use toilet equipment, coupled to innovative pipe systems	University of Exeter
Environmental Health aspects	Health impact assessment methodology for innovative water management strategies	University of Wales, Aberystwyth
On-site water and solid waste treatment options	Deployment envelopes for new development based water treatment and reuse systems at varying scales of application	Cranfield University
SUDS performance at development scale - interactions with rainfall and groundwater	Validated procedures for assessing 'sustainable urban drainage systems' (SUDS) as flood control structures, their effect on water tables, infiltration into sewers, and potential storage of stormwater as groundwater.	HR Wallingford / CEH

Table 3: Examples of WaND reports and recommendations

Work area	Example of output	Research organisation
Social and economic aspects (e.g. Wong, 2005, Sefton and Sharp, 2006)	Results of research into the complex interactions between social, economic, legal, cultural and institutional factors relating to implementation of innovative water management technologies	University of Bradford
Innovations and risks (e.g. Sefton 2007)	Recommendations concerning communication and management strategies required for the successful introduction of more sustainable waste and water management measures	University of Bradford

Strategic project and planning guidance on cross-sectoral and scale-up issues for sustainable development	Evaluation of areas of potential conflict and synergy between different sectoral and spatial dimensions of sustainable development	Cranfield University

3 STAKEHOLDER USE OF FLEXIFRAME

3.1 The common interface

The portal is of a common entry point for WaND outputs. It aims to guide decision makers, actors and other stakeholders to better understand sustainability, and to support the making of decisions that lead to more sustainable solutions for water / wastewater systems. A large section of the portal is dedicated to the work of the consortium; however this paper describes its potential use as decision support by the two professional stakeholders. From the opening page of the portal, stakeholders are directed to the page illustrated in Figure 2. From there they are able to follow routes through the portal that lead them to different types of decision support aimed at their particular user group, or they may follow routes dedicated to other user groups to facilitate cross-sectoral understanding of decision making processes.

A framework structures the stages in the planning, design, construction and maintenance of a New Development, with a focus on more sustainable decisions in water management. Each stage may comprise a number of sub-stages. For example, in the 'Planning permission' stage areas such as special protection, flood risk assessment and consultation are addressed. At key points a decision web can be traversed to obtain appropriate guidance and resources, as well as WaND developed tools. Publicly available information has been structured in a format that could be useful day to day. Simplistic representations of decision-making processes have been included and are based on case studies and interviews; they are descriptive rather than prescriptive of processes.

3.2 User scenario 1: the developer

The developer page as shown in Figure 3 is common to developers, planners and water service providers in all but title, photographs and links to resources, which are tailored to the specific user.

Decision maps have been created based on WaND research. Figure 4 shows a generic decision map for a developer and Figure 5 shows how it is implemented by the portal to provide targeted resources.

Figure 2: Common stakeholder page within the WaND portal

Figure 3: Developer link from stakeholder page in WaND portal

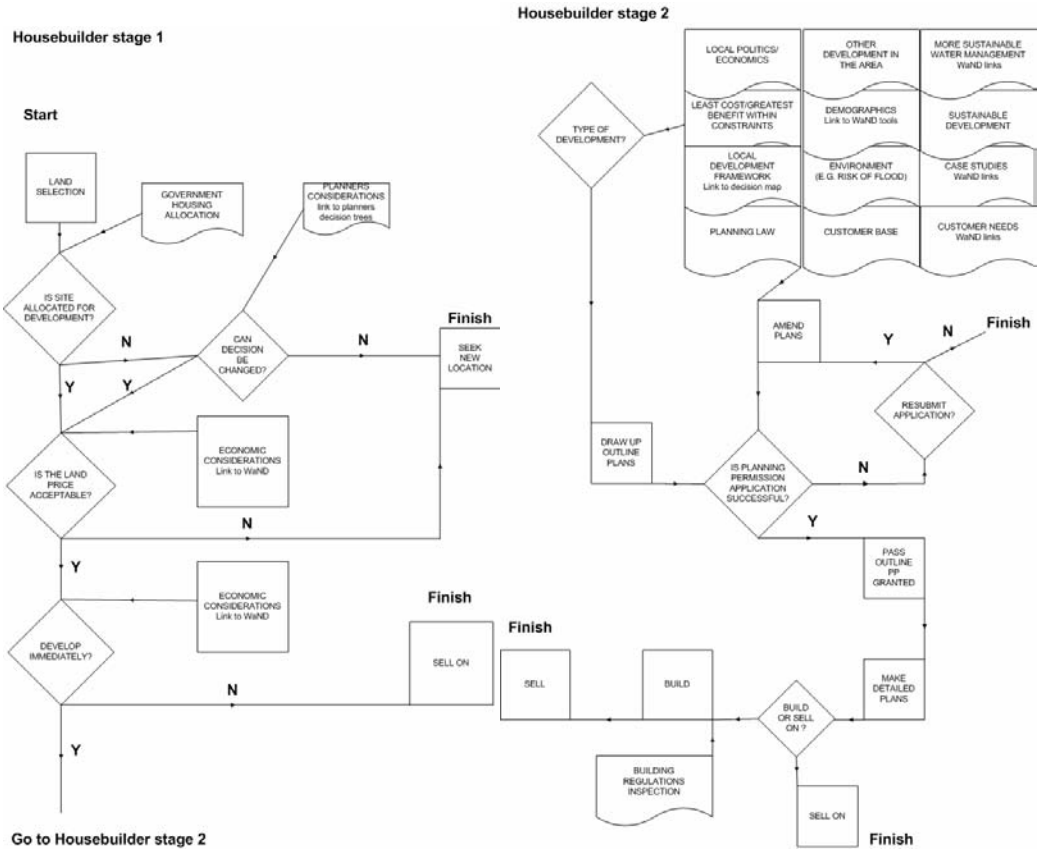

Figure 4: Developer decision map (generic representation)

The portal incorporates a rudimentary Expert System that illustrates the alternative routes/options open to various stakeholders faced with different problems. It consists of a questions and organized answers (defined by the decision map) suggested to orient the stakeholder to proceed through the decision process with utmost consideration of sustainability issues by providing the relevant information, guidance and access to computational and decision making tools (which may, for example, include the WaND decision support toolbox).

Resources for the developer include useful web links to organisations such as the Construction Industry Environmental Forum, the Health and Safety Executive, Local Authority Building Control etc. The developer also has access to outputs of the work of the WaND consortium. Case studies utilised by the consortium illustrate how decisions have been made in practice, where difficulties lie and how issues of sustainability have or have not been incorporated. By reference to the case studies,

Figure 5: Implementation of the developer decision web within the WaND portal

and to examples of the decision processes of other stakeholders, the user may begin to overcome difficulties of cross-sectoral communication. A common case study used by the WaND consortium is the Elvetham Heath residential development at Fleet in Hampshire. The development covers 116 hectares and accommodates 5,000 people, giving considerable scale for research (Wong and Kennedy, unpublished). Claims that the development has adopted the principle of sustainable development and a series of hydrological measure to address water issues also make it of particular interest to the WaND consortium. There are limitations for Elvetham Heath as a case study since the low density of this housing development may not be representative of future development in England and Wales (Franco and Kellagher, unpublished). Elvetham Heath has four sustainable urban drainage systems (SUDS): a retention pond, dry balancing ponds, swales and soakaways. The sustainable water innovations adopted by developers are dual-flush toilets and water-saving washing machines.

Interviews conducted as part of the social and economic aspects of the WaND project (Wong and Kennedy, op.cit.) uncovered opportunities for and barriers to the implementation of more sustainable water innovations within the development. Semi-structured interviews were conducted with five key stakeholders, i.e. the landowner, a district council planner, a householder and representatives of a developer and the water service provider.

The adoption of SUDS is a major issue in their uptake in new housing developments (e.g. Ashley et al., 2006). This has been overcome at Elvetham Heath by consideration of SUDS as part of the public open space in the development. The water company retains ownership of the SUDS components and leases them to the District Council for maintenance. The developers pay commuted sums to the Council

for maintenance of the SUDS in perpetuity. This arrangement provides an illustration of institutional co-operation that may form a model for future developments.

Drawbacks were found to include assumptions of developers that water innovations would reduce market value of properties, whilst property owners indicated that they were not given the option of their uptake. The complex interaction between developers and the regional council based on building regulations was found to be a barrier surmountable only by mutual understanding. Facilitation of communication, by understanding the issues and for example by the use of the project assessment tool (section 4) at an early stage in negotiations could help to break down barriers.

3.3 User scenario 2: the Planner

Local authority planners have varied roles. Flexiframe is generic in its links to resources whilst providing actual case study data. The planner enters the portal in the same way as the developer and has access to the same information. Targeted information for the planner is accessible at the next stage of traversal through the portal. The decision map shown in Figure 5 is an example of case study data available to the planner and shows how flood risk assessment was considered during the planning process for a development in Scotland.

The decision map shown in Figure 5 was developed by the Urban Water Technology Centre, University of Abertay, Dundee (UAD) (Gilmour and Blackwood, unpublished) and is the next step of work based on information flow diagrams that aimed to understand decision making processes and sources and sinks of knowledge within organisations (Bouchart et al., 2002, Blackwood et al., 2004). Identified information used by stakeholders was categorised in order to locate key points in the processes where decisions were made. Information flow diagrams for individual stakeholders were combined to produce composite decision maps. A series of interviews were conducted for data collection and verification. Information flow in flood risk assessment was found to occur mainly between planners and engineers and these were the focus of data collection. The resulting decision map shows interaction with wider stakeholders during the decision making process.

Figure 6 shows how the decision map for flood risk assessment is implemented within Flexiframe. Hyperlinks within the decision map lead the stakeholder to external sources of information as well as decision support and data produced by the WaND consortium.

4 THE PROJECT ASSESSMENT TOOL

The project assessment tool is a top level subjective assessment that uses a scoring system. The tool is implemented as an Excel spreadsheet model with interactive input and uses the Sustainable Water industry Assets Resource Decisions (SWARD)

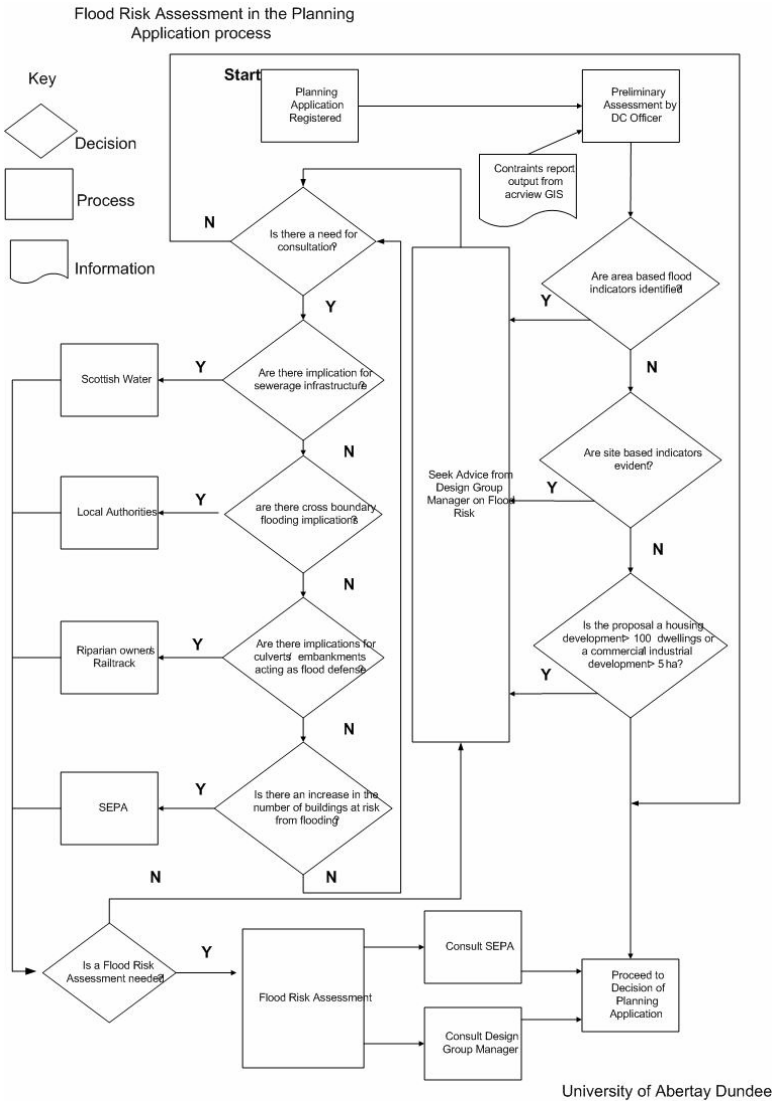

Figure 5: Decision map illustrating consideration of flood risk during the planning process (based on case study data)

structure (Ashley et al., 2004) with added visual output. Four categories of sustainability are considered: economic, environmental, social and technical and a cascading structure of primary and secondary criteria lie beneath each category. Scores are between +3 (best case) and -3 (worst case) with 0 indicating status quo. A score of +3 is given only where the situation is over and above that dictated by regulations. This would be the optimal score for a move towards sustainable development for that criterion. This cannot be considered alone though and will only

indicate sustainability in aggregation with the other scores. Explanations of best and

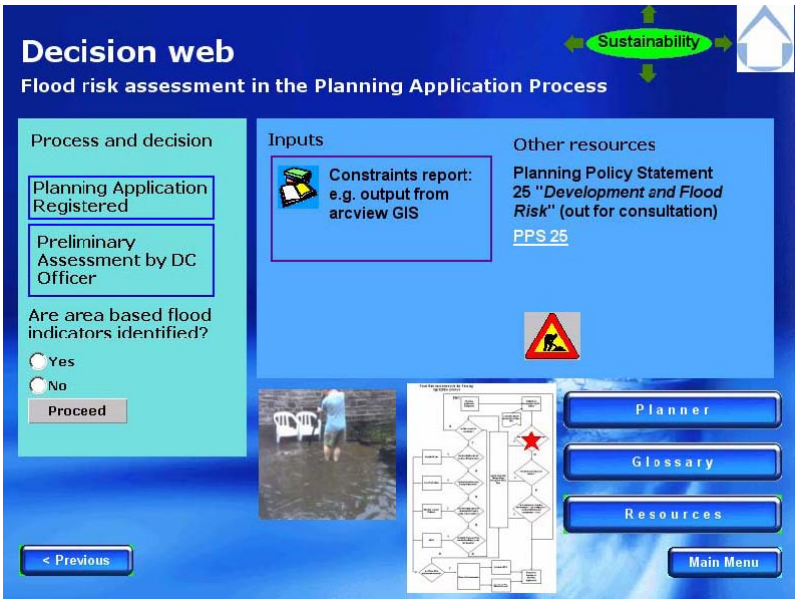

Figure 6: Implementation of the flood risk assessment decision map within Flexiframe

Table 4: An example of best and worse case scenarios for a secondary criterion within the Flexiframe project assessment tool

Category	Primary criterion	Secondary criterion	Best case example (+3)	Worst case example (-3)
Economic	**Affordability**	Impact of new development on local economy	"Development has a positive effect on the local economy. Local products used wherever possible"	"All products required procured from distant sources. Development has a negative effect on the local economy"

worst case are given alongside the score input section. An example of part of the assessment is given in Table 4.The project assessment tool allows stakeholder weightings in order to give context to the analysis. It audits decisions by requiring written explanations of the scores given to each criterion. The development as a whole is considered when using the Project Assessment Tool, including all types of

water management interventions and their interactions. Secondary criteria can be added or existing ones disabled. An aggregated bar chart display gives a clear visual representation of the output from the tool, which is best suited to utilisation by a group of stakeholders rather than an individual.

5 DISCUSSION AND CONCLUSIONS

This paper has showcased the potential application of Flexiframe in practice. Its use has been demonstrated for only two stakeholders and in relation to a limited number of issues; Table 1 shows the broad range of issues addressed by WaND that may be of use to these and other stakeholders. Development of the portal has brought together a wide range of disciplines involved in water management and has been a learning process for the researchers and stakeholders involved. Communication difficulties between sectors (e.g. in the use of terminology, acronyms, and definitions) have illustrated, and often pinpointed the need for greater understanding. Requirements of a tool such as Flexiframe expressed in the initial scoping study are now better understood by those involved in its development and the tool has aimed to fulfil these needs. In bringing together the work of the consortium, it addresses issues of scale, complexity and pragmatism. The ontological basis of the portal has enabled knowledge to be structured and accessed in an understandable and accessible format.

Decision mapping illustrations used within Flexiframe are representations of decision making processes and are mainly based on case study data; they are not necessarily representative of decision making processes for other stakeholders or other local authorities. The decision maps are intended as templates for illustrative purposes that can be used to promote discussion or the formation of new, context-specific decision maps. They provide a structure by which end-users may traverse the portal. As with any conceptual model of a complex situation, the decision map may be incomplete and/or inconsistent; discussions around it however can bring to light the model structure, cause and effect relationships within it and can uncover underlying assumptions, values and preferences of its creators. The decision maps used remain flexible to the inclusion of further input.

The project assessment tool facilitates discussions between stakeholders at a strategic level. It ensures equal consideration of social, economic, technical and environmental issues and provides a means to audit decision processes thus facilitating an iterative and inclusive process of decision making.

The portal is not a complete entity; its aim was always to be flexible, to allow the incorporation of new issues, data and user feedback as they become available. It has the potential to be used as a stand alone decision support tool in the form of a CD or to be implemented within the web. An alternative paper version of the portal is

in production for those without IT skills and that covers the main issues and illustrates how the portal can be used in practice.

The portal is not the answer to cross-sectoral communication or more sustainable water use, but it brings together a broad range of issues and is a valuable resource for use by stakeholders involved in planning for new developments.

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