Master's Thesis Internship – Master Water Science and Management:

"EVALUATING THE WATERSHARE PLATFORM AS A MEANS TO IMPROVE URBAN WATER MANAGEMENT"

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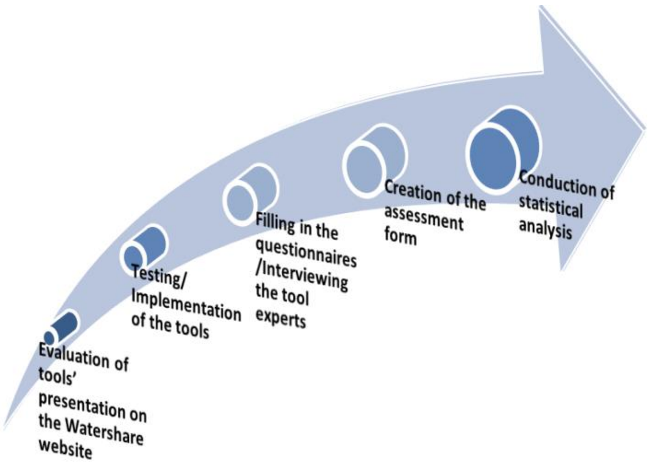
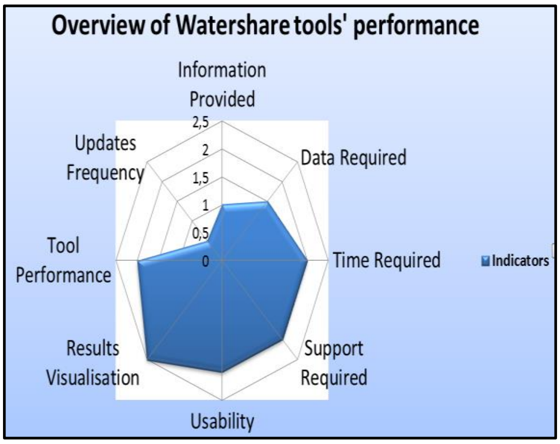
Abstract

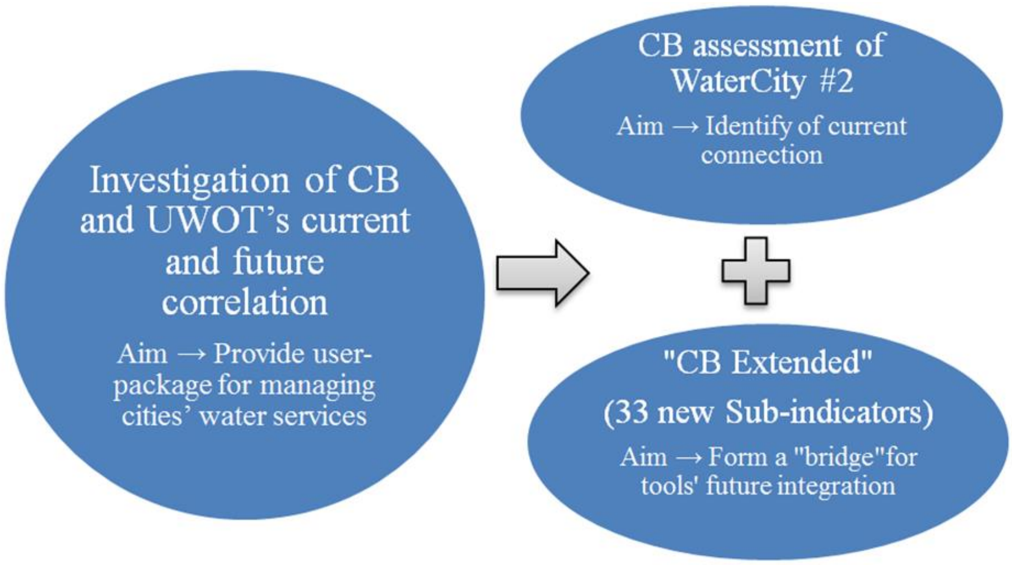
Climate change, environmental degradation and increasing urbanisation rendered water crisis as the global risk with the largest impact. Therefore, a more integrated water management is essential for improving cities' resilience. Along with the global water sector working on this direction, KWR established Watershare, a knowledge platform that provides targeted solutions in the form of 26 specific tools and aims to the actively sharing of water sector knowledge and experience.

Intending to contribute to the usability optimisation of Watershare platform, this report consists of two parts. Part 1 is the first attempt to evaluate the presentation and performance of 15 tools in the Watershare platform. The research gives an overview of the current state of these tools on the Watershare suite of tools, from an end user's perspective. Further, the study provides recommendations for future improvement.





Part 2 focuses on two of the Watershare tools: the City Blueprint (CB) and the Urban Water Optioneering Tool (UWOT). This research is the first phase of a larger project targeting in tools integration, aiming to provide end users with a more comprehensive illustration of cities' water services current state.



Foreword

This thesis has been written as the final part of the Water Science and Management Masters programme of Utrecht University. The study, under the name “Evaluating the Watershare platform as a means to improve urban water management”, was undertaken at the request of the KWR Watercycle Research Institute, where I conducted an internship.

I would like to thank my university supervisor Professor Jasper Griffioen for his valuable guidance and support during these months. I also wish to thank Stef Koop with whom I share the credit of the work for Part 2 of this research and my KWR supervisor Dr. Christos Makropoulos.

Finally, I would like to give my special thanks to the Watershare tool experts and KWR colleagues for the wonderful cooperation and especially, to Dr. Gerard van den Berg and Theo van den Hoven for their instructions and advices during this internship.

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Abbreviations

AM	Arithmetic Mean
BAU	Business As Usual
BOD	Biochemical Oxygen Demand
CB	City Blueprint
CSO	Combined Sewer Overflow
DSS	Decision Support System
FA	Further Ahead
GUI	Graphical User Interface
HI	Hydroinformatics
IUWM	Integrated Urban Water Management
NS	Next Step
NOM	Natural Organic Matter
R&D	Research and Development
UWM	Urban Water Management
WWT	Waste Water Treatment

1. Introduction

1.1 Background

Climate change, environmental degradation and urbanisation are expected to lead to more severe water crisis the coming decades, according to the World Economic Forum, which rated water crisis as the global risk with the largest impact (Global Risks 2015, 2016). Within two decades it is estimated that almost 60% of the world's population will be living in cities and this vast urban population growth will challenge even more the provision of freshwater (Un.org, 2016). A more integrated water management is essential, among others, and the global water sector works on this direction, since the upcoming changes will test the resilience of cities.

In 1987 the term of "sustainable development[1]" was introduced with the Brundtland report (World Commission on Environment and Development, 1987), followed by the Agenda 21 (Rio Conference, 1992). Since then, there has been a great effort from scientists and practitioners, initially to define and then to adopt and integrate the concept of sustainability (Larsen & Gujer, 1997). Towards this direction, new terms and philosophies were presented such as Integrated Urban Water Management (IUWM). According to Bahri (2012), IUWM aims for the alignment of urban development and basin management in order to achieve sustainable economic, social and environmental goals and further, to integrate urban water management with land use planning and economic development. The management of urban water concerns the fields of water supply, urban drainage and wastewater and sludge treatment (IWA, 1997).

Hardy et al. (2005) refer to the multiple meanings of the term of IUWM: firstly, "The integration of all types of interrelated freshwater bodies, including both surface water and groundwater and the consideration of both quantity and quality issues", secondly, "The process of overcoming the partitioning of responsibilities for water resource supply, planning and development that exist amongst the sectoral agencies involved in their provision" and thirdly, "The incorporation of technological, socio-economic, environmental and human health considerations into the management and decision making process". Bach et al. (2014) conclude that "Integrated urban water models should focus more on addressing interplay between social/economical and biophysical/technical issues, while its encompassing software should become more user-friendly".

Scientists and stakeholders are promoting holistic approaches for the management of urban water services by analysing and simulating the urban water cycle, conduct performance assessments for the current and future systems and finally make the decisions and plan the strategies that will be followed. On this path, new technologies are developing as part of reuse strategies, aiming to promote an inner, urban water cycle loop (Barton, Smith, Maheepala, & Barron, 2009). Stuchtey (2015) identifies as the main reason of global water crisis, the violation of the zero-waste imperative; the basic principle of circular economy. For the creation of a new circular water system, he suggests to take under consideration three perspectives: the product perspective that distinguishes the water in consumable and durable, the resource perspective, that focus on a balance between withdrawals and return flows and finally the utility perspective that aims to maximize the value of the current water infrastructure (Stuchtey, 2015). This turn to more sustainable, long-term solutions is expected to strengthen cities'

[1] The Brundtland Report, also known as "Our Common Future" defines sustainable as the "… development that meets the needs of current generations without compromising the ability of future generations to meet their needs and aspirations." (World Commission on Environment and Development, 1987).

robustness and resilience, with resilience defined in this report as "the degree to which a water system continues to perform under progressively increasing disturbance" (BTO, 2016, p. 17).

The rapid growth and application of hydroinformatics also resulted from the necessity of more targeted solutions. For adapting and implementing these solutions and strategies, their performance must be simulated and tested beforehand. For this purpose, Decision Support Systems[2] (DSS) and software tools have been created, such as UWOT, AQUACYCLE, UrbanCycle, UVQ, etc. (Morley et al., 2016). Difficulties have been traced though, in the field of communication and collaboration between the scientists as providers and the "consumers" of these solutions. Despite the fact that Research and Development (R&D) in the field of water technology often results in end products formulated in software tools and models, these products are rarely practically implemented and applied commercially (Makropoulos et al., 2014). Due to this research-to-practise gap, scientists miss the opportunity to practically test these tools through real cases and more extended applications, depriving their possible, further development.

Subsequently, while focusing on these tools' implementation and the existing pressures on the currently designed systems, the expected knowledge gap due to the uncertain future pressures need to be managed as well. Thus, the development of efficient water management strategies is deemed necessary so that the urban water systems can be as much as possible well-prepared for the upcoming changes. As part of this initiative towards well-planned strategies Watershare, a knowledge platform introduced by KWR, provides targeted solutions in the form of 26 specific tools, clustered in 5 different Communities of Practise (CoP).

1.2 Aim

This research consists of two parts and attempts to contribute to the usability optimisation of the Watershare platform. In Part 1, by reviewing the presentation of 15 tools of the Watershare suite of tools, this work identifies possible gaps or room for improvement regarding their description in the individual tool sheets of the website. Then, by testing these tools and evaluate their performance and level of usability (user-friendliness) during their application. The intention is to discover aspects that can be ameliorated in order to make the tools more approachable and easy to be implemented.

Part 2 is the first phase of a larger project that aims to identify the connections between two of the Watershare tools, the City Blueprint (CB) and the Urban Water Optioneering Tool (UWOT) and improve their cohesion. This correlation is attempted as an effort to provide end users with a more integrated user-package for managing cities' water services. It is considered that the combined use of these two tools and their complementary outputs will allow a more integrated and holistic view of cities' current condition. This will facilitate the profiling of cities' resilience and thus, allow to plan effective strategies for strengthening cities water services. Initially, the extent of tools' current correlation and interaction is examined, tracing to what extent the current versions of the two tools use similar data for fulfilling their purpose. Then, to assist in tools integration, City Blueprint sub-indicators are developed aiming to form a "bridge" between the two tools.

[2] "A DSS is typically an interactive software-based facility that can be used to compile assess and present information about a system where human activities and natural processes interact such as the urban water cycle. A DSS does not make decisions but rather manages and presents information in a way that supports the judgement of decision makers allowing them to learn from past actions and explore potential interventions" (Philip & Salian, 2011).

1.3 Research questions

The research questions for the first part are as follows:

1. What conclusions can be drawn regarding the presentation of the tools on the Watershare website?

a. To what extent the information regarding the required data (amount and type) and level of expertise is indicated on the website?
b. How descriptive each tool sheet is, regarding the provided case studies?

2. What are the basic requirements (data, time, expertise, support) for the use of the Watershare Tools from an end user's perspective?

3. What conclusions can be drawn regarding the performance of the Watershare Tools, after their assessment from an end user's perspective?

a. What is the level of usability of the Watershare Tools (quality of supporting material and manual, step by step support provided by the software, intuitiveness)?
b. To what extent is the visualization/ representation of the results adequate?
c. What is the performance of the tools regarding ease of computation/ simulation (bugs, crashes, etc.)?

4. What is the frequency of updates on the Watershare website?

The research questions for the second part are:

1. In which City Blueprint Categories are data gaps located, obstructing the integration of City Blueprint and UWOT approaches?

2. Which new sub-indicators can possibly bridge this data gap and integrate the two approaches?

2. Background

2.1 Hydroinformatics and Integrated Urban Water Management (IUWM)

Abbott (2009) introduced the term of hydroinformatics and defined it as "the study of the flows of knowledge and data related to the flow of water and all that it transports, together with interactions with both the natural and the manmade or artificial environments". This integration of computational hydraulics and artificial intelligence can be used as a source of data, producing new knowledge and as a mean of knowledge management (Abbott, 1999).

Gualtieri (2011) summarises the aim of hydroinformatics as "the provision, integration and operation of information management tools for water in the environment covering the four major domains of the physical world, the virtual world, the organizational world and the societal world, with the appropriate interfaces between these worlds, and with bringing about concomitant changes in both the built and social environments". Specialised models such as RIBASIM, Hydronomeas or GoldSim have been developed for the optimisation of supply management, by identifying the optimal operational strategies (Rozos & Makropoulos, 2013). Focusing on demand management and aiming to the best estimation of urban areas water demand, few models have been developed such as the Aquacycle model, the City Water Balance (CWB) model and the Urban Water Optioneering Tool (UWOT) (Rozos & Makropoulos, 2013).

With hydroinformatics enhancing and supporting the efficiency and functionality of IUWM, a number of projects have taken place the past years towards the same direction. The SWITCH project was a major research partnership, funded by the European Commission, that took place between 2006 and 2011. The main outcome of this project, the "SWITCH" approach (a demand-guided approach) aimed to a shift in more sustainable urban water management practices, with more immediate actions for the identification, development and application of solutions (Switchurbanwater.eu, 2016). The TRUST (TRansitions to the Urban Water Services of Tomorrow) project followed (2011 to 2015); an integrated research project, funded by the European Union, designed to explore innovations and tools to create a more sustainable water future (Trust-i.net, 2016).

Currently, scientists and numerous stakeholders are testing and evaluating innovative solutions concerning the sustainable use of the ecosystem in European urban areas, in the EU project DESSIN (Demonstrate Ecosystem Services Enabling Innovation in the Water Sector), so as to validate them (Dessin-Project, 2016). The SUBSOL project (bringing coastal SUBsurface water SOLutions to the market), part of the EU programme Horizon 2020 and with a wide range of partners as well, is anticipated to promote original ideas and strategies related to water resources management, enhancing the sustainable development of coastal areas around the world (SUBSOL, 2016).

Furthermore, integrated and efficient urban water management is one of the main areas of interest for several organizations, e.g. the Global Water Research Coalition (GWRC), the International Water Association (IWA), the World Bank's Water Global Practise, the Global Water Partnership (GWP), etc.

2.2 Tools and platforms

In order to continue and intensify the efforts towards integrated urban water management, the cooperation among water experts and the sharing of knowledge and expertise is deemed necessary. To this effect, for example, the Danish Hydraulic Institute (DHI) delivers a series of tools. DHI has developed the "MIKE powered by DHI" technologies and tools, aiming to provide their clients with solutions to urban water challenges[3]. Deltares is working among others on integrated solutions and urban planning design. The Dutch institute allows the free availability of its software and models to promote openness and transparency (Deltares, 2016).

2.3 Evaluating Hydroinformatics platforms

Scientists and institutes develop tools in order to provide them to end users that will apply them commercially, an effort that frequently is fruitless. The difficulty in the transition of a tool from a research product to a commercial, practically implemented one, arises because of several reasons, e.g. the licence cost. Makropoulos et al. (2014) summed up the most important causes, based on end user's requirements:

1. *User-friendliness (usability) of the tools*
2. *Credibility of the tools*
3. *Consecutive maintenance of the tools and customer support*
4. *Lack of a recognisable brand (for the tool to belong to)*

The evaluation of the performance of these tools and platforms can be an effective solution and guarantee that proper guidance is provided to the end users, facilitating the decision making process (Schoumans & Silgram, 2003). As an example, the EUROHARP project had as an objective to conduct a scientific evaluation of nine different tools that quantify diffuse nutrient losses in different water systems (surface freshwater and coastal waters) (EUROHARP, 2016). The 15 indicators used for this intercomparison were established by all tool developers (Berlin, 2002) and concerned among others data requirement, operational experience and skills requirement of users, participation in previous model comparison studies, applicability, etc. (Schoumans & Silgram, 2003).

Following ISO (the International Organisation for Standardization) and its guidance, usability (user-friendliness) in software engineering is defined as "the extent to which a software (tool) can be used by specified consumers to achieve quantified objectives with effectiveness, efficiency and satisfaction in a quantified context of use[4]" (ISO 9241-11:1998, 2016). ISO's guidance states that usability is influenced by the context of use: the users, tasks, equipment (hardware, software and materials), physical and social environment and by the circumstances under which the product is used (ISO 9241-11:1998, 2016).

According to Nielsen (1993), the usability of a user interface is not a single, one-dimensional property, but it consists of several components. The term of usability is usually related to characteristics such as

[3] Source: Mikepoweredbydhi.com, 2016.

[4] With effectiveness defined as the "accuracy and completeness with which users achieve specified goals", efficiency as the "resources expended in relation to the accuracy and completeness with which users achieve goals", and satisfaction termed as the "freedom from discomfort, and positive attitudes towards the use of the product" (ISO 9241-11:1998, 2016).

learnability, efficiency, memorability, errors and satisfaction. The description of these attributes, as it was outlined by Nielsen (1993) is included in Table 2.1.

Table 2.1: Description of usability attributes (Nielsen, 1993)

Attribute	Description
Learnability	The system should be easy to learn so that the user can rapidly start getting some work done with the system.
Efficiency	The system should be efficient to use, so that once the user has learned the system, a high level of productivity is possible.
Memorability	The system should be easy to remember, so that the casual user is able to return to the system after some period of not having used it, without having to learn everything all over again.
Errors	The system should have a lower error rate, so that users make few errors during the use of the system, and so that if they do make errors they can easily recover from them. Further, catastrophic errors must not occur.
Satisfaction	The system should be pleasant to use, so that users are subjectively satisfied when using it.

2.4 The Watershare concept

Watershare, launched by KWR Watercycle Research Institute at the IWA World Water Conference in Busan (2012), is a platform of global collaboration between highly reputable international institutes, aiming to the actively sharing of water sector knowledge and experience. The Watershare membership consists of a global network of water research institutes, utilities and private firms from Europe (10 members), South-Africa (2 members), south-east Asia (4 members) and Mexico (1 member) that is continuously expanding (Zwolsman et al., 2014). The platform aims to facilitate the contact between the "consumers" of the tools with the providers of water expertise through a reputable, quality assured environment that supplies targeted solutions ready to be implemented.

The cooperation and flow of knowledge is mainly achieved by the development of a series of tools, models, decision matrixes and supporting materials. These knowledge products (Watershare tools) are based on members' working models and methods in the field of water supply and wastewater treatment. Figure 2.1 presents an example of Watershare tools, available under the "Resilient Urban Water Management" CoP, supporting resilience assessment and improvement (BTO, 2016). Other ways of cooperation are targeted workshops, joint research proposals (e.g. EU Horizon 2020, the EU framework programme for research and innovation), exchange of staff, internships, etc.

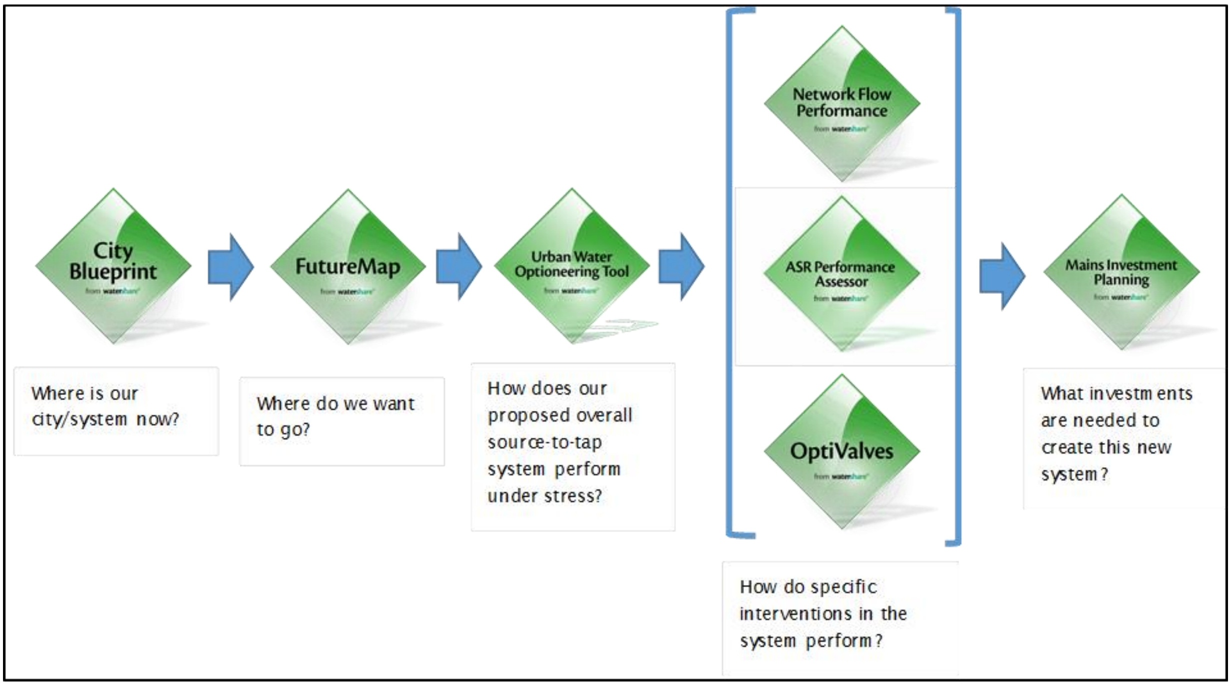


Figure 2.1: Watershare tools, available under the "Resilient Urban Water Management" CoP (BTO, 2016).

The credibility and quality of the provided tools are assured (before they are included in the Watershare Suite of Tools), by peer review publications and practical track records (Zwolsman et al., 2014). Then they can be accessed online by the other Watershare members and be applied, for solving the existing water problems on behalf of the end user clients. Practical support from the Tool Experts is also provided in the form of introductory courses, training programmes, webinars, etc. The provision of feedback after the implementation in a case study consists the final step of the process, providing the opportunity for further development and improvement of the tools and generating a creative and productive cooperation (Watershare, 2016).

2.5 City Blueprint (CB) and Urban Water Optioneering Tool (UWOT)

Aiming to IUWM, the first step of an integrated decision-making process is to understand the city's water system and its various influences (Philip & Salian, 2011). In this context, City Blueprint is a quick-scan tool for the assessment of the basic water services and the IUWM situation at a city level, involving all the relevant stakeholders. The CB is one of the Watershare tools, as well as an action under the European Innovation Partnership on Water (EIP-water), part of the H2020 BlueSCities project (Watershare, 2016). It is a method for the assessment of cities' sustainability and the resilience of their integrated water resources management. It includes a wide range of methodologies (the water footprint, urban metabolism, ecosystem services methodologies, etc.), which have been incorporated in seven broad categories of indicators (Koop et al., 2015):

1. Water quality
2. Solid waste treatment
3. Basic water services
4. Wastewater treatment
5. Infrastructure
6. Climate robustness
7. Governance (including public participation).

For implementing the tool, data concerning the basic water services of the city are required. These can be found through literature research and by cooperation with the city authorities. The City Blueprint Index which is the overall score of the sustainability of Integrated Water Resources Management of the city gives a snapshot of the city's three layers: human settlement, infrastructural networks and water-related natural environment. This Index can be used as a guide for the problems each city is struggling with and hence effective solutions need to be investigated. The baseline assessment of the CB tool, that can further indicate which Watershare Tools are necessary for each city, is the first step towards the creation of water-wise cities.

For generating a good representation of the cause and effect relationships within the urban water cycle system all the interactions and influential elements need to be taken under consideration (Philip & Salian, 2011). This can be realised with modelling tools that can also act as DSS. The Urban Water Optioneering Tool (UWOT), part of the Watershare tools, is an urban water cycle model that recognizes every urban water flow as result of a demand and thus simulates demand signals instead of flows. Through a metabolism modeling approach the tool can simulate the entire water supply network, "including abstractions from the hydrosystem, operation of reservoirs, transmission of water, water treatment, distribution, water consumption at the appliance level, sewerage network and treatment and finally disposal to the water bodies" (Rozos & Makropoulos, 2013). UWOT has two main parts, the internal and the external water system. The internal system includes the generation of the demand (in a household level) and the disposal of wastewater and stormwater to water bodies (example of Athens internal system, Figure 2.2). The external system consists of abstractions and transmission and treatment of raw water (example of Athens external system, Figure 2.3) (Rozos & Makropoulos, 2013).

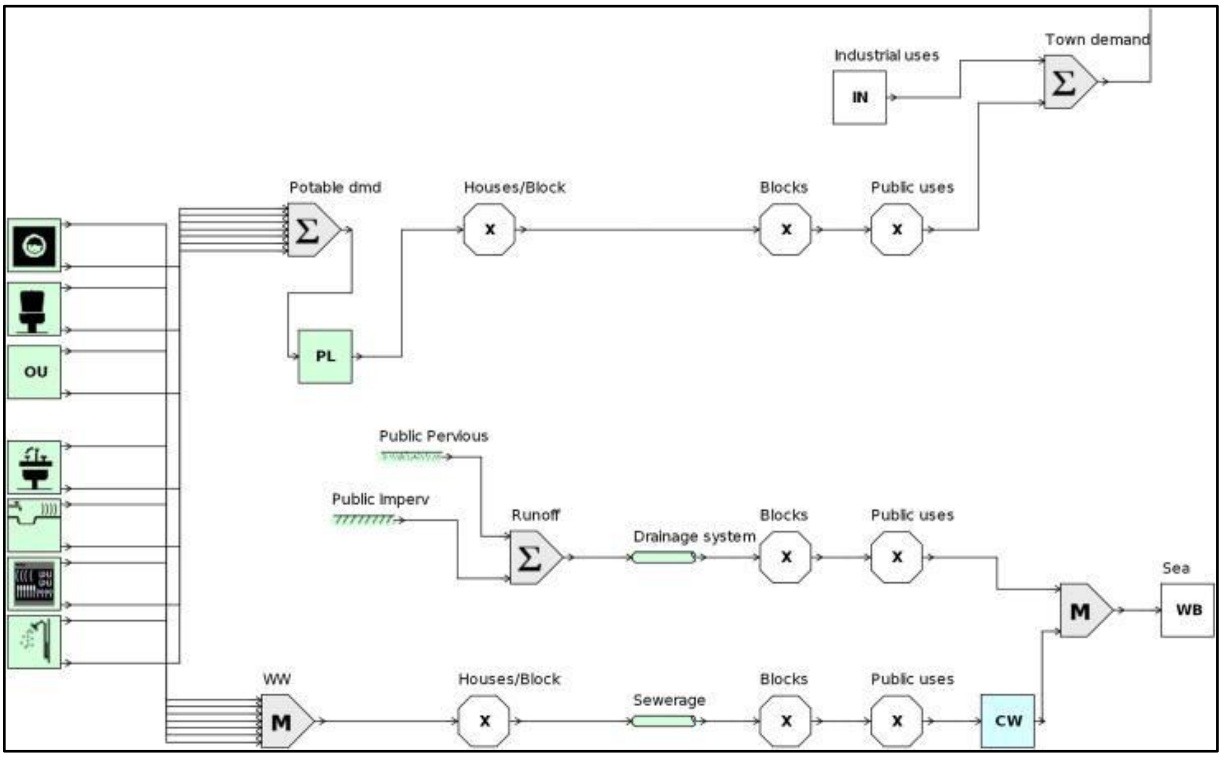


Figure 2.2: Simplified representation of Athens internal water system in UWOT (Rozos & Makropoulos, 2013).

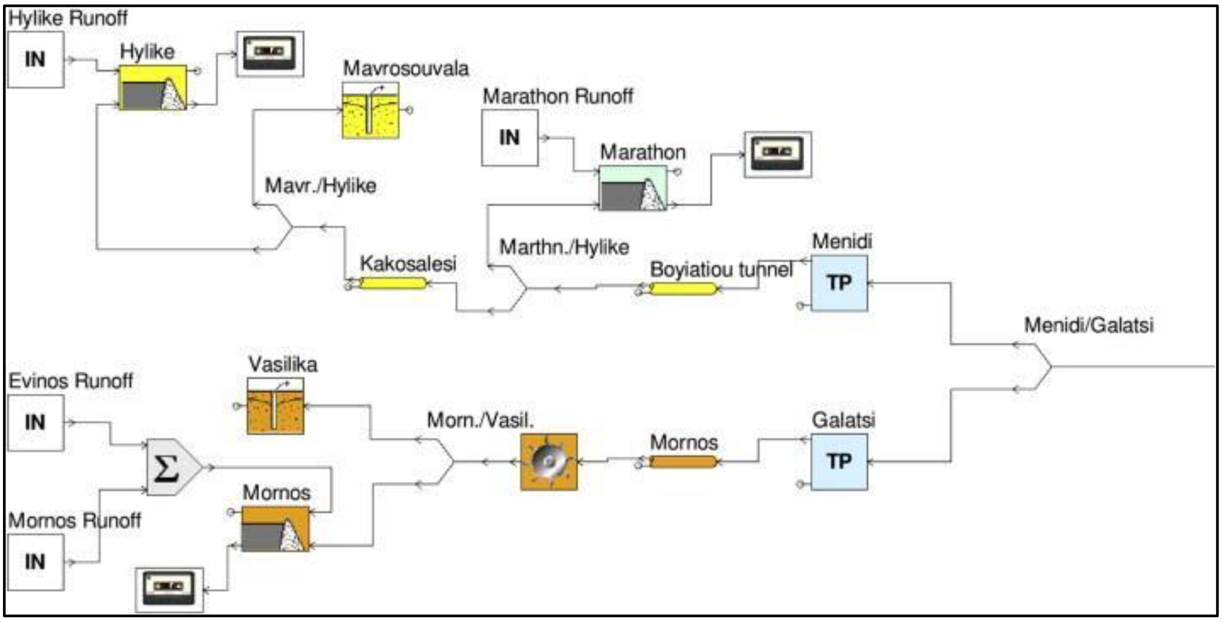


Figure 2.3: Representation of Athens external water supply system in UWOT (Rozos & Makropoulos, 2013).

3. Materials and Methods

3.1 Part 1 - Evaluation of the Watershare tools

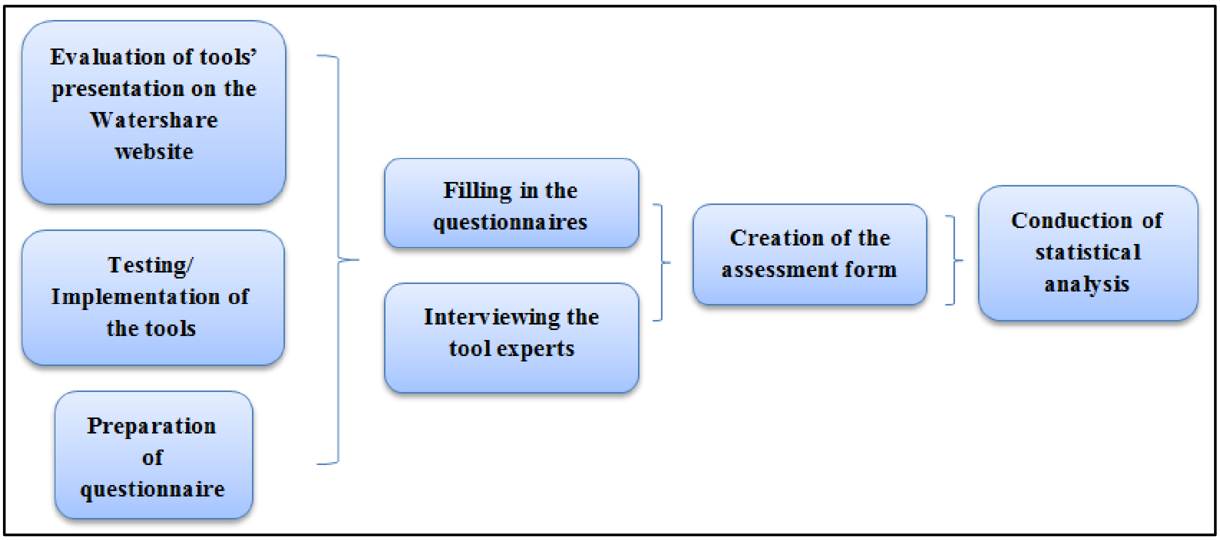
The currently developed Watershare tools sum up to 26. Due to limited time the evaluation of the total of the tools was not feasible, therefore 15 tools were selected that are closely related to urban water management. The evaluation was conducted for addressing the research questions of the first part. The assessment concerns firstly the information provided on the Watershare platform regarding their aim and application, and secondly their performance. A brief description of these tools is given in Table 3.1 (in alphabetical order).

Table 3.1: Watershare Tools focused on Urban Water Management (Makropoulos et al., 2014; Watershare, 2016)

Watershare Tool	*Issue addressed*
AbatES	AbatES is a Decision Support System with information on emerging substances. It is designed to inform actors in the water sector about emerging substances including their possible abatement methods, both technical and non-technical.
ASR Performance Assessor	This tool can quickly estimate the performance of Aquifer Storage and Recovery (ASR), based on commonly available, a priori, hydrogeological and operational parameters. It is a decision-support tool in the field of ASR. Typically, unviable set-ups will be recognized efficiently and can be avoided, so that more focus can be given to promising cases.
BioStab	Provides diagnosis of the treatment processes underlying the failure to produce biologically stable water, and advice on how to improve the treatment train for the production of biologically stable water.
City Blueprint	This is a quick-scan tool for the assessment of the Integrated Urban Water Management (IUWM) situation in a city, which involves all the relevant stakeholders. It gives a snapshot of the city's three layers, that are: human settlement, infrastructural networks and water-related natural environment.
FutureMap	FutureMap is an online questionnaire for characterising, both quantitatively and qualitatively, the dimensions of an individual's time horizon and perspective that influence what motivates his or her work-related decisions and actions. This will allow to wisely develop multi-annual strategic plans.
Mains Investment Planning	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 analysis of flow volume data using the Comparison of Flow Pattern Distributions (CFPD) method provides insight into customer behaviour, leakages and non-registered network parameters, contributing to effective operational management and leakage reduction.
NOMatter	Assistance in the selection and position of NOM (Natural Organic Matter) 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 at 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.
Urban Water Optioneering Tool	UWOT is a model that simulates the generation and routing of urban water demands to facilitate the planning and assessment of distributed interventions in the urban water cycle. The planning and assessment is based on various metrics estimated by UWOT, such as potable water demand, runoff volume and required energy.
WASS	WASS (Wastewater Treatment Selection System) is a decision guidance system that can help in the initial screening of possible techniques for the treatment of industrial waste water.
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 designs 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.

First, the evaluation of the presentation of these 15 tools on the different tool sheets was conducted (indication of data and time requirements, number of updates, etc.). Next, their performance during their application was investigated, from a wide perspective (step by step support provided by the software, ease of computation, results visualisation, etc.). Finally, the basic requirements (data, time, expertise, etc.) for using the tools were recorded. A questionnaire was created for illustrating in a quantitative way the observations of this in situ assessment, followed by the formation of an assessment form and the conduction of a statistical analysis. The procedure followed is given in Scheme 3.1 and is described in detail below.



Scheme 3.1: Description of First Part - Evaluation of the Watershare tools

- **Step 1: Evaluation of tools' presentation on the Watershare website**

For this objective the presentation of each tool on the website was examined, aiming to discover possible aspects that can be optimised. Each tool is presented under different tool sheets on the Watershare website. The description is subdivided in six categories per tool sheet, named: Start, Manual, Training, Cases, References, Download the Toolsheet (Figure 3.1, Watershare website).

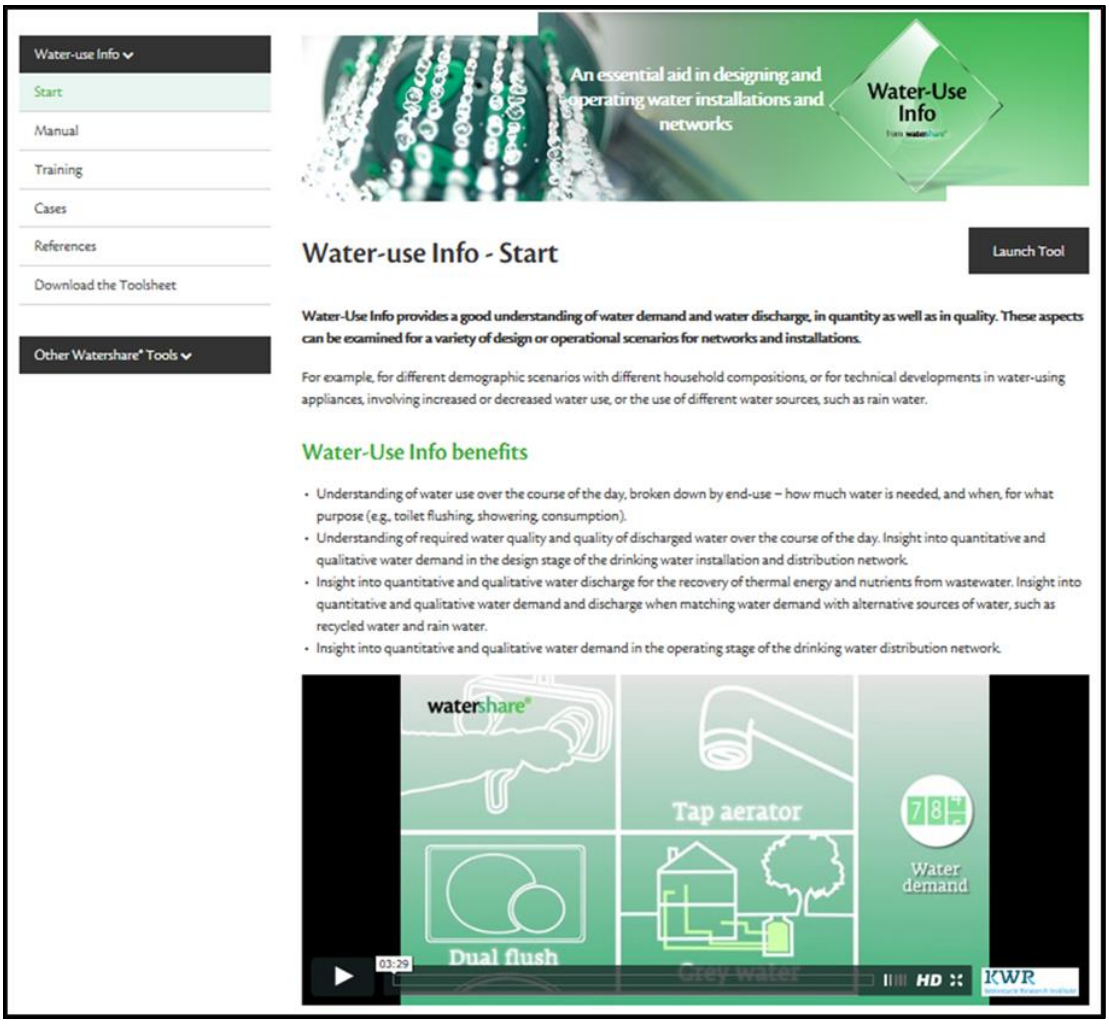


Figure 3.1: Example of tool presentation on the Watershare website (Start page) (Watershare website, 2016).

More specifically, the study investigated to what extent each of the aforementioned description categories include all the necessary information for communicating the concept and function of each tool. The conclusions drawn from this evaluation (including description and observations/ recommendations for each tool) were reflected in 15 individual reports (an example of an individual report is found in Appendix A).

- **Step 2: Testing/ Implementation of the Tools**

Watershare members and potential end users can test the tools through the website, before applying them in a real case. This same procedure was performed at this stage. By selecting the "Launch Tool" button, the chosen tool is available for testing. The required input data were either included in the Manual category or were obtained from the internet and the corresponding literature. In some cases[5] when more complicated or larger amounts of data were needed, these were provided by the tool expert. The steps followed during tools' implementation and observations/recommendations for this part were also included in the individual reports (example, Appendix A).

[5] ASR Performance Assessor, Mains Investment Planning, Network Flow Performance, WellGrapher.

❑ **Step 3: Preparation of questionnaire**

The aforementioned described terms and methods related to usability (Chapter 2.5), were taken under consideration while formulating the questions and indicators that composed respectively the questionnaire and assessment form for the evaluation of the Watershare tools. Nevertheless, specific analytical usability evaluation methods were not followed during this procedure, but mostly a combination of them. Along with assistance from the KWR supervisors, questions were prepared to formulate a questionnaire with a 1 to 5 measurement scale (the questionnaire can be found in Appendix B). The questions concerned the tools' presentation on the Watershare website (questions 1 to 3 and question 8), the frequency of updates (question 4), the required data (questions 5 and 6), the required time for tools' implementation (question 7), tools' performance during their testing (questions 9 to 12) and the required support by the tool experts (question 13). Additionally, 5 more questions were included in the questionnaire concerning the new allocation of the tools in 5 different Communities of Practise (CoP), within the Watershare suite. These questionnaires were then answered by the master student after testing each tool and by the tool experts (see next steps).

❑ **Step 4: Filling in the questionnaires/ Interviewing the tool experts**

After finalising the three previous steps, the filling in of the prepared questionnaires was undertaken. These completed questionnaires were also included in the individual reports (Appendix A). Table 3.2 shows the data sources used to answer the questionnaire. Additionally, the tool experts (developers of the tools) filled in the same questionnaire during a personal interview with the student (interviewer-administered questionnaire), in order to capture and include possibly diverse opinions and perspectives. An exception was the developer of the WASS tool who is located in Belgium and therefore the communication was done by e-mails.

Table 3.2: Data sources of master student's answers to the questionnaire

Question	**Source**
1. Indication on the Watershare website of the amount and type of data required for implementing the tool	Watershare website (“Manual” category)
2. Indication on the Watershare website of the level of expertise required by the end user for tool's implementation	Watershare website (“Manual” category)
3. Presentation of Watershare Case Studies on the Watershare website	Watershare website (“Cases” category)
4. Number of updates (new versions, new functionality, etc.)	Teun Jansen (developer- Atos company)
5. Amount and type of data required for tool's implementation	Watershare website, Tool implementation
6. Availability of data required for tool's implementation	Tool implementation
7. Amount of time required/ consumed for entering data and setting up the tool for a case (including time required for additional software tool)	Tool implementation
8. Quality of support material and manual provided	Watershare website (“Manual” category”), Tool implementation
9. Level of step by step support provided by the software	Tool implementation
10. Intuitiveness of the graphical user interface (GUI)	Tool implementation
11. Ease of computation/ simulation (bugs, crashes, speed of simulation, etc.)	Tool implementation
12. Visualization/ representation of the results (narrative, logical, numerical, graphical)	Tool implementation
13. Level of required support (by the tool experts)	Watershare website (“Training” category)

❑ **Step 5: Creation of the assessment form**

The next step was to formulate an assessment form. Based on the first 13 questions of the questionnaire, 8 indicators were created. The answers of both the student and the experts, were taken under consideration for calculating the numerical value of the indicators. The correlation between indicators, arithmetic means and symbols of the assessment form is shown in Table 3.3.

Table 3.3: Correlation between Indicators, Arithmetic Means and Symbols of the assessment form

Indicators	**Arithmetic Mean (A.M.) - Symbols**		
	0 - 1,667	1,668 - 3,333	3,334 – 5
Information provided			
Updates frequency			
Data required			
Time required			
User-friendliness			
Tool performance			
Results visualisation			
	3-Limited (e-mails)	4-Moderate (e-mails and/or meetings)	5-Extensive (meetings, seminars, etc.)
Support required			

For example, the value of the indicator "Information provided" is the arithmetic mean (AM) of the questions 1, 2 and 3. For indicators that depend only on one question, the numerical value of that question was used. Table 3.4 is an example of the "Mains Investment Planning" tool, presenting the indicators' results based on the arithmetic mean (AM) of the corresponding questions (of both the student and the tool expert).

Table 3.4: Indicators' results based on the AM of the corresponding questions (example, "Mains Investment Planning" tool)

	Indicators							
Tool	*Information provided*	*Updates frequency*	*Data required*	*Time required*	*User-friendliness*	*Tool performance*	*Results visualisation*	*Required support*
Mains Investment Planning								
A.M. student	2	1	5	1	4	5	4	3
(A.M. tool expert)	1,67	1	4,5	1	3,67	5	4	3
Corresponding questions	1, 2, 3	4	5, 6	7	8, 9, 10	11	12	13

- **Step 6: Conduction of statistical analysis**

Having completed the 15 tool assessment forms, the final step was an analysis of the results. Different graphs were created in order to illustrate and compare the presentations and different elements on the website and also the different performances during tools' implementation. Two groups of graphs were created based on the 8 indicators. The first group of 8 graphs was comparing the performance of every tool regarding each indicator (presented in Chapter 4) and the second group of 15 tools illustrated the overall performance of each tool (Appendix C).

3.2 Part 2 - Investigation of CB and UWOT's current and future correlation

The research focused on two of the Watershare tools in Part 2: the City Blueprint (CB) and the Urban Water Optioneering Tool (UWOT), both part of the KWR Resilience Assessment components. This study was the first phase of a larger project aimed to create a more integrated resilience profiling for cities, and provide it as a user-package for facilitating the planning of water-wise strategies. The procedure followed for Part 2 is given in Figure 3.2 and is further described below.

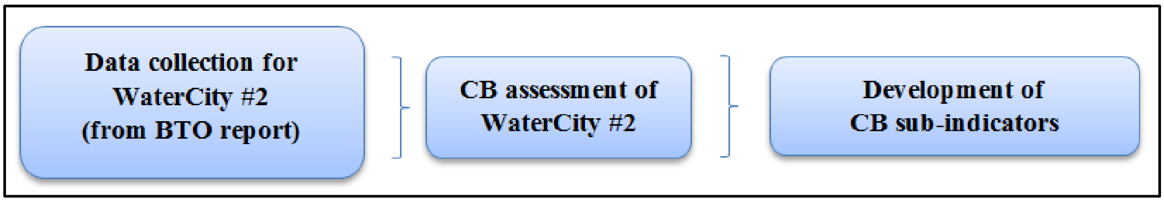


Figure 3.2: Procedure followed for Part 2

- **Phase 1: Investigation of the current correlation between the CB tool and the UWOT**

In Phase 1 was investigated to what extent the current versions of the two tools use similar data for fulfilling their purpose. Practically, was inspected if a specific set of data could be used for the implementation of both tools. UWOT was already used in the report "Developing Water Wise Cities: A methodological proposition" (BTO, 2016) for assessing the resilience of WaterCity (a synthetic case study). More specific, a resilience assessment was carried out for the city's three different scenarios; Business As Usual (BAU), Next Step (NS) and Further Ahead (FA). These scenarios represent three progressively more technologically advanced (from a water system perspective) sets of configurations.

Therefore, the CB assessment of these three different scenarios was conducted in the current study, using the same data. Firstly, the necessary data were extracted from the BTO report and used to calculate for each scenario the 25 CB Indicators. Secondly, through the CB Index; the overall score of CB, was quantitatively assessed which changes within the three scenarios of the resilience assessment (UWOT) were also reflected in the CB assessment.

- **Phase 2: Development of CB sub-indicators**

The next step was to adapt both CB and UWOT, for their best possible integration. Therefore, during Phase 2 was created a list of new sub-indicators to be included in a "CB extended" version. A description of the steps followed during this procedure is given below, in Figure 3.3. The principal idea of each CB core Indicator was analysed, aiming to find subcomponents with a distinct physico-chemical entity, in order to compose new CB sub-indicators. The next step was the mathematical definition of these sub-indicators. Finally, the correlation between each sub-indicator and UWOT objectives was determined.

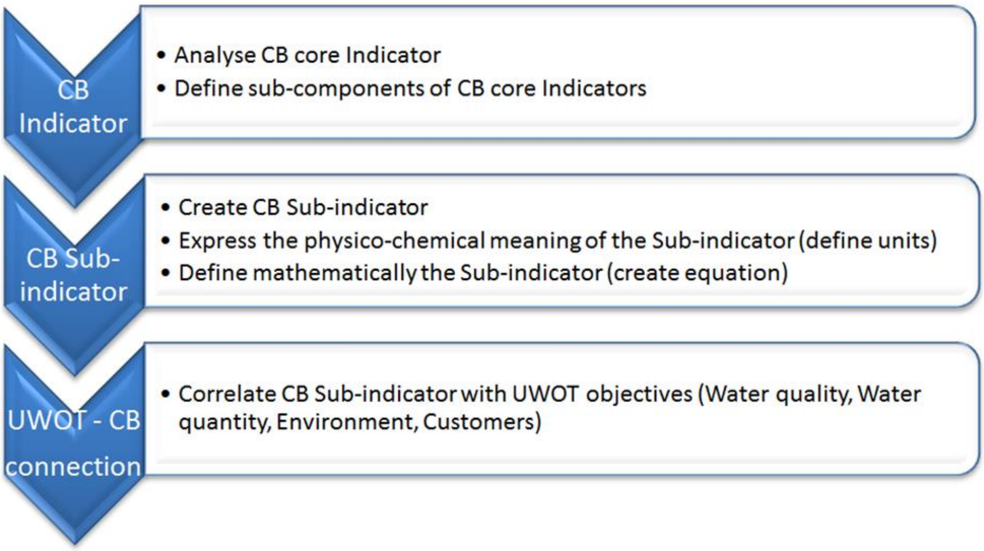


Figure 3.3: Steps followed for the creation of CB Sub-indicators

4. Results and Discussion - Part 1 - Evaluation of the Watershare tools

4.1 Part 1 - Results and Discussion

The main findings of this study and their interpretation are described in this part. The completion of the questionnaires was followed by the mathematical determination of 8 indicators that created 15 different assessment forms (one for each tool). The results of the 8 indicators are presented below, in 8 radar charts. The answers of both participants are included (blue colour for the student, red colour for the tool experts) and in case these are widely different, will be further commented.

Figure 4.1 displays the outcome of Indicator 1 "Information provided" that concerned the presentation of the tools on the Watershare website (based on the provided information about the required data, required level of expertise and the number of case studies). Looking at Figure 4.1 it is apparent that the majority of the tool sheets (11 tools) lack some of the aforementioned information and thus scores low to moderate, on the radar chart. That resulted mostly from the absence of any indication regarding the required level of expertise on the tool sheets. This absence can be explained by the fact that tool experts were not asked explicitly to include the required level of expertise in the tool sheets.

Also, the relatively low scores show that there were inadequate descriptions of the exact amount and type of data required in the tool sheets. This might have resulted from the absence of specific or more detailed instructions on what had to be included in each tool sheet, during the "building" of tools presentation on the website. Finally, the gained scores were also affected by the number of the provided case studies. A sufficient number of case studies was not included in approximately two-thirds of the tools (3 tools with zero cases and 5 tools with one case). The rest of the tool sheets contained either 2 different cases (4 tools) or 3 cases (2 tools) and lastly, 4 case studies were described in one tool sheet . This small amount of cases might reflect that these tools were not further applied after their development or that these were used, but for some reason there was no relevant update on the website. As a final remark from the chart, there was not a total correspondence between student's (blue colour) and experts' answers (red colour), since the latter in general terms, tended to be more strict with their work.

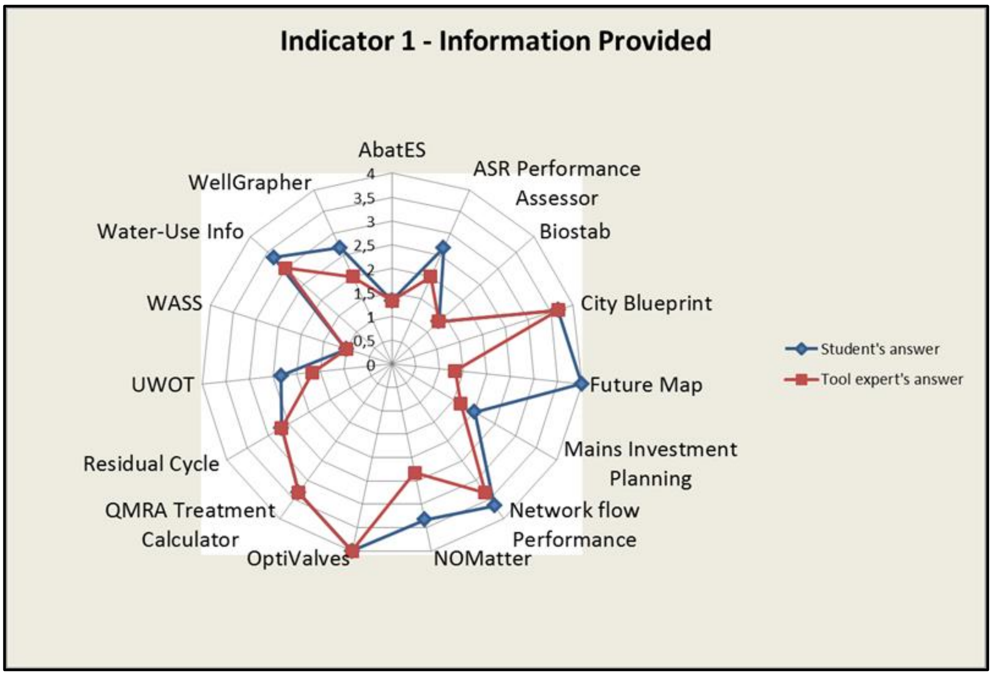


Figure 4.1: Outcome of Indicator 1: "Information provided", including student's score (blue colour) and tool experts' score (red colour), from 0 (minimum information provided) to 4 (maximum information provided).

The results of Indicator 2 "Data required" (originating from question 4 of the questionnaire), are reflected in Figure 4.2. More than one-third of the tools (6) scored the maximum points, meaning that only operational data are required for their application (and possibly literature search), that usually are available and easily accessible. The rest of the tools needs additionally, data storage, monitoring network or data extracted from a different software tool. For these tools the availability can also depend on country's monitoring data or the performance of an additional software tool, making data extraction more challenging in some cases. Finally, a minority of 2 tools might need further assumptions due to more extensive lack of data in some cases. All of the above findings provide insights into the type of data required for implementing a tool and their availability. Nevertheless, this illustration should be seen more as a general overview, since each case study is different, with the availability of data strongly depends on people and countries.

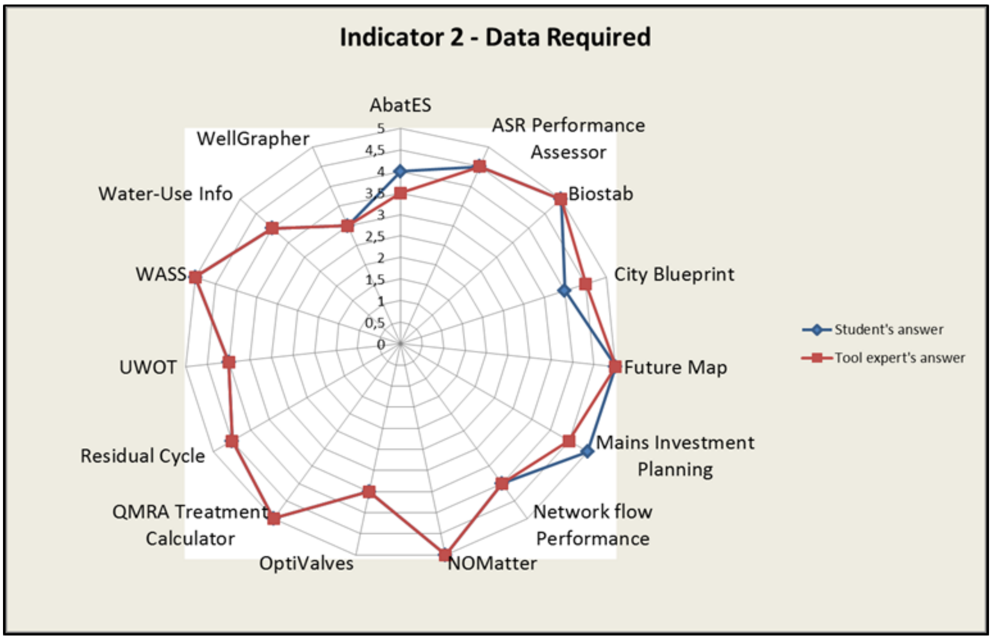


Figure 4.2: Outcome of Indicator 2: “Data required” including student’s score (blue colour) and tool experts’ score (red colour), from 0 (minimum data required) to 5 (maximum data required).

The values of Indicator 3 “Time required” (based on question 6 of the questionnaire), are shown in Figure 4.3. Two-thirds of the tools need 1 to 4 hours for entering the data, follow the steps and run the programme. The rest of the tools needs either one working day (3 tools) or 2 to 3 days (1 tool) due to the use of additional software tools that might also require large amounts of data. These findings are important for showing that the implementation of the majority of the tools is straightforward and not time consuming. Nevertheless, it is easily understood that the required time depends mainly on the complexity of each tool, which is determined by the complexity of the problem it aims to solve.

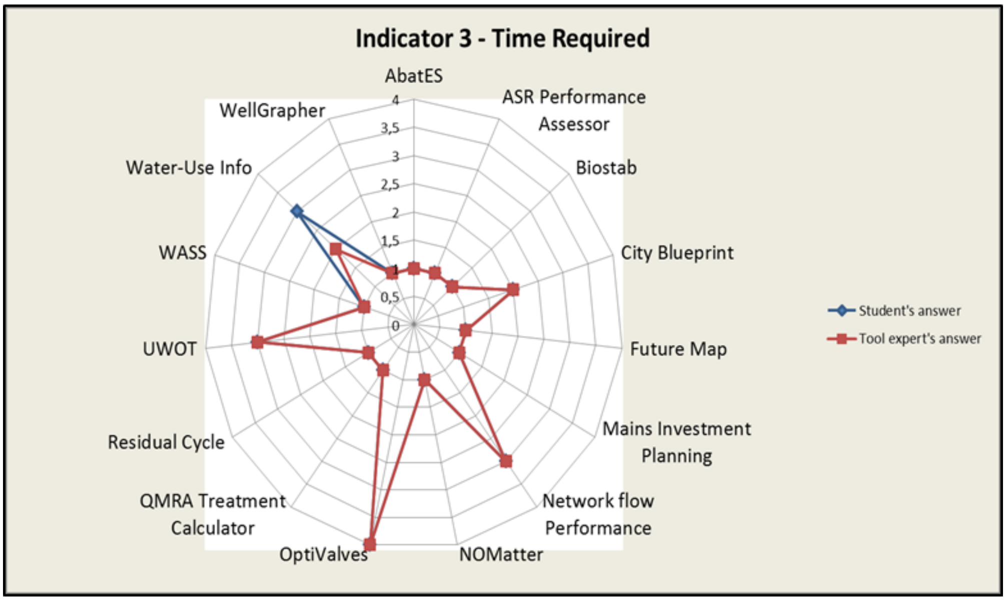


Figure 4.3: Outcome of Indicator 3: “Time required” including student’s score (blue colour) and tool experts’ score (red colour), from 0 (minimum time required) to 4 (maximum time required).

For Indicator 4 “Support required” (originating from question 7 of the questionnaire), the form of support was subdivided into three types: limited support is required (meaning assistance through e-mails), moderate support is required (additionally, some meetings or an introductory course are needed) or extensive support is required (in addition, seminars, training programmes, etc.). As it is reflected in Figure 4.4, an end user will need limited support for applying two-thirds of the tools. For the rest of the tools, the tool experts will have to provide the users with either moderate (4 tools) or extensive (1 tool) assistance. These findings illustrate that in general terms, the implementation of a tool is a rather straightforward procedure that can be carried out by end users without demanding extensive support.

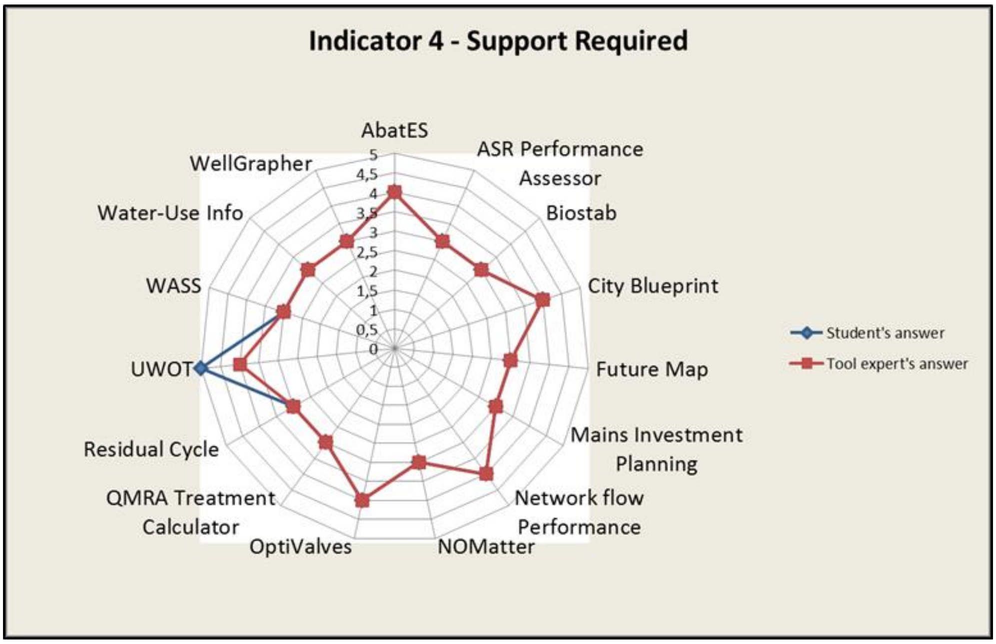


Figure 4.4: Outcome of Indicator 4: “Support required” including student’s score (blue colour) and tool experts’ score (red colour), from 0 (minimum support required) to 5 (maximum support required).

Indicator 5 “Tool Usability” concerns the user-friendliness and ease to apply each tool. The indicator occurred as a combination of questions 8, 9 and 10 of the questionnaire. The questions concerned the quality of the provided supporting material and manual, the level of step by step support provided by the software and finally the intuitiveness of the graphical user interface (GUI). The outcome is plotted in Figure 4.5. The overall performance of one-third of the tools can be characterised as moderate and very satisfactory to excellent for the rest of the tools. The moderate performances mainly resulted from the inadequate step by step support provided by the software (3 tools). Furthermore, 4 more tools were rated relatively low in this part of “Usability”, but higher in the other two (provided supporting material and intuitiveness). The step by step support was characterised as inadequate in three cases: when no instructions were provided, when general instructions were given on the website and when general instructions were included in the first step of the application.

The moderate results were also affected by the absence or poor information given on the “Manual” tool sheet of the website. This tool sheet aimed to include material regarding the function of the tool, such as description of how it works, implementation steps, tool manual or demo files when needed, etc. In total, one third of the “Manual” tool sheets (concerning 5 tools) needed improvement. Finally, the GUI of the majority of the tools (12) was characterised as intuitive. This finding provides empirical confirmation that the concept and function of these tools were easily to be perceived and their implementation was a rather uncomplicated procedure. Finally, as for the differences between the answers of the student and the tool experts (different colours in the chart), these resulted again from the stricter evaluation of the latter.

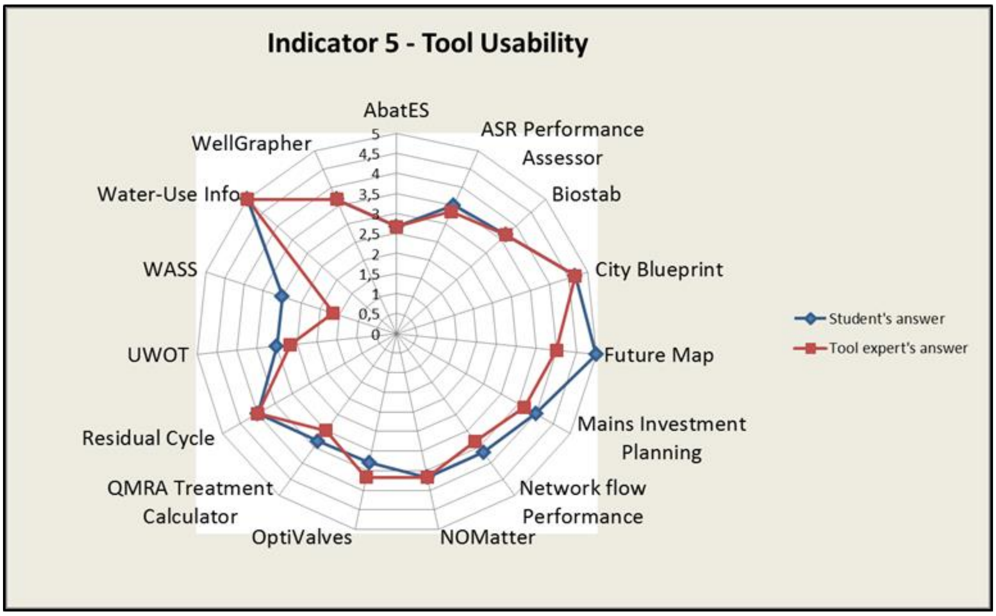


Figure 4.5: Outcome of Indicator 5: "Tool Usability" including student's score (blue colour) and tool experts' score (red colour), from 0 (minimum tool usability) to 5 (maximum tool usability).

The 6th Indicator, "Results visualisation" quantified the different kinds of visualising the outcome of each tool (question 11 in the questionnaire). A narrative representation was considered as less descriptive, followed by a logical, numerical and graphical illustration. A combination of two or more of these types was considered as optimal and gained the maximum points. Figure 4.6 reveals that for the greater part of the tools (12 tools) their results are illustrated either graphically or with two and more different ways, enhancing the interpretation of tools' outcome. Two of the remaining tools were less descriptive, with the results presented in a narrative or logical way. Finally, the last tool lacked a graphical representation, possibly due to an error. These findings are favorable for the majority of the tools regarding their good results visualisation, nonetheless there is still room for improvement in this area as well.

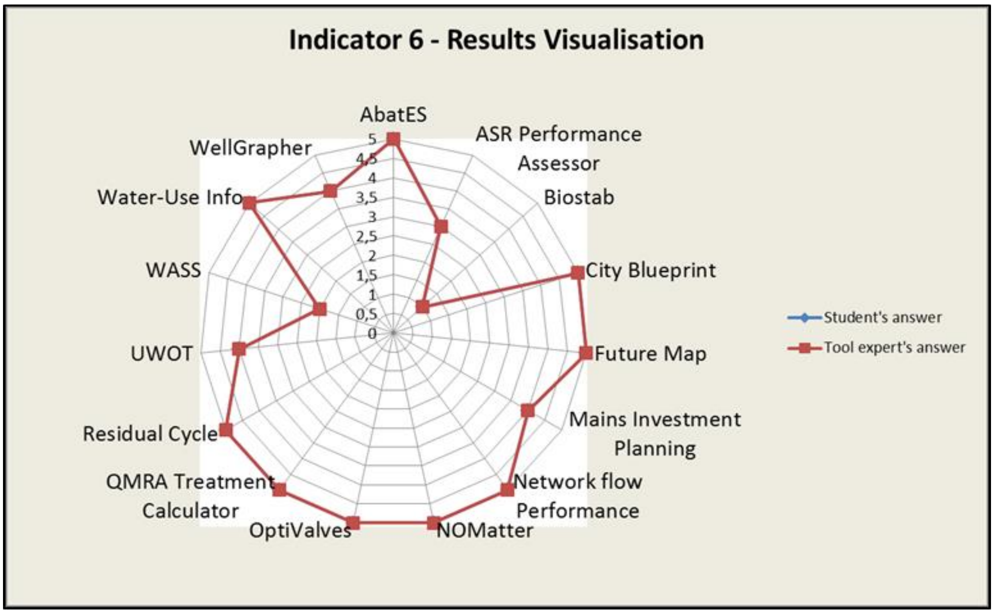


Figure 4.6: Outcome of Indicator 6: "Results visualisation" including student's score (blue colour) and tool experts' score (red colour), from 0 (minimum results visualisation) to 5 (maximum results visualisation).

For the 7th Indicator "Tool performance" several software problems that can occur during the application of a tool were taken under consideration (concerns question 12 of the questionnaire). Malfunctions that affect the ease of computation/ simulation include low simulation speeds, occurrence of crushes or bugs, and more extensive ones as application errors. In the current evaluation, an "Application error" occurred only once during a tool's implementation, making it impossible to complete the testing. As it is indicated in Figure 4.7, apart from that isolated event, the developers of three more tools mentioned recorded low simulation speeds and for one tool, in addition, the occurrence of a crush. Nevertheless, these problems hadn't occurred during the application of the majority of tools (two-thirds). These findings most probably reveal an effective software development. Secondarily, might indicate that some tools are not frequently used and thus possible malfunctions have not yet been detected.

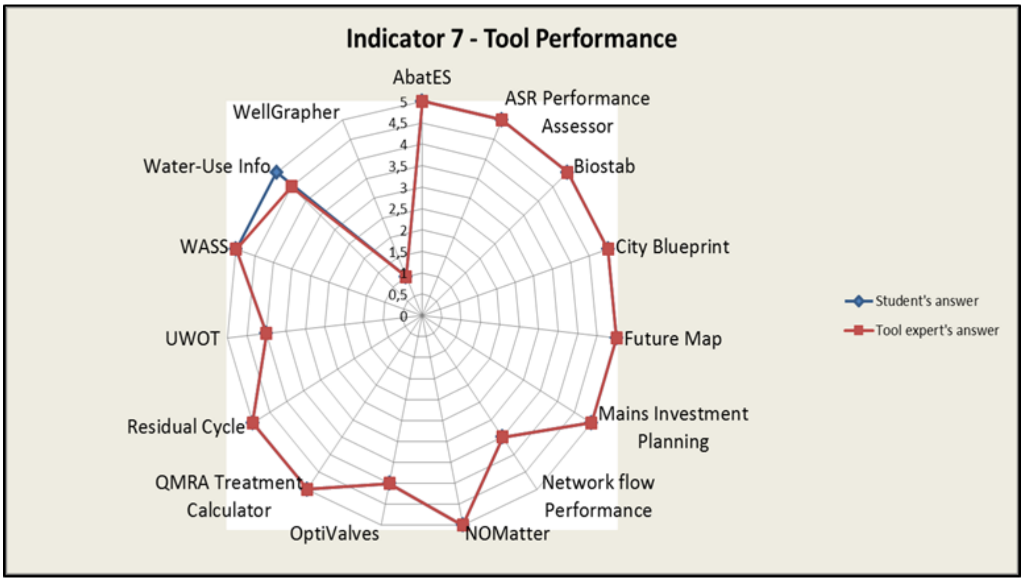


Figure 4.7: Outcome of Indicator 7: "Tool performance" including student's score (blue colour) and tool experts' score (red colour), from 0 (minimum tool performance) to 5 (maximum tool performance).

The last Indicator (8th) "Updates frequency" is a measurement of the number of updates that took place during 2014 - 2016. This time limitation occurred due to lack of data for the previous two years (2012, 2013). Nevertheless, more data were provided for some cases from the tool experts during the interviews. The updates included bug fixes, new applications, adaptations and link updates. Figure 4.8 shows the performance of the tools regarding the number of updates. During the aforementioned period, one-third of the tools had zero updates (5 tools), 4 tools had one update, one-third had 2 updates (5 tools) and the remaining tool had 5 updates. What stands out in this chart is the limited number of updates for the vast number of tools, at least during these two years. The fact that most of these tools were developed and already tested for malfunctions before 2014 is one of the main reasons. That reason also explains why one of the tools had far more updates compared to the others, since it was added in the toolbox more recently. Finally, the frequency of updates depends also on projects' funding, that can lead to restrictions when funds availability is limited.

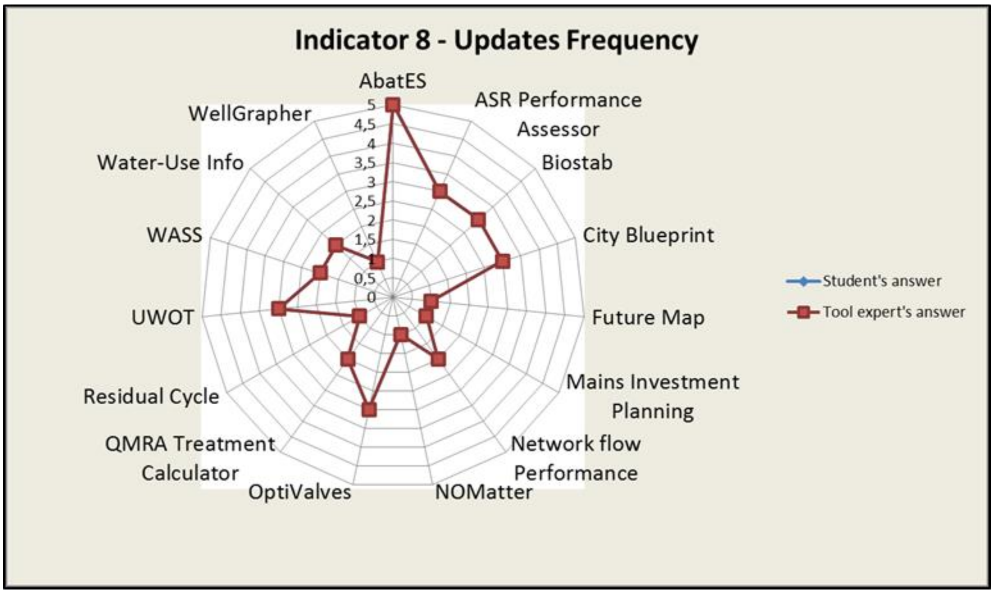


Figure 4.8: Outcome of Indicator 8: "Updates frequency" including student's score (blue colour) and tool experts' score (red colour), from 0 (minimum updates frequency) to 5 (maximum updates frequency).

All of the above results provide significant insights into the most important features of these 15 Watershare tools, as these were determined by the current study: tools presentation on the website, basic requirements for tools application, general performance during tools application and finally number of updates (for the years 2014 - 2016). Finally, some of the tools were already since 2012 in Watershare toolbox, without having been used by other members or end-users. That might had led to a lack of ownership and motivation for experts, resulting to less efforts towards tools' optimisation. The creation of Communities of Practise (CoP) aimed to further stimulate apart from the end users, also the tool experts and their partners. The allocation of the tools in the new communities intents to achieve further collaborations, renewal of the existing tools and development of new models and applications.

4.2 Part 1 - Limitations of the study

This section critically assesses the methodology followed in the current report and the research limitations. Firstly, the evaluation and assessment of Watershare tools that composed the first part of this study, were executed by a non-expert (in software tools). The method of evaluation didn't follow a specific, professional procedure, but a more empirical one. The process was driven by the experience, knowledge and intuitiveness of the people involved (MSc student and KWR supervisors) regarding their vision for the presentation of the tools on the Watershare website. Moreover, the self-reported method of forming the possible answers of the questionnaire could have led to biased results (at least to a certain extent). To reduce as much as possible this risk, it was decided to interview the tool experts as well. Indeed, the radar charts revealed that the difference between the answers given by the student and by the tool experts was not significant. In any respect, interviewing the tool developers put the base for many of the recommendations given in chapter 6.

Regarding the questionnaires, few concerns were expressed during interviews. In more detail, the questions and possible answers provided were deemed quite general, not able to capture the specific features and functions of each individual tool. As one interviewee commented: "Fixed answers cannot be given since often the answer depends on the situation of the tool user, which can vary". While this holds, the required data, time and support for implementing a tool also depend highly on its complexity, which is strongly related to the nature of the problems to be solved. Regarding the frequency of updates, principal limitation was the fact that recorded data were only available for the period 2014 - 2016 and not for the previous two years. Nevertheless, it was decided to include this indicator aiming to inspect at least the most current occurrence of updates.

It should also be mentioned, that the testing of the tools wasn't aiming to evaluate the tool itself or its value and usefulness in the Watershare toolbox. This was considered to be self-evident. The results included in this chapter should be considered more as an indicator of the general performance of the tools on the website, as it was perceived by an end user.

Finally, further research is deemed necessary, initially for testing the rest of the Watershare tools (11 more tools). Then, research should be carried out considering the opinion of Watershare members and end users for the usability and applicability of Watershare tools they have already used. Tools' presentation on the website should be subject of criticism by members and end users as well. This part of the evaluation was not possible to be included in the present project due to lack of time.

5. Results and Discussion - Part 2 - Investigation of CB and UWOT's current and future correlation

5.1 Part 2 - Results and Discussion

The main findings of Part 2 of this study are described and interpreted in this chapter. The first step of this phase was the collection of data from the report "Developing Water Wise Cities: A methodological proposition" (BTO, 2016). The data concerned the three different scenarios of WaterCity #2, Business As Usual (BAU), Next Step (NS) and Further Ahead (FA). Table 5.1 presents the calculation results of the 25 CB Indicators, for the three scenarios. Seven of these Indicators had changed within the three configurations and are highlighted in Table 5.1: Nutrient recovery, Sewage sludge recycling, Stormwater separation, Climate adaptation, Drinking water consumption, Management and action plans and Water efficiency measures. Since each scenario was technologically more advanced than the previous one, the values of the indicators were increased from BAU to the final FA scenario.

		Indicator number																								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	BCI (Blue City Index = geometric mean)	Secondary WWT	Tertiary WWT	Groundwater quality	Solid waste collected	Solid waste recycled	Solid waste energy recovered	Access to drinking water	Access to sanitation	Drinking water quality	Nutrient recovery	Energy recovery	Sewage sludge recycling	WWT Energy efficiency	Stormwater separation	Average age sewer	Water system leakages	Operation cost recovery	Green space	Climate adaptation	Drinking water consumption	Climate robust buildings	Management and action plans	Public participation	Water efficiency measures	Attractiveness
WaterCity #2 - BAU	5,2	9,0	7,5	6,1	5,0	2,0	0,0	10	10	9,9	2,0	5,0	7,0	5,0	5,0	7,0	6,0	5,0	4,0	7,0	9,98	5,0	5,0	4,0	5,0	5,0
WaterCity #2 - NS	5,7	9,0	7,5	6,1	5,0	2,0	0,0	10	10	9,9	5,0	5,0	8,0	5,0	7,0	7,0	6,0	5,0	4,0	9,0	10,0	5,0	7,0	4,0	8,0	5,0
WaterCity #2 - FA	6,2	9,0	7,5	6,1	5,0	2,0	0,0	10	10	9,9	10	5,0	10	5,0	10	7,0	6,0	5,0	4,0	10	9,98	5,0	9,0	4,0	10	5,0

Table 5.1: CB indicators for the three configurations (BAU, NS, FA)

The reader will perceive that the majority of indicators remained the same within the three configurations; changes that did occur within the city's scenarios, was not able to be captured by the CB Indicators. Therefore, most of the data given in the BTO report, were necessary for UWOT, but were not those required for conducting the CB assessment of WaterCity #2. The aforementioned results are also illustrated in the CB Index (Figure 5.1).

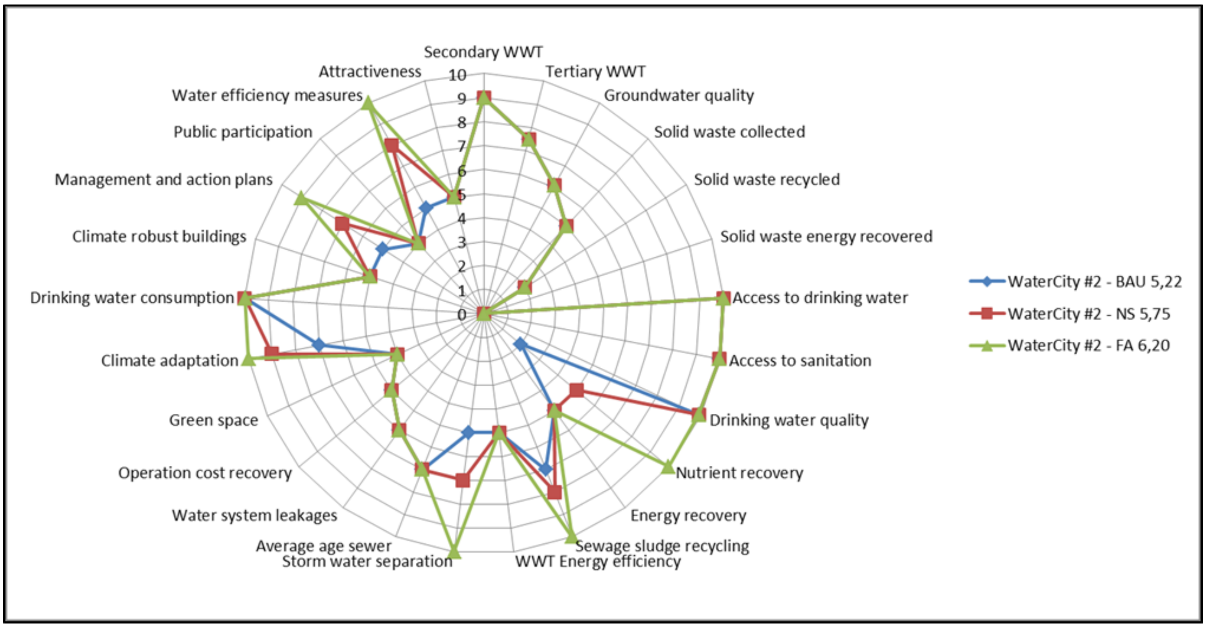


Figure 5.1: City Blueprint Index for the three configurations of WaterCity #2; Business As Usual (BAU), Next Step (NS) and Further Ahead (FA), from 0 to 10 (minimum to maximum score for CB Indicators).

After locating this extended data gap between the two tools, it was deemed necessary to investigate ways to connect and integrate these two approaches. Thus, it was decided to create a “City Blueprint extended” version including new, more dynamic sub-indicators that could also be plotted and included in UWOT. That was achieved by investigating which of the concepts of the initial 25 CB indicators include elements that can be connected more directly with the four objectives of UWOT: water quantity, water quality, environment and customers. After defining what each sub-indicator could measure, a suitable and feasible way of calculating it was added, along with the proper units.In this way, the new sub-indicators would be easier to be inserted as new elements in UWOT model and be plotted.

The result of this process was a set of 33 possible sub-indicators. Appendix D contains the end product of this phase, a detailed table including definition, measurement units, way of calculation and type of connection with UWOT for each sub-indicator. Table 5.2 contains part of this information: the connection of CB Sub-indicators with CB core indicators and with UWOT objectives.

Table 5.2: City Blueprint – UWOT sub-indicators

CB Category	CB Indicator	Sub-indicator	UWOT objectives
I. Water quality	**1. Secondary WWT (Waste Water Treatment)** **2. Tertiary WWT**	A. Nitrogen presence/ concentration	Water quality, Environment
		B. BOD level/ presence (Biochemical Oxygen Demand)	Water quality, Environment
		C. WWT performance	Water quality, Environment
		D. CSO Volume (Combined Sewer Overflow)	Water quality
	3. Groundwater quality	A. Chloride concentration	Water quality
II. Solid waste treatment	**4. Solid waste collected** **5. Solid waste recycled** **6. Solid waste energy recovered**	A. Plastic particles	Environment
III. Basic water services	**7. Access to drinking water**	A. Water disruption/ interruption	Water quantity
		B. Water supply endpoint	Water quality
	8. Access to sanitation	A. Untreated wastewater	Customers
	9. Drinking water quality	A. Water hardness	Water quality
		B. Pharmaceutical residues	Water quality
		C. Pesticide residues	Water quality
		D. Heavy metals occurrence	Water quality
		E. Overall quality failure	Water quality
IV. Wastewater treatment	**10. Nutrient recovery** **11. Energy recovery** **12. Sewage sludge recycling** **13. WWT energy efficiency**	A. WWT energy consumption	Environment
V. Infrastructure	**14. Stormwater separation**	A. CSO Frequency	Customers
		B. Wastewater transport	Environment
	15. Average age sewer	-	-
	16. Water system leakages	A. Drinking water leakages	Customers
		B. Wastewater leakages	Customers
		C. Drinking water transport	Environment
	17. Operation cost recovery	A. Annual maintenance cost	Customers
		B. Annual replacement cost	Customers
VI. Climate robustness	**18. Green space**	A. Urban temperature alteration/ variation	Environment
	19. Climate adaptation	A. Urban drainage flooding	Customers
		B. Green roofs cover	Environment
		C. Use of rainwater	Environment
		D. Impermeable surface	Environment
	20. Drinking water consumption	A. Domestic water self-reliance	Water quantity
	21. Climate robust buildings	A. Energy efficient buildings	Environment
VII. Governance	**22. Management and action plans** **23. Public participation**	-	-
	24. Water efficiency measures	A. Water efficient buildings	
		B. Industrial water self-reliance	Water quantity
		C. Drinking water energy consumption	Environment
		D. Industrial water use	Water quantity
	25. Attractiveness	-	-

The majority of the initial CB Indicators was able to be further analysed and expressed in a more quantitative way, that would allow them to be included in the UWOT model. These newly formed Sub-indicators were also easily connected with one or more of the UWOT objectives. Nevertheless, for CB Category 2 “Solid waste treatment” (Indicators: Solid waste collected, Solid waste recycled and Solid waste energy recovery) and CB category 7 “Governance” (Indicators: Management and action plans, Public participation and Attractiveness) the sub-indicator cells are blank. It was not feasible to find a relation and create sub-indicators that could be included in UWOT, since the model does not deal with these aspects in its current version.

Finally, the CB Sub-indicators proposed are the initial effort of creating the “CB extended” version and most probably will undergo changes. At the current state, this list probably includes some usable Sub-Indicators. However, unless further investigation is conducted, this list only indicates that suitable Sub-Indicators can be existed for connecting CB with UWOT.

5.2 Part 2 - Limitations of the study

Concluding, further limitations and a critical assessment of the work conducted during Part 2 is followed. Concerning data collection, most of the data needed for calculating the CB Indicators could not be found in the BTO report. Therefore, the already existed CB Indicators for Rotterdam were used, since WaterCity #2 resembled the city of Rotterdam (according to the authors of the BTO report). This extended use of “borrowed” CB Indicators did not lead to the most accurate WaterCity #2 CB assessment. Nevertheless, the aim was achieved; to confirm that the same set of data would not cover the data needs of both CB tool and UWOT. Regarding the second phase of the study, the calculation (specific equations) of some of the developed CB sub-indicators has not yet determined, due to the limited time (indicated with “To be added” in table of Appendix D).

6. Conclusion and Recommendations

6.1 Part 1 - Evaluation of the Watershare tools

The first part of this thesis was undertaken in order to assess the current state of 15 Watershare tools. The main research questions raised at the beginning of the report concerned the presentation of software tools on the website, the basic requirements for applying them, tools' ease of applicability from an end user perspective and finally their number of updates.

In more detail the first question aimed to examine to what extent the information regarding the required data (amount and type), level of expertise and case studies were indicated on the Watershare website. It is concluded that more than two-thirds of the 15 tools were lacking, at least to some degree, parts of this information (11 tools).

The second research question investigated the basic requirements (data, time, expertise, support) of the tools in order to be implemented by an end user. The exact information of this study was listed in the 15 individual reports. The investigation into the required data revealed that one-third of the tools needs operational data and literature search. The rest demands data storage, monitoring network or data extracted from another software tool. The availability of data varies and might depend on country's monitoring data or the performance of the additional software tool. The findings regarding the required time indicated that two-thirds of the tools require less than 4 hours for being implemented. Regarding the required level of expertise, the majority of the tool experts argued that no particular knowledge or high level of expertise is required. As for the required support, the research showed that limited support (assistance through e-mails) is needed during the implementation of two-thirds of the tools.

The third question evaluated the overall performance of the 15 Watershare Tools during their application. That comprised of the level of usability (including quality of supporting material and manual, step-by-step support provided by the software and tools intuitiveness), the output visualisation and the ease of computation. Regarding usability, the performance of two-thirds of the tools was characterised as very satisfactory to excellent. More than two-thirds of the tools included descriptive ways of results representation. Similarly, two-thirds of the tools had no recorded malfunctions affecting their ease of simulation.

Finally, the frequency of updates (bug fixes, new applications, adaptations and link updates) on the Watershare website was the subject of the fourth question. With almost two-thirds of the tools having 0 to 1 update during two years, the frequency of updates can be described as absent.

6.2 Part 1 - Further recommendations

Summarising, the current research was required, as the first attempt to evaluate the Watershare tools, aiming to provide an overview of their current state and facilitate changes that might follow. In Table 6.1 is presented all the information that can be included in the different Description Categories of the website, for the optimal tools' presentation.

Table 6.1 Information that should be included in the Description Categories for tools optimal illustration

Description Categories	**Information included**
Start (Introduction)	Introduction to the Tool Tool benefits Introduction video
Manual	"How does it work?" Tool Manual (when needed) Software Demo files (when needed) Data and level of expertise required (in detail)
Training	Available forms of support
Cases	Description of enrolled cases
References	Publications that the tool is mentioned Number of publications Number of cities/country that the tool is enrolled
Toolsheet	General overview of the Tool

Supplementary recommendations are found in Figure 6.1. For example, an "Info table" including the required data, time, expertise and support for tool's implementation can be added in the "Start" category. This overview e.g. in the form of infographic, will briefly inform the end user about tool's basic requirements. In the "Manual" category a walkthrough video tutorial can be added, describing tool's implementation process, step by step. Additionally, the data workflow can be documented and then be accessible on the website. Thus, tools' simulations can be easily reproduced e.g. while testing more complicated software tools. Specific and more detailed suggestions focusing on each tool, are included in the individual tool reports.

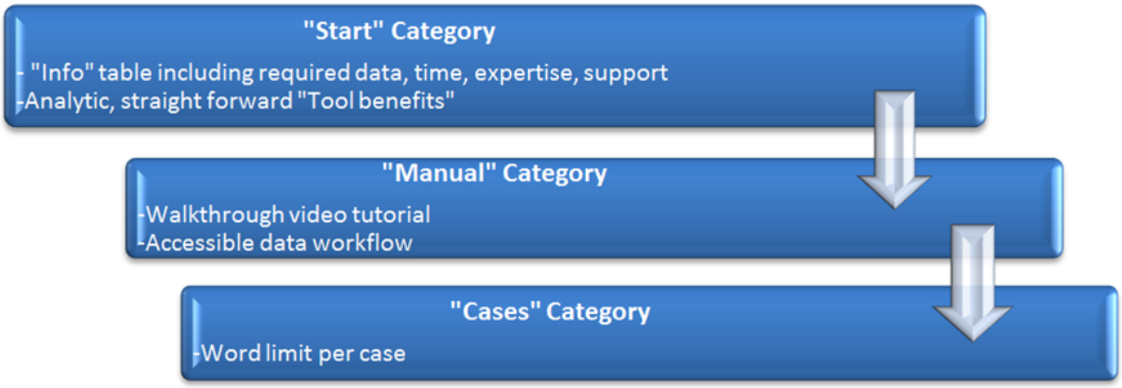


Figure 6.1 Supplementary recommendations for tools presentation on the Watershare website.

Finally, further suggestions to Watershare platform's administrators are found in Figure 6.2. The improvement of tools' presentation on the Watershare website is the main objective of the current report. Nevertheless, in order to attract the interest of new members, end users, etc. free webinars or information days regarding the CoP can also be provided. For the optimisation of website's function, annual updates can be scheduled, along with tests for validating the function and performance of tools.

As a general remark, deficiencies and malfunctions could have been prevented and solved on time and optimisations and updates could have been realised earlier, if there was a closer communication between tool experts and platform managers. An improvement of this cooperation would facilitate the operation of Watershare platform and maintain, if not enhance, its reliability to end users that wouldn't have to deal with the aforementioned problems while implementing one of the tools.

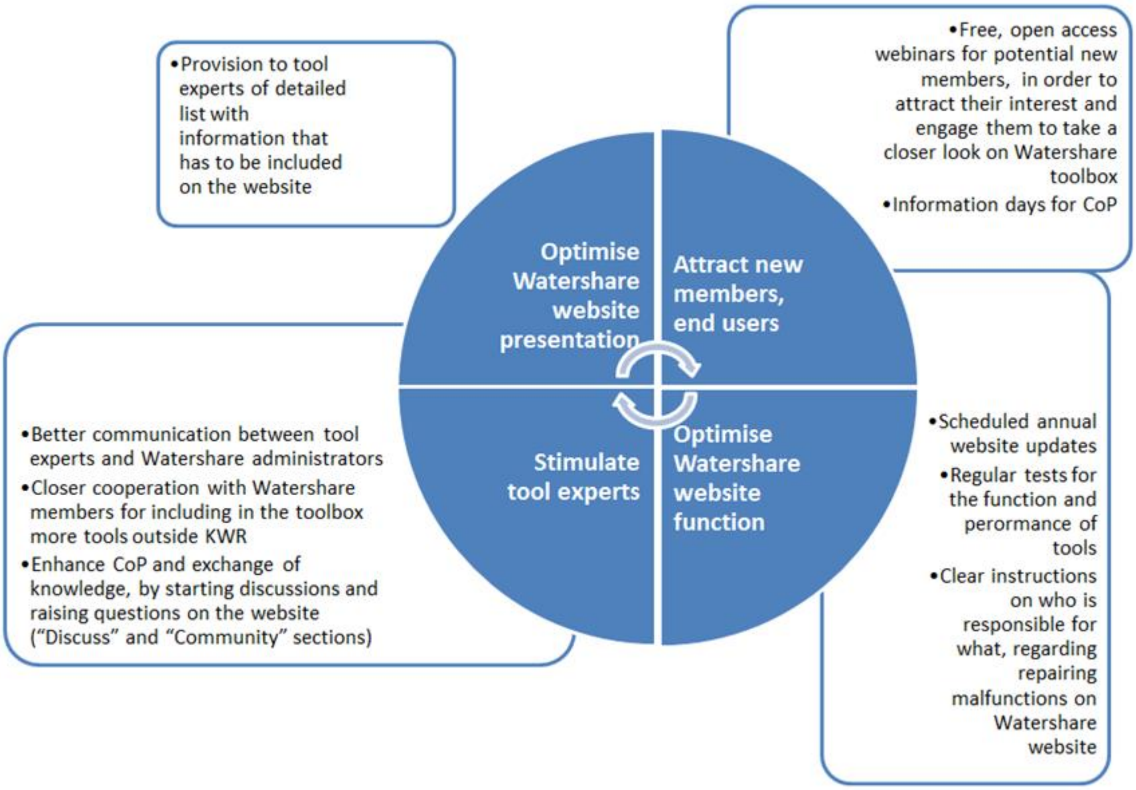


Figure 6.2: Further suggestions for Watershare platform

6.3 Part 2 - Investigation of CB and UWOT's current and future correlation

Part 2 of this research was part of a larger project, aimed to identify the connections between the KWR Resilience Assessment components (which include CB tool and UWOT) and improve their cohesion. This correlation was attempted in order to provide end users with a more integrated user-package for managing cities' water services. The combined use of these two tools would create a more integrated and holistic view of cities condition, since it would use the different and possibly complementary outputs of both approaches. The questions raised for this part concerned the data gaps between the two approaches and ways to effectively bridge the aforementioned gap.

In the first phase of this part, the CB assessment of WaterCity #2, investigated to what extent the current versions of the two tools use similar data for fulfilling their purpose. The result of this work, the CB Index, located data gaps in the overwhelming majority of the CB Indicators (18 out of 25 Indicators). All 7 City Blueprint Categories were lacking data, but especially for the first three Categories (Water quality, Solid waste treatment and Basic water services) no connection was able to be identified (Table 5.1).

Thus, in the second phase a "City Blueprint extended" version was formed, for improving CB and UWOT's cohesion. New CB sub-indicators created and added in the already existing indicator list. The main idea was that these sub-indicators could also be included and plotted in UWOT, forming a "bridge" between these two assessments. Table 5.2 (Chapter 5) and Appendix D answer research question 2, by providing the detailed list of the possibly new sub-indicators.

6.4 Part 1 & 2 - Overall conclusion

Overall, this study concludes that the 15 Watershare tools that were under investigation, do function into the Watershare platform; nevertheless, the internal communication between tool experts and Watershare managers should be optimised, fixed updates have to be established and the function and performance of the tools should be tested regularly. Regarding CB tool and UWOT's correlation, the CB sub-indicators consist an initial proposed list and further research is needed in order to justify or not their suitability and usability. Nevertheless, this attempt is promising for the integration of more Watershare tools, that can lead to further collaboration within the Watershare members and the development of new software tools.

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Appendix A

Individual Report - ASR Performance Assessor (Tool Expert: Koen Zuurbier)

I. Overall Tool Assessment (Tool presentation on Watershare website and implementation)

	Indicators							
Tool	*Information[6] provided*	*Updates frequency*	*Data required*	*Time required*	*User-friendliness*	*Tool performance*	*Results visualisation*	*Required support*
ASR Performance Assessor								
A.M. student	2,67	3	4,5	1	3,5	5	3	3
(A.M. tool expert)	2	3	4,5	1	3,33	5	3	3
Corresponding questions	1, 2, 3	4	5, 6	7	8, 9, 10	11	12	13

II. Presentation of the tool on Watershare Website

Start: Excellent (including tool benefits and information movie)
Manual: Excellent
Training: Excellent
Cases: Excellent (2 cases are presented)
References: Excellent

Observations/ Recommendations:

- **Manual:** A priori indication of the required level of expertise could be added (nonetheless, implementation tools indicate it).
- **Manual:** Existence of two images that cannot open.
- **Training:** Fixed steps (similar to the other tools) could be added.
- **Cases:** Further explanation of the cases could be added.

III. Implementation of the tool (Launch Tool)

(Appendix A - Implementation Steps)

Type of required data:

- Quantitative data regarding:

[6] On the Watershare website.

Injection, Storage and Recovery time (days)
Injection volume (Q, in m^3)
Thickness target aquifer (H, in m)
Hydraulic gradient (i)
Salt concentration (C in mg/L Cl)
Horizontal conductivity (Kh, in m/d)
Anisotropy (Kh/Kz) of target aquifer
Dispersivity (d, in m)

Amount of time required for the selection of data: ≤ 1 day (?).
Amount of time required for the implementation of the tool: ≤1 day.

Visualisation/ Representation:

- **Results/ Recommendations:** Performance indication as text, Recovery efficiency in table.

IV. Questionnaire (answer by master student(*), tool expert(*) and both (*))

1. Please indicate your estimation for the following questions:

Scale/ Questions	Absent 1	Less descriptive 2	Moderate descriptive 3	Descriptive 4	Very descriptive 5
1. Indication on the Watershare website of the amount and type of data required for implementing the tool	No indication	Type of data (simple reference)	Type of data (further description)	Amount and type of data (simple reference)	Amount and type of data (further description)
2. Indication on the Watershare website of the level of expertise required by the end user for tool's implementation	No indication	-	Procedure description indicates the level of expertise required	-	Indication of the required level
3. Presentation of Watershare Case Studies on the Watershare website	0 cases	1 case	2 cases	3 cases	≥4 cases
4. Number of updates[7] (new versions, new functionality, etc.)	0 times	1 time	2 times	3 times	≥ 4 times

[7] The number of updates concerns the period from May 2014 to June 2016.

Scale/ Questions	Unreasonable 1	Less reasonable 2	Fair 3	Reasonable 4	Very reasonable 5
5. Amount and type of data required for tool's implementation	Further research for obtaining the necessary amount and type of data is required	Excessive amounts of different kinds of data are required	(Number 4) And/ or data extracted from a different software tool are required	(Number 5) And/ or data storage, monitoring network and/ or data from public sources are required	Operational data and/ or literature search are required

Scale/ Questions	Absent 1	Poor 2	Moderate 3	Good 4	Excellent 5
6. Availability of data required for tool's implementation	There are no data available	Data are missing and assumptions must be made	(Number 4) And/ or data can be extracted from a different software tool	(Number 5) And/ or data depend on country's monitoring data	All needed data are available

Scale/ Questions	1	2	3	4	5
7. Amount of time required/ consumed for entering data and setting up the tool for a case (including time required for additional software tool)	1-4 hours	4-7 hours	1 day[8]	2-3 days	>3 days

Scale/ Questions	Absent 1	Poor 2	Moderate 3	Good 4	Excellent 5

[8] Working day (8 hours).

8. Quality of support material and manual[9] provided	No support material or manual provided	"How does it work" Short description	"How does it work" Further description	In addition: "Software" or "Implementation steps"	In addition: Tool manual, Demo files
9. Level of step by step support provided by the software	No instructions provided	Only general instructions provided on the website	General instructions provided at the first step of the application	Instructions provided in every step	Detailed instructions and information provided in every step
10. Intuitiveness[10] of the graphical user interface (GUI)				x	
11. Ease of computation/ simulation (bugs, crashes, speed of simulation, etc.)	Occurrence of "Application error"	Occurrence of bug(s) and/ or crush(es)	Occurrence of a crush (isolated incident)	Low simulation speed	None of the previous mentioned

Scale/ Questions	1	2	3	4	5
12. Visualization/ representation of the results (narrative, logical, numerical, graphical)	Narrative representation	Logical representation	Numerical representation	Graphical representation	Combination of two or more types of representation * numerical, graphical (should be there as well)

[9] Subsections of the Manual Category (Watershare website): "How does it work?", Software, Tool manual (when needed), Demo files (when needed).

[10] A User Interface (UI) is intuitive when users understand its behaviour and effect without use of reason, experimentation, assistance, or special training.
Alternatively, A UI is intuitive when it has an appropriate combination of: Affordance, expectation, efficiency, responsiveness, forgiveness, explorability, no frustration.

Question	
13. Level of required support[11] (by the tool experts)	Amount of times: 0 times

2. Please indicate in which of the following CoP the tool you have developed can be categorised:

Scale/ Communities of Practice	*Strongly disagree*	*Disagree*	*Not applicable*	*Agree*	*Strongly agree*
1. Subsurface Water Solutions					x
2. Future-proof Water Infrastructures				x	
3. Resource Recovery and Upcycling				x	
4. Emerging Substances			x		
5. Resilient Urban Water Management				x	

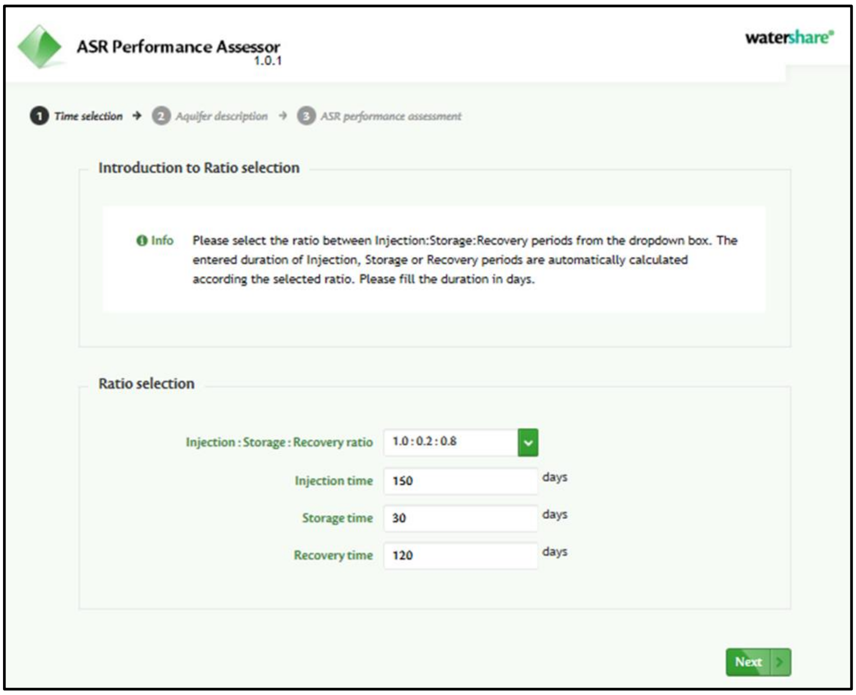
3. Please provide any further suggestions/ recommendations regarding the current questionnaire:

- **Question 6: Depends also on the country (for some countries it might be necessary to search old/ older reports)**
- **Manual toolsheet: The "How does it work" part needs further description**
- **The tool was aimed to have a graph as an output as well (absent in the current version)**
- **The tool should export in the end also a report including the input, description of the procedure, output (if it is feasible)**
- **The tool should be publicly available**

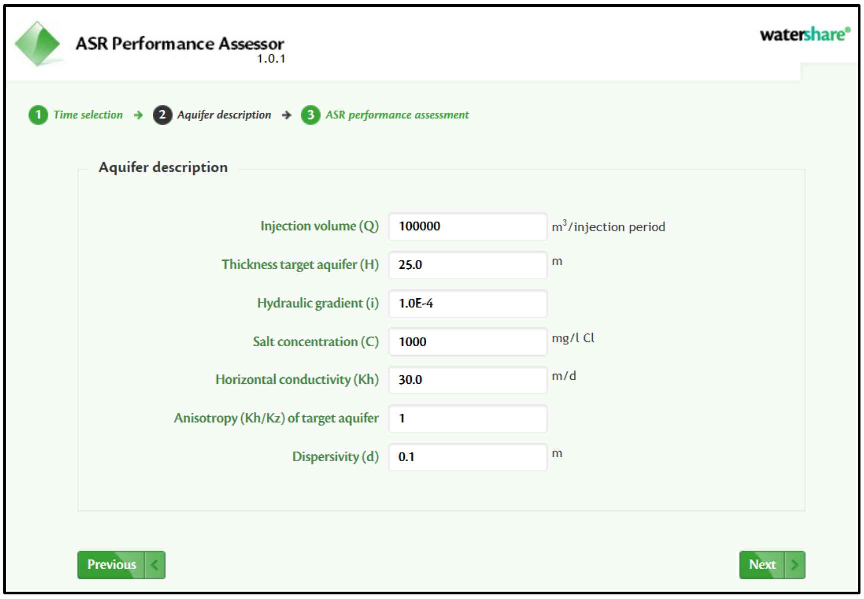
[11] Support by the Tool Experts, in the form of introductory/ more elaborate courses, training programmes, webinars, etc.

Implementation Steps

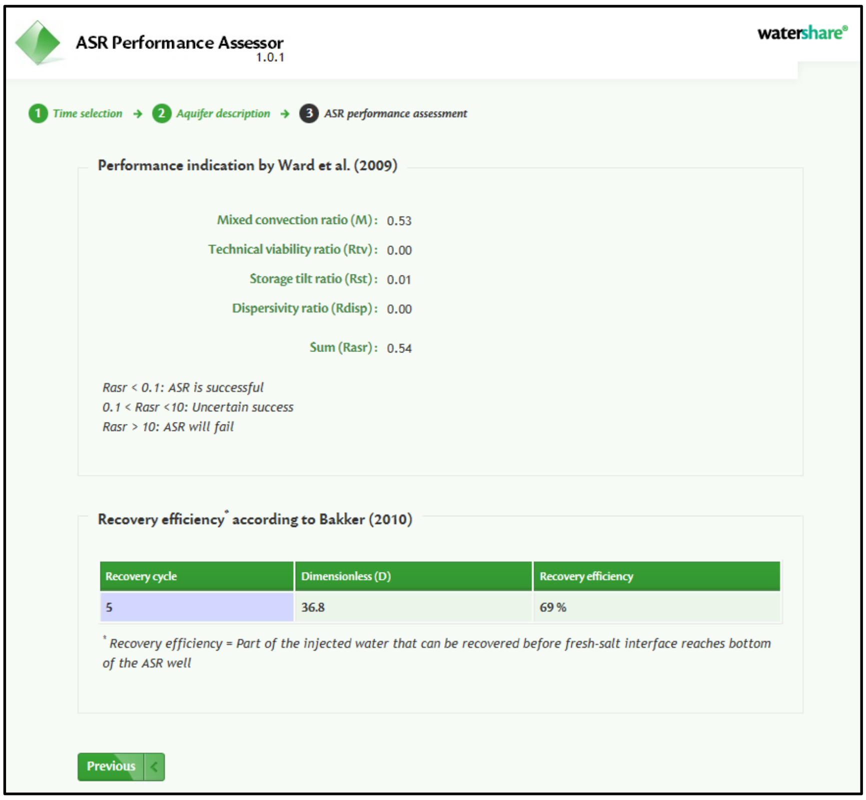
- **First Step:** Time selection



- **Second Step:** Aquifer description



- **Third Step:** ASR performance assessment



Appendix B

Watershare Tools – Questionnaire

1. Please indicate your estimation for the following questions:

Scale/ Questions	Absent 1	Less descriptive 2	Moderate descriptive 3	Descriptive 4	Very descriptive 5
1. Indication on the Watershare website of the amount and type of data required for implementing the tool	No indication	Type of data (simple reference)	Type of data (further description)	Amount and type of data (simple reference)	Amount and type of data (further description)
2. Indication on the Watershare website of the level of expertise required by the end user for tool's implementation	No indication	-	Procedure description indicates the level of expertise required	-	Indication of the required level
3. Presentation of Watershare Case Studies on the Watershare website	0 cases	1 case	2 cases	3 cases	≥4 cases
4. Frequency of updates[12] (new versions, new functionality, etc.)	0 times	1 time	2 times	3 times	≥ 4 times

Scale/ Questions	Unreasonable 1	Less reasonable 2	Fair 3	Reasonabl e 4	Very reasonable 5
5. Amount and type of data required for tool's	Further research for	Excessive amounts of	(Number 4)	(Number 5) And/ or	Operational data and/ or

[12] The frequency of updates concerns the period from May 2014 to June 2016.

implementation	obtaining the necessary amount and type of data is required	different kinds of data are required	And/ or data extracted from a different software tool are required	data storage, monitoring network and/ or data from public sources are required	literature search are required

Scale/ Questions	**Absent 1**	**Poor 2**	**Moderate 3**	**Good 4**	**Excellent 5**
6. Availability of data required for tool's implementation	There are no data available	Data are missing and assumptions must be made	(Number 4) And/ or data can be extracted from a different software tool	(Number 5) And/ or data depend on country's monitoring data	All needed data are available

Scale/ Questions	**1**	**2**	**3**	**4**	**5**
7. Amount of time required/ consumed for entering data and setting up the tool for a case (including time required for additional software tool)	1-4 hours	4-7 hours	1 day[13]	2-3 days	>3 days

[13] Working day (8 hours).

Scale/ Questions	Absent 1	Poor 2	Moderate 3	Good 4	Excellent 5
8. Quality of support material and manual[14] provided	No support material or manual provided	"How does it work" Short description	"How does it work" Further description	In addition: "Software" or "Implementation steps"	In addition: Tool manual, Demo files
9. Level of step by step support provided by the software	No instructions provided	Only general instructions provided on the website	General instructions provided at the first step of the application	Instructions provided in every step	Detailed instructions and information provided in every step
10. Intuitiveness[15] of the graphical user interface (GUI)					
11. Ease of computation/ simulation (bugs, crashes, speed of simulation, etc.)	Occurrence of "Application error"	Occurrence of bug(s) and/ or crush(es)	Occurrence of a crush (isolated incident)	Low simulation speed	None of the previous mentioned

Scale/ Questions	1	2	3	4	5
12. Visualization/ representation of the results (narrative, logical, numerical, graphical)	Narrative representatio n	Logical representatio n	Numerical representatio n	Graphical representatio n	Combination of two or more types of representatio n

[14] Subsections of the Manual Category (Watershare website): "How does it work?", "Software", "Implementation Steps", Tool manual (when needed), Demo files (when needed).

[15] A User Interface (UI) is intuitive when users understand its behaviour and effect without use of reason, experimentation, assistance, or special training.
Alternatively, A UI is intuitive when it has an appropriate combination of: Affordance, expectation, efficiency, responsiveness, forgiveness, explorability, no frustration.

Question	
13. Level of required support[16] (by the tool experts)	Amount of times:

Following a problem-based approach the tools currently included in the Watershare Suite will be allocated under five different Communities of Practice (CoP).

2. Please indicate in which of the following CoP the tool you have developed can be categorised:

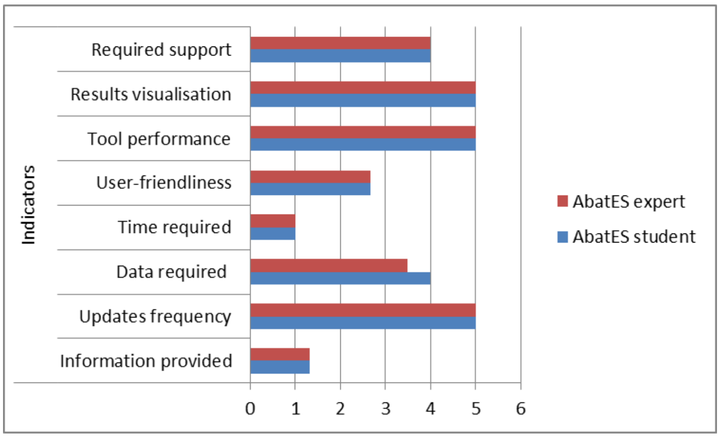
Scale/ Communities of Practice	*Strongly disagree*	*Disagree*	*Not applicable*	*Agree*	*Strongly agree*
1. Subsurface Water Solutions					
2. Future-proof Water Infrastructures					
3. Resource Recovery and Upcycling					
4. Emerging Substances					
5. Resilient Urban Water Management					

[16] Support by the Tool Experts, in the form of introductory/ more elaborate courses, training programmes, webinars, etc.

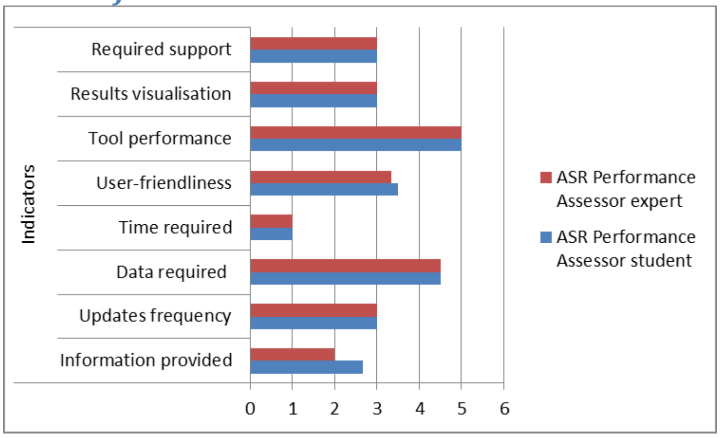
Appendix C

Overall performance of 15 Watershare tools

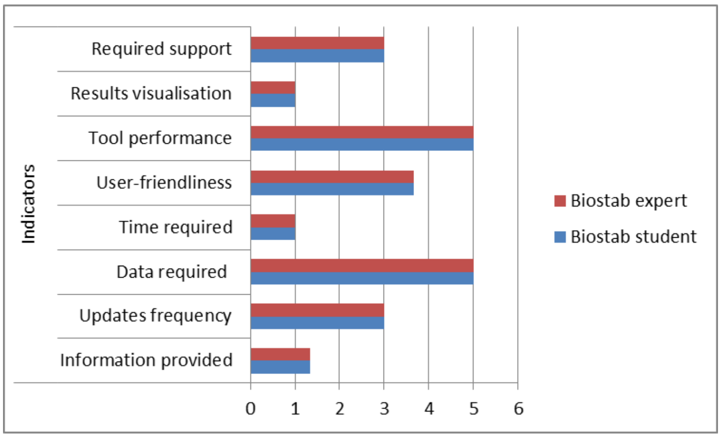
Abates Tool



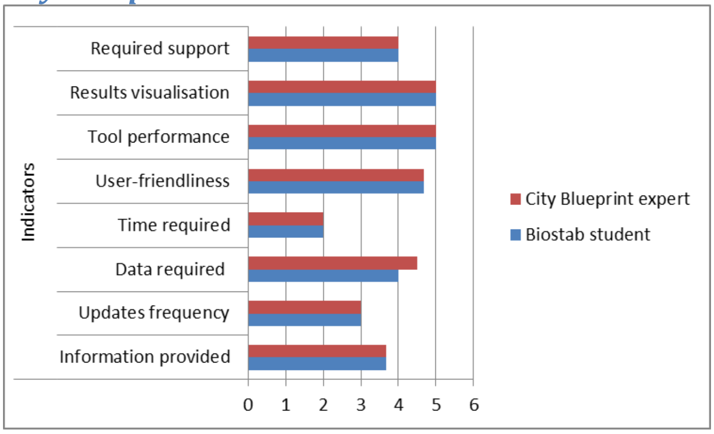
ASR Performance Assessor Tool



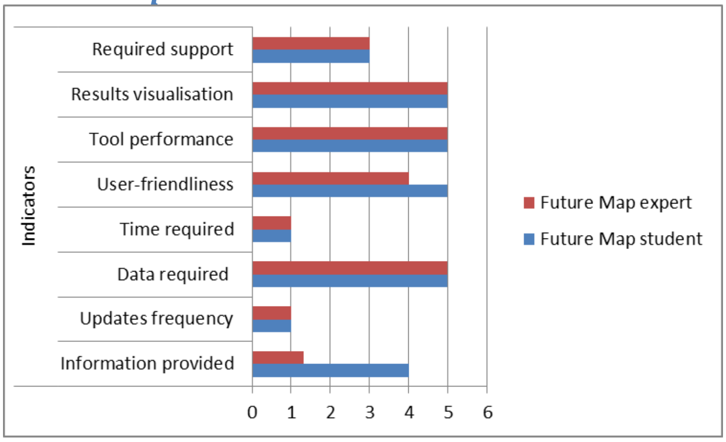
Biostab Tool



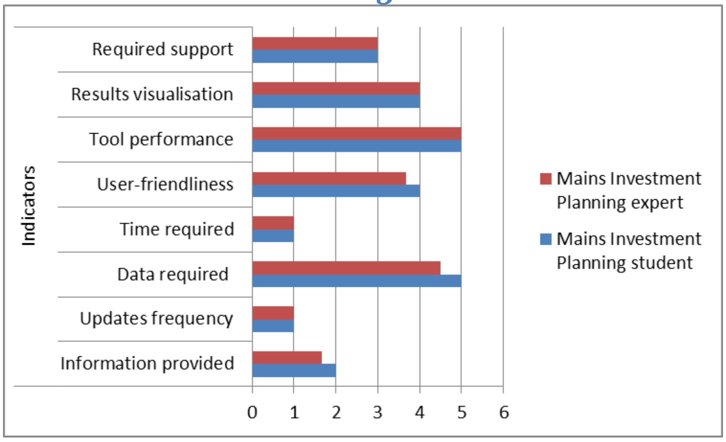
City Blueprint Tool



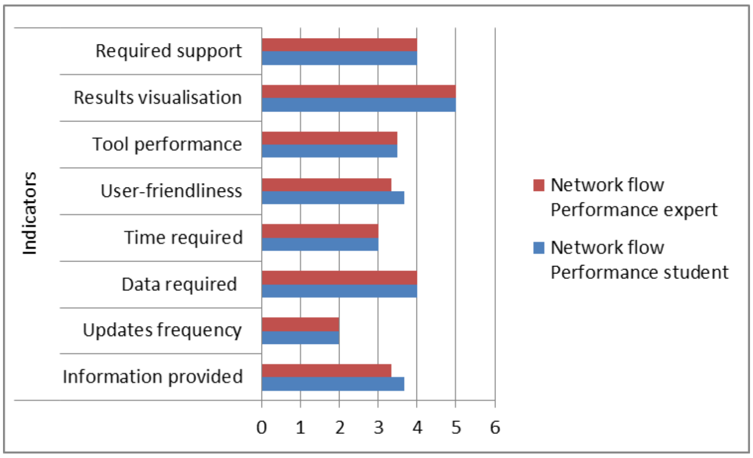
Future Map Tool



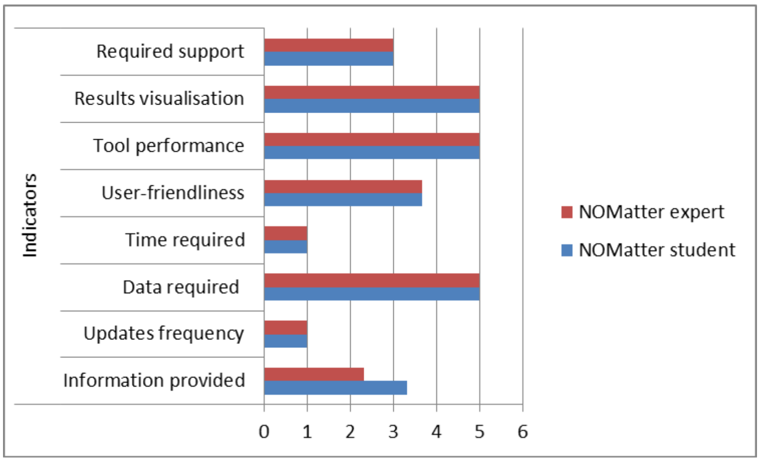
Mains Investment Planning Tool



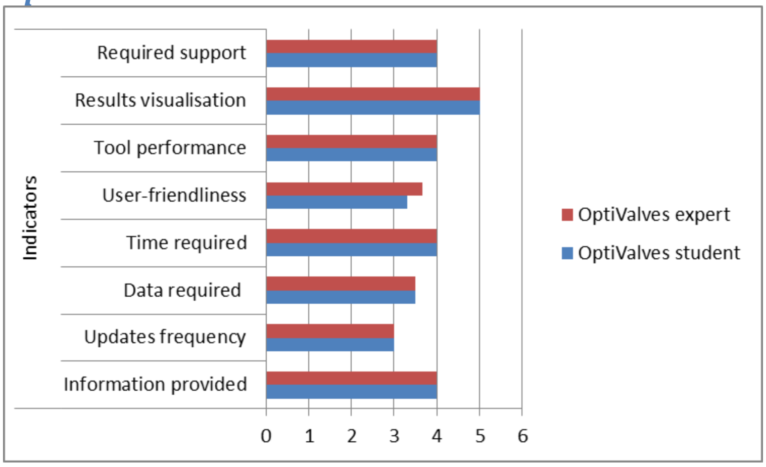
Network Flow Performance Tool



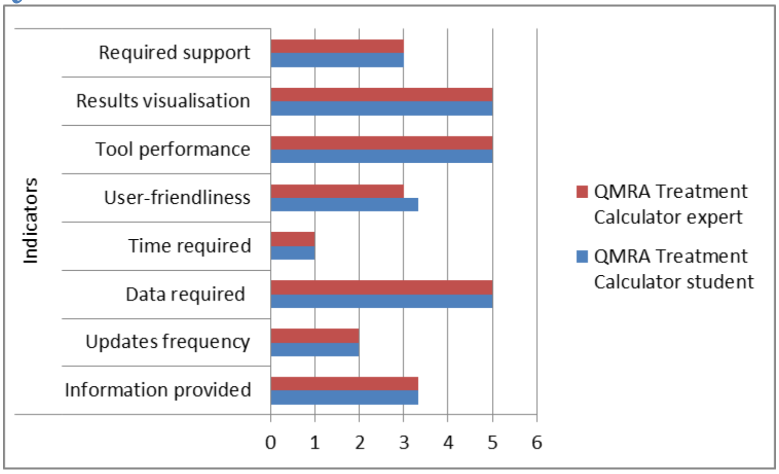
NOMatter Tool



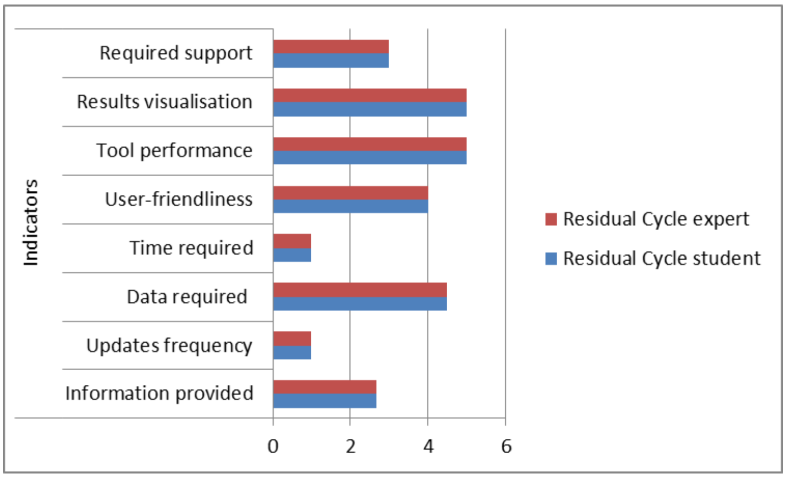
OptiValves Tool



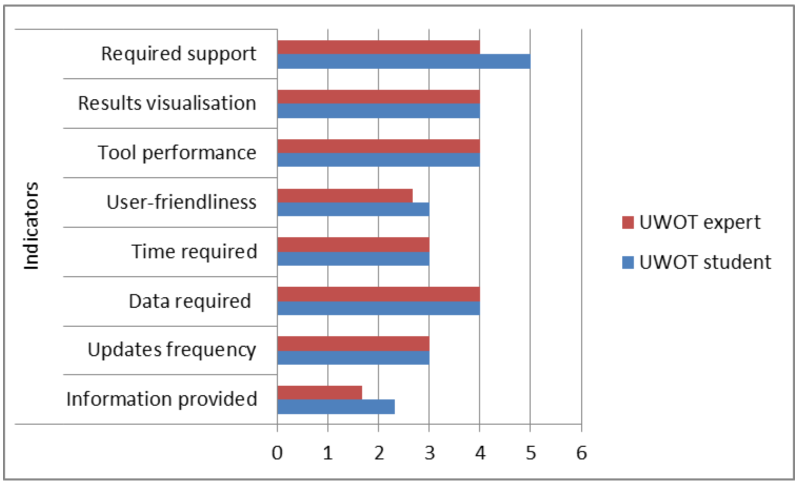
QMRA Treatment Calculator Tool



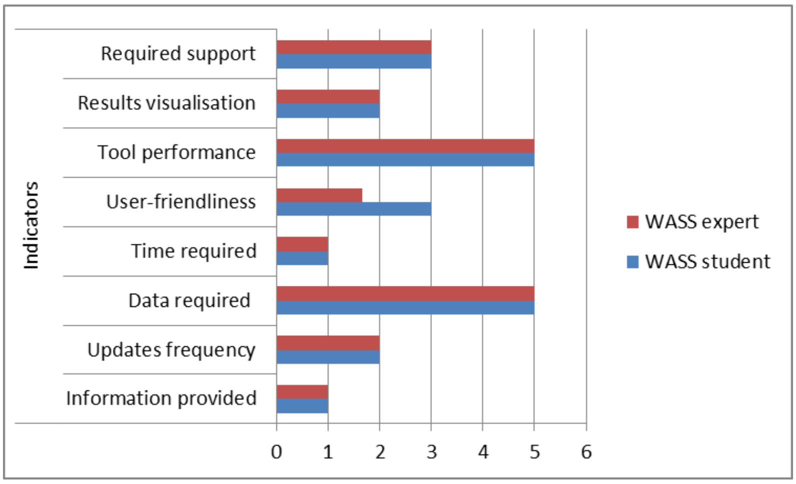
Residual Cycle Tool



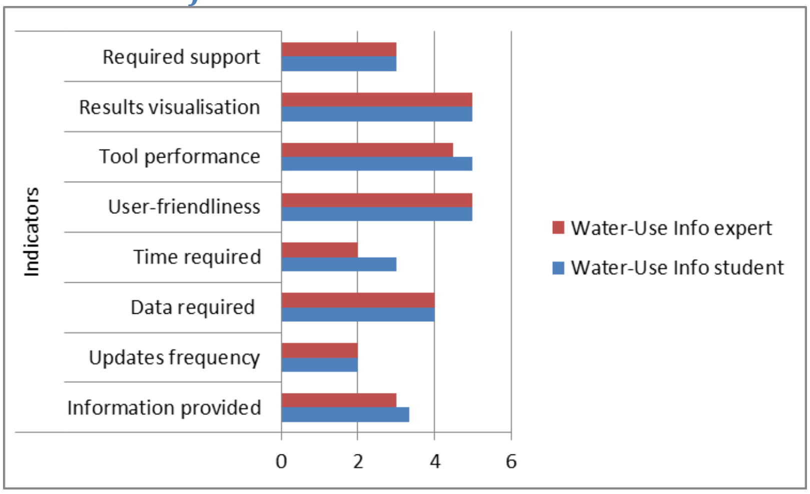
UWOT Tool



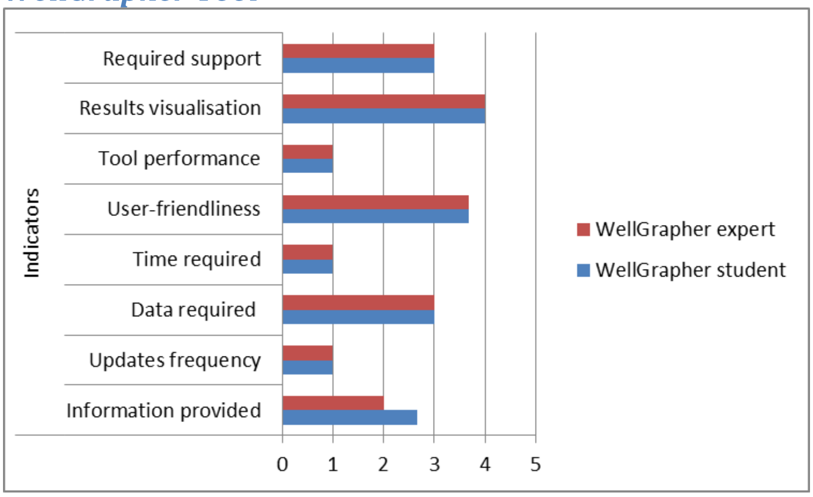
WASS Tool



Water-Use Info Tool



WellGrapher Tool



Appendix D

Part 2 - CB Sub-indicators detailed table (including definition, measurement units, way of calculation and type of connection with UWOT for each sub-indicator)

CB Category	CB Indicator	Sub-indicator	Definition sub-indicator	Units	Calculation	UWOT connection
I. Water quality	**1. Secondary WWT (Waste Water Treatment)** **2. Tertiary WWT**	A. Nitrogen presence/ concentration	Measure of the concentration of nitrogen in the water	- Concentration - (0 to 10 points score)	(To be added)	Objectives: Water quality, Environment
		B. BOD level/ presence (Biochemical Oxygen Demand)	Measure of the BOD value in the water	- Concentration - (0 to 10 points score)	(To be added)	Objectives: Water quality, Environment
		C. WWT performance	Measure of the % of performance failure of the WWT	- % failure - (Reliability in 0 to 10 point score)	[1-(∑volume untreated/∑total volume)]*10	Objectives: Water quality, Environment
		D. CSO Volume (Combined Sewer Overflow)	Measure of the volume of water spilled per year, over the volume delivered safely to the WWTP	- m^3 / year - (0 to 10 points score) * Total volume of water during CSO	Linear interpolation of scores where 0 is given to the highest CSO yearly volume configured and 10 to the lowest CSO yearly volume configured	Objective: Water quality
	3. Groundwater quality	A. Chloride concentration	Measure of the concentration of chloride in the water	- Concentration - (0 to 10 points score)	1- (∑volume insufficient quality/ ∑demand)	Objective: Water quality
II. Solid waste treatment	**4. Solid waste collected** **5. Solid waste recycled** **6. Solid waste energy recovered**	A. Plastic particles	Measure of the concentration of plastic particles in the water	- Concentration - (0 to 10 points score)	(To be added)	Objective: Environment
III. Basic water services	**7. Access to drinking water**	A. Water disruption/ interruption	Measure of the volume of water/ min failed to be delivered	- m^3/ min - (0 to 10 points score)	[1- (∑volume undelivered/ ∑demand)]*10	Objective: Water quantity
		B. Water supply endpoint	Measure of the volume of water ends up to households,	- % of water ends up to household connection instead of public	[m^3 to household connection / m^3 total supply]*100	Objective: Water quality

			over the total volume of supplied water	standpipes		
	8. Access to sanitation	A. Untreated wastewater	Measure of the volume of wastewater/ min failed to be collected	- m3/ min -(0 to 10 points score)	[1- (∑volume uncollected/ ∑demand)]*10	Objective: Customers
	9. Drinking water quality	A. Water hardness	Measure of the water hardness value in the water	- Concentration - (0 to 10 points score)	1- (∑volume insufficient quality/ ∑demand)	Objective: Water quality
		B. Pharmaceutical residues	Measure of the concentration of pharmaceutical residues in the water	- Concentration - (0 to 10 points score)	1- (∑volume insufficient quality/ ∑demand)	Objective: Water quality
		C. Pesticide residues	Measure of the concentration of pesticide residues in the water	- Concentration - (0 to 10 points score)	1- (∑volume insufficient quality/ ∑demand)	Objective: Water quality
		D. Heavy metals occurrence	Measure of the concentration of heavy metals in the water	- Concentration - (0 to 10 points score)	1- (∑volume insufficient quality/ ∑demand)	Objective: Water quality
		E. Overall quality failure	Measure of the volume of water with insufficient quality/ min delivered	- min or m^3/ day or year - (0 to 10 points score) * This could be the aggregate of all water quality indicators previously proposed	[1- (∑volume insufficient quality/ ∑demand)]*10	Objective: Water quality
IV. Wastewater treatment	**10. Nutrient recovery** **11. Energy recovery** **12. Sewage sludge recycling** **13. WWT energy efficiency**	A. WWT energy consumption	Measure of the annual energy consumption of the WWT	- kWh/ m^3 - (0 to 10 points score)	Linear interpolation of scores where 0 is given to the highest energy consumption configured and 10 to the lowest energy consumption configured	Objective: Environment
V. Infrastructure	**14. Stormwater separation**	A. CSO (Combined Sewer Overflow) Frequency	Measure of the amount of CSO events annually	- CSO events / year -(0 to 10 points score)	Linear interpolation of scores where 0 is given to the highest CSO frequency	Objective: Customers

				configured and 10 to the lowest CSO frequency configured	
	B. Wastewater transport	Measure of the total km of wastewater transport per capita	- Km of WWT transport / capita * Reduction due to decentralised WWT plants or ramified infrastructure	Linear interpolation of scores where 0 is given to the max number of km WWT/ capita configured and 10 to the min number of km WWT/ capita configured	Objective: Environment
15. Average age sewer	-	-	-	-	-
16. Water system leakages	A. Drinking water leakages	Measure of the volume of drinking water losses/ year due to system leakages	- % of drinking water volume lost - (0 to 10 point score) - Leakage rates of 50% or more are taken as maximum value and thus scored zero	X= drinking water system leakages (%) $\frac{50-X}{50-0}*10$	Objective: Customers
	B. Wastewater leakages	Measure of the volume of wastewater losses/ year due to system leakages	- % of wastewater volume lost - (0 to 10 point score) - Leakage rates of 50% or more are taken as maximum value and thus scored zero	X = wastewater system leakages (%) $\frac{50-X}{50-0}*10$	Objective: Customers
	C. Drinking water transport	Measure of the total km of drinking water transport per capita	- Km of drinking water transport / capita * Reduction due to ramified infrastructure	Linear interpolation of scores where 0 is given to the max number of km drinking water pipes/ capita configured and 10 to the min number of km drinking water pipes/ capita configured	Objective: Environment
17. Operation cost recovery	A. Annual maintenance cost	Measure of the balance between annual maintenance cost and total	- %, ratio or € - (0 to 10 point score)	[1- (annual maintenance cost/ total annual infrastructure cost)]*10	Objective: Customers

			annual infrastructure cost			
		B. Annual replacement cost	Measure of the balance between annual replacement cost and total annual infrastructure cost	- %, ratio or € - (0 to 10 point score)	[1- (annual replacement cost/ total annual infrastructure cost)]*10	Objective: Customers
VI. Climate robustness	**18. Green space**	A. Urban temperature alteration/ variation (UHI)	Measure of the relation between the temperatures of Urban Heat Island (UHI) and urban surrounding	- Δ temperature - (0 to 10 point score) * Temperature difference between 10% of surface area with highest temperature and urban surrounding	[Temperature heat islands (areas with 10% highest temperature) / temperature urban surrounding] * 10	Objective: Environment
	19. Climate adaptation	A. Urban drainage flooding	Measure of the frequency of urban drainage flooding due to rainfall	- Flood frequency / year	[Floods / year] *100	Objective: Customers
		B. Green roofs cover	Measure of the number of buildings with green roofs, over the total number of buildings	- % of buildings with green roofs	[Number of green roof-buildings / total number of buildings] *10	
		C. Use of rainwater	Measure of the number of buildings applying rainwater harvesting, over the total number of buildings	- % of buildings applying rainwater harvesting	[Number of rainwater harvesting-buildings / total number of buildings] *10	
		D. Impermeable surface	Measure of the relation between impermeable and total urban surface	- % of impermeable surface - (0 to 10 point score)	[km^2 impermeable surface /km^2 total surface]*10	Objective: Environment
	20. Drinking water consumption	A. Domestic water self-reliance	Measure of the amount of consumed water, originated from household sources: rainwater	- % water consumption from own sources - (0 to 10 point score)	[m^3 consumption of own source / m^3 total demand] * 10	Objective: Water quantity

			harvesting, grey water reuse			
	21. Climate robust buildings	A. Energy efficient buildings	Measure of the number of buildings implementing policies for energy efficiency	- % of buildings implementing policies for energy efficiency	[Number of energy efficient buildings / total number of buildings] *10	Objective: Environment
VII. Governance	**22. Management and action plans** **23. Public participation**	-	-	-	-	-
	24. Water efficiency measures	A. Water efficient buildings	Measure of the number of buildings implementing water saving measures and/ or water efficient design	- % of buildings implementing water saving measures	[Number of water saving- buildings / total number of buildings] *10	
		B. Industrial water self-reliance	Measure of the amount of consumed l water, originated from own, industrial sources: rainwater harvesting, grey water reuse, groundwater form own source	- % water consumption from own sources - (0 to 10 point score)	[m^3 industrial consumption of own source/ m^3 total demand] * 10	Objective: Water quantity
		C. Drinking water energy consumption	Measure of the annual energy consumption for drinking water production (and distribution?)	- kWh/ m^3 - (0 to 10 points score)	Linear interpolation of scores where 0 is given to the highest energy consumption configured and 10 to the lowest energy consumption configured	Objective: Environment
		D. Industrial water use	Measure of the annual volume of industrial water use	- m^3 water use - (0 to 10 point score)	Linear interpolation of scores where 0 is given to the highest industrial water	Objective: Water quantity

					consumption configured and 10 to the lowest industrial water consumption configured	
	25. Attractiveness	-	-	-	-	-