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GETTING HYDROINFORMATIC TOOLS FROM RESEARCH INTO PRACTICE: THE *WATERSHARE* APPROACH

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The global Water Sector is faced with significant challenges, including, but not restricted to aging infrastructure, fluctuating populations, new pollutants, more stringent regulations and the need for benchmarking their performance. At the same time the Sector remains very fragmented and hence its R&D often doesn't have the critical mass to develop the tools and models that are required. Although research institutes and academia do develop such tools, the road from the research environment to the first practical application often proves an insurmountable barrier. *Watershare* offers a platform for such a transition: Launched as an online placeholder for expert water-related tools, *Watershare* supports a closer collaboration between knowledge providers and knowledge consumers, within a quality assured environment. The *Watershare* concept encompasses a variety of benchmarked tools designed for areas like water quality and health, sustainability, water technology, asset design and management, and water systems. This paper briefly describes the main tools that are already in the toolbox and suggests possible gaps that need to be filled. The paper explains the way *Watershare* operates as a community of practice as well as one of collaborative research and knowledge co-creation. Synergies between the members of the *Watershare* environment are explained and strategies supporting an organic, demand-driven, content creation addressing explicit needs of the Water Sector are outlined. It is suggested that this platform can act as a powerful vehicle to bring to market tools and innovation that has been up to date confined only to research prototypes while allowing for their application globally and providing Water Companies of different scales cost-effective access to high quality, benchmarked software tools.

INTRODUCTION

More often than not, research products (such as tools, models etc) do not find a route to market, but remain in the drawers of individual researchers, without really influencing everyday practice or indeed policy making ([1], [2]). There are certainly several reasons for the existence and persistence of this gap, but we argue that four of the most crucial ones can be summarised as follows:

- End users need tools to be *user friendly* [2]: Researchers develop the tools (primarily) for them and not for third parties. In commercial software development significant investment is spent towards interfaces and error handling resulting from users mistreating the code through the interfaces. It also goes into making sure that the results are produced in industry standard format etc. Individual researchers don't necessarily have the time or interest to do this particularly since by the time their tool is completed the project funding has also finished.
- End users need to be assured of the *credibility* of the tools: research prototypes are developed and tested against a necessarily limited data set – and under specific pre-conditions. To apply them in practice the end users need some assurance in terms of benchmarking and quality control. This necessarily has to be independent from the developer but it is difficult to arrange at the researcher level.
- *Maintenance* and customer support must be ubiquitous: When an operator obtains a licence and bases everyday activities on a particular tool they need to know that support is a phone call away. This is vital in particular in cases where the tool is locally installed and hence vulnerable to general software updates on the client side (e.g. a new version of the OS). Individual experts/researchers can't easily fit this type of support in their everyday routines.
- End users prefer a recognisable *brand*: To some extent this is not a new reason, but a combination or proxy for the three elements above. An end user will buy an expensive license from a commercial vendor because he/she believes that the brand implies user-friendliness, credibility and customer support. However once such a brand exists, supported by the three elements above, it is easier to maintain the brand than to maintain awareness of the three elements individually. In other words if you can ensure the three elements above exist then it pays to create a brand to house them under.

The paper explains how *Watershare*, which is an online platform acting as a "toolbox" for encapsulated knowledge products (e.g. software tools and models, as well as knowledge enabling their correct application) developed in a research environment and which are (or could be) useful to end users – such as water companies – aims to fill this gap between research prototypes and market uptake by addressing all the above elements.

WHAT IS *WATERSHARE*

Watershare is an online toolbox for knowledge products (models, tools, decision matrixes and supporting material) targeting the urban water cycle (from water quality and health, to sustainability, water technology, asset design, and water systems management). The initiative is currently spearheaded by KWR Watercycle Research Institute in the Netherlands in a partnership with Water Institutions around the world, including but not restricted to Kompetenzzentrum Wasser Berlin, the Swedish Water & Wastewater Association, the Naturalis

Biodiversity Center in Leiden, VITO in Flanders and the National Technical University of Athens.

Watershare recognised early on, that despite limitations (see for example the four points discussed above) research tools have several advantages over commercially available software, and could be used in a complementary fashion to them. Specifically, there are (at least) three major areas where research tools excel over commercial ones:

- Research tools are generally more advanced than commercial ones, at least for a period of time, between the generation of the new concept/approach/technique and its wide (and slow) acceptance by everybody. Early adopters would thus have a competitive edge for a while.
- Research tools can be (and are) created for more targeted, less ubiquitous problems. Researchers are keen to address a problem because it exists not necessarily because there is a big market for it. This means that owners of more niche problems can only find solutions in the research environment. The same applies to problems/questions that may be widespread, in that everybody needs answers to them, but to get them they would only need to use tools once a year – for example strategic planning/horizon scanning problems. These also don't make for a good commercial market and this niche can and is also be filled by research software.
- Research tools are charged for less (although they don't necessarily cost less), as commercial vendors require larger overheads and rely on selling software as their main business model. Knowledge development institutions have other business models and do not need (and often don't want or cannot) charge much for their products (e.g. when they are partly funded by public research funds). Instead they often opt for indirect revenue from new research projects being developed when they work with end-users coming up with new questions to be addressed by their tools.

An image of the *Watershare* website thematically arranged to provide access to benchmarked research tools can be seen in Figure 1.

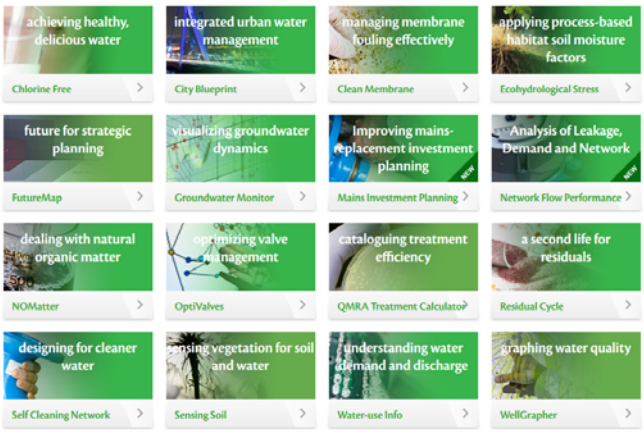

Figure 1. The main themes under which the *Watershare* tools are grouped to date

As a partnership built around the idea of bringing research tools to market, *Watershare* is constantly evolving, focusing on better addressing the barriers to the uptake of research software by end users and water practitioners worldwide. In this evolution, of primary importance is the refinement of the roles of individual stakeholders within the *Watershare* community. In the following section we present a vision for *Watershare* roles that in combination address, it is suggested, several key barriers and drastically improves the potential for including, improving and providing research tools to practitioners.

ADDRESSING THE LIMITATIONS OF RESEARCH SOFTWARE THROUGH THE *WATERSHARE* PARADIGM: A DIVISION OF ROLES

Watershare envisages four types of roles for partners that constitute what will be termed henceforth the *four pillars* of *Watershare*: (i) the *Watershare* development team, (ii) the tool providers (at both institutional and individual researcher level), (iii) the end users (e.g. water companies or consultants) and (iv) the knowledge institutes. In the following section a brief overview of these roles, is presented together with the rationale for which this role is construed, with an emphasis on how such an arrangement attempts to address the barriers discussed earlier.

(1) **The *Watershare* development team**: This is a dedicated team of water engineers, software developers, business experts and project managers whose function is to ensure the delivery of the four critical requirements for industry uptake. Specifically, the team:

- Ensures that *Watershare* tools comply with key standards (including for example OpenMI ([3], [4]), WaterML [5] and relevant OGC standards) and develops user-tool interaction interfaces (e.g. GUIs etc). Compliance to standards is a central tenet of the *Watershare* vision, to ensure interoperability between *Watershare* tools and commercial software that is inevitably used in all water companies – thus lowering the barrier of acceptance of any new tool by a water company.
- Undertakes or coordinates benchmarking and quality assurance exercises for new tools [6] (in collaboration with external experts and professional organisations – e.g. IWA). This is undertaken in collaboration with key people from each knowledge institute organisation (e.g. pillar 4 institutes below).
- Undertakes and facilitates continuous maintenance and customer support for all tools under license. A significant part of this (e.g. patches for new OS releases) is undertaken by software developers within the *Watershare* team with a much smaller fraction reaching (in a curated form) the original researchers/developers of the tools. The latter only deal with customer queries related to for example to customers expressing wishes for additional functionality or new developments for their tools.
- Develops knowledge-bases and choice support functionality for *Watershare* ([7], [8]). This is a high level, central hydroinformatic development foreseen at the *Watershare* level. The idea is that *Watershare* can proactively support an intelligent "match-making" between problem identification (by the end user) and problem solution (by the tool developers) through a "tool selection support" environment underpinned by an evolving knowledge

base. The level of interactivity of such an environment can increase progressively and indeed organically as more tools are added to the mix. This can act as a significant added value service to both tool developers and end users for using *Watershare*.

(2) The tool providers: The tool (or more generally knowledge) providers can be research institutes, research teams within research institutes or individual researchers within research institutes. The only requirement for entry into the *Watershare* concept is that the tool provider needs to have a "relevant" tool and be able to support its implementation (ie. work with *Watershare* team to launch and maintain). Since this is always an individual expert and never an organisation, the key target audience is *de facto* the individual. To ensure that tool providers are committed enough to provide confidence for the continuous support of the relevant *Watershare* tools to be added to the toolbox, they need to undertake a number of actions requested by the *Watershare* development team on their own time and budget, before a tool can be accepted. In other words, they need to invest in getting a tool into *Watershare* – hence showing dedication. Suitable benefits to the tool developers can be agreed between them and *Watershare*, provided that enough of the license's overhead is allocated to ensure the platform's ability to deliver what is described under pillar 1. In exchange the developers accept the obligation to guarantee a specific level of support/maintenance of their tools. The support required by developers (as opposed to the one provided by *Watershare* itself at the central level) is related to error handling of a scientific nature (e.g. cases where the equations provided yield errors not previously identified) and/or minor updates related to desired new features etc. Communications between developers and end users is foreseen to be handled through *Watershare*, either synchronously (arrangement of tele-conferences) or asynchronously (e.g. through user forums).

(3) The end users: End users of *Watershare* tools include Water Companies, but also consultants, as well as research institutes that would like to expand the services they provide to clients. These "problem owners" can access *Watershare* and identify tools and knowledge that will be useful to their operations. They can then select the tools they are willing to try and pay the relevant license fee for the tools selected and the desired level of maintenance and support. The end users, also receive a number of additional benefits from a *Watershare* license (as opposed to multiple individual licenses from each individual tool developer): a visible association to *Watershare* which improves branding, participation in the *Watershare* community, such as participation in targeted workshops within IWA and WSSTP events and free trials of other software tools within the *Watershare* suite (e.g. new tools that have been recently added – or tools that are considered by *Watershare* as complimentary to the ones selected). This is envisaged to increase the visibility of research software tools by the water industry, thus promoting a positive feedback loop of collaboration, research and new applications at the European and Global scales. Furthermore, consultants (or knowledge institutes interested to provide consultancy services) can also become members and use the *Watershare* tools to deliver better, knowledge intensive services to local and regional partners.

(4) The Knowledge Institutes: The fourth important pillar of *Watershare* are knowledge institutes, which by their nature are focusing on developing new knowledge and facilitate its transfer to market, promoting collaboration between researchers and striving for high scientific standards. This fourth pillar is associated with *Watershare* in two ways:

- by undertaking the obligation to support benchmarking, reviewing and testing of new tools, that fall within their areas of expertise – a form of in kind contribution to developing the *Watershare* project.
- by providing monetary support to *Watershare* through membership fees that are used to facilitate the work within pillar 1.

Knowledge institutes are invited to actively steer *Watershare* strategic decision making, deciding on licensing policies, opening new calls for tools in specific areas or targeting particular geographic regions and/or knowledge domains (through workshops, conferences, trials of specific tools etc). They together form *Watershare*'s scientific core and provide the level of quality assurance that end users require from any tool they decide to use in their everyday operations.

CURRENT TOOLS AND FUTURE PLANS

The current initial portfolio of tools included in the *Watershare* suit can be seen in Table 1, together with a short description of what problem each tool addresses.

Table 1. Current tools within the *Watershare* environment

***Watershare* Tool**	**Issue addressed**
ChlorineFree	The tool provides insight into the process of attaining chlorine-free drinking water through its ten-step plan and supports for decision-making in implementing the complex programme aimed at dispensing with residual disinfectants.
City Blueprint	This is a quick-scan tool for the assessment of the Integrated Urban Water Management (IUWM) situation in a city, which incorporates all the relevant stakeholders. It gives you and your clients a snapshot of the city's three layers, that is: human settlement, infrastructural networks and water-related natural environment.
CleanMembrane	The tool provides insights into the type and severity of membrane fouling and damage, proposes an optimal strategy in combating membrane fouling and damage and helps with the management of membrane fouling and damage.
Ecohydrological Stress	This allows the user to derive and apply process-based habitat factors of soil moisture, i.e. drought stress and oxygen stress.
FutureMap	FutureMap makes it possible to develop multi-annual strategic plans. The data can also be used by futures researchers and strategic planners wanting to define a temporal limit for horizon scanning and trend analysis. It is a multi-measure method, with an internal validity check, and is based on a clear model of Time Perspective, which makes clear the conceptual relationships between the various dimensions.
Groundwater Monitor	Groundwater Monitor allows hydrogeologists to get the most out of their groundwater data, while minimizing the effort and costs of the process. It enables: efficient data processing and data validation; flexible and clear analyses and visualizations; improved understanding of the structure

	and functioning of the groundwater system from which they originated
Mains Investment Planning Tool	The tool calculates the investment requirements for the replacement of water mains. By defining the expected remaining life for different groups of water mains, and combining this information with the distribution network as a whole, the program produces an overview of the volume of mains that need to be replaced, the period of replacement and the associated investments.
Network Flow Performance	The user can generate a display of complex and difficult-to-read flow volume time series, for example, for a particular District Metered Area (DMA) or a supply area. This provides support in the interpretation of the changes present in the time series in terms of known processes and influences (weather, holidays, etc.) and indications of unknown processes (new leakages, wrong valve positions, customer behaviour).
NOMatter	Assistance in the selection and position of NOM removal processes in existing water treatment schemes which results in the optimal technical and economic choice for NOM removal.
Optivalves	The tool provides insight into how a targeted valve maintenance programme will enhance network performance and reduce maintenance costs. It provides better understanding of how valves affect the performance of drinking water distribution systems as well as improved performance of the most important valves. Management support on the operational and tactical level.
QMRA Treatment Calculator	QMRA Treatment Calculator is a database containing information about the efficacy of the most used treatment processes to eliminate pathogenic viruses, bacteria and protozoa. On this basis it indicates the factors that affect efficacy.
Residual Cycle	This is a decision-making support tool that encompasses all relevant aspects of the reuse of residuals, primarily those from drinking water treatment processes. The tool includes available residuals (volume, quality, and their fluctuations over time), potential applications of the residuals (volume, quality, and their fluctuations over time), Matching of supply and demand of residuals in the region, logistics and costs and legal aspects and permits.
Self-Cleaning Networks	The tool provides the design rules for networks that can maintain a certain self-cleaning velocity at least once every day and calculates the water velocity and pressure in your design. At this velocity sediments are kept in suspension, thus preventing their accumulation and hence discoloration
Sensing Soil	This tool calculates, for a given vegetation plot, factors like groundwater levels, soil acidity and soil nutrient fertility. The results allow for conclusions about the landscape, as well as for monitoring the impact of alternative measures on the landscape.
Water-Use Info	The tool provides an understanding of water demand and water discharge, in quantity as well as in quality. These aspects can be examined for a variety of design or operational scenarios for networks and installations.
WellGrapher	The tool predicts the water quality of abstracted water based on the influences of various land uses and a minimum of information on the subsurface transport. It provides insight into the effect of changes in land use on the quality of well water, using a minimum amount of data.

The toolkit is expected to grow organically, as additional researchers and knowledge institutes join the *Watershare* project. For example, it is foreseen that the UWOT tool ([9], [10]) will be added to the *Watershare* platform in the near future, providing it with a whole city modelling perspective for water cycle management.

CONCLUSIONS

This paper presented the idea, current status and (part of) the future vision of the *Watershare* online platform and related initiative. *Watershare*'s strategic ambition is to link research tool development in the urban water disciplines with end users and practitioners on the ground by addressing a number of barriers identified in this transition. The paper presented an outline of the key pillars of *Watershare* in terms of roles for different stakeholders that could potentially collaborate in bridging this well-known gap. It also presented a first set of tools that are already available within the *Watershare* environment, supporting the authors' claim that the *Watershare*

initiative is well on its way to attempt its vision. Although this approach is by no means the only possible way forward [11], it is hoped that it is a positive and inclusive contribution towards this goal and one which is open to researchers, software developers, knowledge institutes and water companies worldwide. Beyond an online knowledge and tool "box", *Watershare* aspires to create a network of partners, supporting and promoting the idea of a positive feedback loop between research, testing, real world application and demonstration and back again – promoting hopefully a more efficient and sustainable water future.

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