WatERP

Water Enhanced Resource Planning

“Where water supply meets demand”

GA number: 318603

WP 7 : Pilots

D 7.1.1 : "Holistic Auditing"

V1.0 2013-03-01

www.waterp-fp7.eu

Document Information

Project Number	318603	**Acronym**	WatERP
Full title	Water Enhanced Resource Planning "Where water supply meets demand"		
Project URL	**http://www.waterp-fp7.eu**		
Project officer	Stefanous Grouvras		

Deliverable	**Number**	7.1.1	**Title**	Holistic Auditing
Work Package	**Number**	7	**Title**	Pilots

Date of delivery	**Contractual**	5	**Actual**	5
Nature	Prototype ☐ Report ☑ Dissemination ☐ Other ☐			
Dissemination Level	Public ☑ Consortium ☐			

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Abstract (for dissemination)	Description of the defined methodology to validate the suitability of the data supplied by the pilot sites and also the methodology to evaluate and validate the designed ontology.
Key words	Methodology, data, pilots, evaluation, validation, ontology, knowledge base

Executive Summary

The objective of Work Package 7 (WP7) is to test and validate the feasibility of connecting various components and monitoring systems involved in water distribution networks and technologies within the unified WatERP Open Management Platform. WP7 plays an active role in the definition and development of the final platform since it checks that the previous Work Packages (WPs) fit the requirements for the real-time implementation of the platform over the pilot areas.

The specific objectives of this deliverable are, on the one hand, to ensure that information provided by the demonstration objects are adequate and aligned with the developments that will be done in the rest of the work packages. In this line, during this document we propose a methodology to be followed with the information to be collected in each pilot depending on the role they adopt within the WatERP project. On the other hand, it is essential that the knowledge base development is aligned with the user needs or requirements from the knowledge base within the project.

Thus, deliverable 7.1.1 consists in the report of the defined methodology to validate the suitability of the information provided by the pilots from the WPs' point of view (e.g. check that pilots have supplied the necessary information to fulfill the requirements) and the proposed methodology for the evaluation of the designed ontology, as well as the results of applying the validation procedures to the knowledge base.

As project situation is in an early stage of development, most of the Work Packages' outputs to be evaluated do not have the necessary maturity to start the validation stage. For this reason, validation over knowledge base cannot be performed until the next iteration of the taxonomy, ontology and functional model. Despite that, some documentation regarding the data supplied by the pilots has already been released and we did the most of that situation to do a preliminary validation of the pilots' data.

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1. Introduction

The objective of Work Package 7 (WP7) is to test and validate the feasibility of connecting various components and monitoring systems involved in water distribution networks and technologies within the unified WatERP Open Management Platform.

WP7 plays an active role in the definition and development of the final platform since it checks that the previous Work Packages (WPs) fit the requirements for the real-time implementation of the platform over the pilot areas.

Focusing in this deliverable, on the one hand, one specific objective is to ensure that information provided by the demonstration objects are adequate and aligned with the developments to be done in the rest work packages. In this line, during this document we propose a methodology to be followed with the information to be collected in each pilot depending it role in the WatERP project. The resultant methodology is a form (or checklist) that show which information is accomplished for the pilot and which information is needed to be collected.

On the other hand, as another specific objective is to ensure that knowledge base development is aligned with the user needs or requirements for the knowledge base inside the project. Furthermore, during knowledge base construction quality levels and aspects related with time response, size, granularity, etc; has been taken into account in order to represent as better as possible processes and information over the pilots. Knowledge base methodology validation methodology adopted is focused also in filling a form with the calculation of the selected metrics to describe knowledge base. As a result of this form we obtain a classification of the ontology based on metrics and then recommendations to further iteration over the ontology will be discovered.

Hence, this task will be done concurrently with the knowledge base development. Thus, this deliverable will become an iterative document that will gather up all the changes made and perform the (re) evaluation of the elements of the knowledge base.

As project situation is in early stage of development, most of the Work Packages to be validated do not have the needed maturity to start the validation stage. For this reason, validation over knowledge base cannot be performed until the next iteration of the taxonomy, ontology and functional model.

2. Pilots' data validation

In WatERP project, demonstration objects are needed to provide useful information to the rest of the Work Packages. Information provided by the two demonstration objects (Spanish and German pilots) must accomplish quality levels and similarity between both pilots in order to give support for the work packages that needs the information.

For this reason, during present section a methodology to validate the information required for the pilots is defined. The main aim to define a validation over the pilots is focused on maintaining necessary quality and detail level of information that will be used in the rest of work packages during the WatERP life cycle.

During the present section a brief description of the pilots also is done with the aim of understand two different situations that WatERP will solve. Introducing brief description of the pilots is necessary to understand the pilots' validation methodology and also to focalize and detail what information is needed for each pilot.

In the one hand, in the Spanish pilot optimize water resources management to avoid the problem of water scarcity of the region, is the main challenge. In this case, information about the upper part of the distribution chain is mainly demanded. Information about the actors involved the resources (natural and artificial), systems used to manage the water resources, etc; are necessary to enhance the description and definition of the rest of the work packages (e.g Knowledge Base, DSS, etc). In the other hand, in the German pilot the main challenge is focused on reducing energy-consumption incurred by the water utilities for operating their facilities. In this case, information related with distribution of water to the users is provided. In detail, in the German pilot the information is focused on providing detail information about water distribution systems, actors involved in the distribution, etc.

2.1 Spanish pilot (Ter-Llobregat)

The Spanish pilot case is focused on the Ter- LLobregat river system. This pilot is localized on the northeastern part of Spain, in Catalonia. The territory of Catalonia is subdivided into two hydrographic area: the internal basins which consist of the rivers that are fully contained within this region, and the interregional basins of the Ebro River which are only partially situated in Catalonia. The Ter-Llobregat river system is located within the internal basins, which represent 52% of the territory and 92% of the population.

The Ter-Llobregat system comprises the basis of several rivers such as Ter, Daró, Besòs, LLobregat and Foix. The total average of the mentioned rivers is 1,840 hm^3/year (period 1940-2008), of which 816 hm^3/year comes from the Ter and 676 hm^3/year from the Llobregat. Hence, Ter-LLobregat watersheds provide 81% total water resources of the pilot.

Natural resources (inflows) are regulated by reservoirs for the Ter and LLobregat River. In case of Ter river, the reservoirs are Sau (151 hm^3) and Susqueda (233 hm^3). In case of LLobregat river, the reservoirs that manages the water are Baells (109 hm^3), Santa Ponç (24 hm^3) and Llosa del Cavall (80 hm^3). Total reservoir storage capacity volume in the LLobregat represents 32% of the average annual inflows under normal conditions, while this percentage is 47% for the Ter. Taking into account the two river together, the ratio is 40%. As a result of this ratios showed, the Ter river is naturally more regular than the LLobregat. Consequently, the Ter provides 44% of the Ter-Llobregat system's natural water inflows under normal circumstances, and with greater regularity. For these reasons, the Ter river tends to be less affected by drought episodes than the Llobregat and is a key resource in the Ter-Llobregat water supply system. However, not all water demand is supplied by this rivers. In the Ter-Llobregat system also natural water is obtained from a desalination water process. Current desalination plants that are involved in ter-LLobregat system are located in Torderá and El Prat de LLobregat. The Tordera desalination plant has a capacity of 10 hm^3/year (currently being increased to 20 hm^3/year) and the plant in El Prat de Llobregat, 60 hm^3/year.

Water competent authority of the Ter-LLobregat River Basins is the Catalan Water Agency (ACA) that is an entity of the Government of Catalonia. The ACA is in charge of manages and supervise the resources that involve the mentioned basis. The responsibilities of the ACA are summarized on Table 1. The Ter-LLobregat system feeds water demand of metropolitan area of Barcelona (AMB) as a main concentration of people and economic activity. Furthermore, the system also supplies water to Girona and its surroundings, as well as the coastal area between the Gulf of Roses and the province of Tarragona.

Actor	Organization type and legal status	Responsibilities
ACA	Public administration	- Resource planning - Owner and manager of many reservoirs - Planning, construction, operation and monitoring of hydraulic works - Resource distribution supervision - Quality and environmental requirements supervision - Responsible for sanitation and upstream water supply outside municipalities - Management, collection, administration and distribution of the financial resources it receives

Table 1 "ACA responsibilities"

The Ter-LLobregat pilot case is focused on upper part of the water distribution chain whose main aim is to optimize water resources management to avoid the problem of water scarcity of the region.

2.2 German pilot (Karlsruhe)

The German pilot case is focused on the city of Karlsruhe. Karlsruhe is a city located in the south west of Germany and approximately has 300,000 inhabitants. In German pilot case, drinking water distribution involves the city of Karlsruhe and also surrounding areas.

The drinking water in the city of Karlsruhe is provided by four well fields or water works located around the city. The production of water comes from ground water of the aquifer nearest to the surface. The only treatment necessary to produce drinking water is focused on removing iron and manganese from subtracted water. The output of the 4 water works is in sum 23 to 24 Million m^3 of drinking water per year. The drinking water network has a length of about 900 kilometers. However, a small part of city of Karlsruhe receives drinking water from other sources (approximately 11,000 inhabitants).

In case of German pilot, the authority in charge of the distribution of drinking water throughout Karlsruhe city is Stadtwerke Karlsruhe GmbH (SWKA). This organization is focused on building and operating a ground water and pumping stations in order to distribute drinking water in a satisfactory manner (Table 2). Thanks to the huge amount of water available and high possibility to build and operate a ground water well in the Karlsruhe region, drinking water supplied by SWKA is not used for agriculture purpose. Furthermore, for matters in which water quality standards are not critical, it is much cheaper to build and operate a ground water well than buying the water from the drinking water supplier (agriculture, industrial processes, cooling, even a lot of private backyards have their own wells for irrigation).

Actor	Organization type and legal status	Responsibilities
Stadtwerke Karlsruhe GmbH (SWKA)	Privately organized, publicly owned	Well fields (waterworks), reservoirs and pumping stations of the distribution network

Table 2 “SWKA responsibilities”

Germany in general (with some exceptions) and also the German pilot has not to deal with water scarcity. Thus, this pilot case will focus on the distribution system, and particularly the operations management. Complementary to the water-saving goal that dominates in the more Southern European countries, the German pilot will put strong emphasis on the energy-consumption incurred by the water utilities for operating their facilities.

2.3 Pilots validation methodology

In the context of a project like WatERP, where the collaboration and interaction with the pilot sites is basic to succeed, it is essential to ensure that the data supplied by them is aligned with the needs of the WPs who, in turn, will satisfy the pilots' requirements.

Over the pilots described in the previous section, based on their objective inside WatERP project and also based on its management, a methodology has been developed. The resultant methodology to collect information from pilots has been done specifically and manually in the context of WatERP requirements and objectives.

Pilots validation methodology is focused on a checklist in which information is listed and categorized. Information needed and selected from demonstration objects has been done viewing pilots information, analyzing pilot's procedures and management activities (resource management and distribution management) and evaluating which information are needed to reach work packages objectives.

During project evolvement do not discard to add some more categories to the methodology in case that in the previous study from pilots some information was not taken into account.

The methodology goal is to check that both pilots supply the same kind and amount of information and with the same detail level. Furthermore, checking pilots' information in an objective manner also facilitates to ensure quality in the information collected.

The resultant pilot validation methodology is shown in Table 3. First results over information provided by the pilots will be presented in Section 4.1. The table must be filled using "Yes/YES" if information is collected with good level of detail and quality; "No/NO" if information collected is not provided and/or do not reach desirable levels of quality and detail; and "Not Applicable/NOT APPLICABLE" if the information is not applicable for the pilot.

Category	Item	Availability	
		ACA	SWKA
Geographical and demographic	Geographical situation and environment		
	Description of land use		
	Population coverage/people supplied		
	Water supply chain roles (e.g. bulk water supplier, water authority, etc.)		
	Institutional framework (which are the actors involved in which activity, property of each institution, etc)		
Institutional and financial framework	Actors involved in which activity		
	Organization type and legal status of each actor		
	Institutional hierarchy		
	Responsibilities matrix		

	Financial framework		
Water use	Water use sectors, uses and users.		
Infrastructure	Water supply system diagram		
	Water sources (including capacity, storage capacity and number of wells)		
	Treatment plants (including type of treatment)		
	Desalination plants (including capacity)		
	Reservoirs/tanks (including volume, area, hydroelectric turbine, etc.)		
	Pumping stations (including number and capacity)		
	Pipeline system		
Data collection	Information about ground water (including sensors/meters, units and frequency)		
	Information about regulated water (including sensors/meters, units and frequency)		
	Information about produced water (including sensors/meters, units and frequency)		
	Information about flows (including sensors/meters, units and frequency)		
	Information about water consumption (including sensors/meters, units and frequency)		
	Information about energy consumption (including sensors/meters, units and frequency)		
	Information about meteorology (including sensors/meters, units and frequency)		
Systems	Information about the information transmission to the systems		
	Hydraulic/hydrologic models		
	Data flow diagram		
	IT systems architecture and list of used software		
	Available interfaces to export/import data with specification of storage type (DB, file, etc.), format and access policy		
Historical data	Water flows (including frequency and availability)		
	Drinking water supply (including frequency and availability)		
	Output of water works (including frequency and availability)		
	Water consumption (including frequency and availability)		
	Population (including frequency and availability)		
	Population prediction (including frequency and availability)		
	Water consumption statistics/trends (including frequency and availability)		

Table 3 "Pilots' data validation checklist"

3. Knowledge base validation

As mentioned in the introduction chapter the knowledge base artifacts created within WatERP are expected to evolve during the project. Therefore, the validation methodology should be based in an objective model so that the evaluations done in the different iterations of this deliverable are comparable. This way we will ensure that the modifications made to the ontology do not decrease its quality nor introduce any kind of error or inconsistency.

In this chapter we will first explore the techniques and methodologies applied to ontology validation that are available in the literature in section 3.1. An overview of several papers regarding ontology construction, evaluation and validation will be given as well as a classification of such methods and its strengths and weaknesses. Once the state of the art is known we will propose our own ontology evaluation and validation methodology in section 3.2.

Our goal when designing the methodology is to define metrics in order to obtain objective values that, as a whole, define the goodness of the ontology. Those metrics will be put into groups -we call them "layers"- and each group will represent a perspective we want the ontology to be evaluated from. Once we obtain the result of each metric we can compute a score for each layer. Those values can be used to compare our ontology against other ones and will reflect its strengths (that is, the points that have reached the desired quality) and weaknesses (that is, the items that should be improved).

3.1 State of the art

Current ontology construction methodologies in the semantic field are focused on defining a process to easy construction of the ontologies since requirements definition to the validation. Most widely ontology construction methodologies are NeoN (Suárez de Figueroa Baonza, Gomez Perez, & Ferandez López, 2010), Methodology (Gomez-Perez, Fernandez-López, & Corcho, 2003), On-To-Knowledge (Staab, Schnurr, Studer, & Sure, 2001) and Diligent (Pinto, Tempich, & Staab, 2004). Most of these processes focus the ontology construction in obtain the needed requirements (interviews, competency questions, etc), external ontologies and data models inclusion (Standard taxonomies, tsaurus, ontologies) and methods to easy maintain the ontology once it has been constructed (focused on processes to easy apply new changes). As a weakness of studied methodologies is the non detailed definition of a validation model over the ontology life-cycle. The ontology construction models validate the ontology focusing on the accomplishment of the requirements. The accomplishment of the requirements is based on correct ontology answers to the competency questions or defined requirements.

Based on this weakness in the ontology construction methodologies, ontological validation methods have been widely defined. A preliminary classification of the methodologies can be found in the paper

Ontological Evaluation and Validation (Tartir, S., Arpinar, I.B., Sheth, P.) and in *Handbook on Ontologies* (Staab & Studer, Handbook on Ontologies, 2009). In both studies there is identified three types of approaches for the evaluation and validation of ontologies: evolution-based, logical (rule-based) and metric-based (feature-based).

3.1.1 Evolution-based

The main point of evolution-based approaches is to track the changes on the ontology over it life-cycle. The evolution-based approach has into account variables such as time, changes between different versions and also gets indicators about ontology quality. All with the aim of detect any invalid changes made to the ontology during it evolvement. Furthermore, this kind of approach can be subdivided based in the change scope in:

- **Changes in conceptualization**: Those can result from a changing view of the world and from a change in usage perspective.
- **Changes in the domain**: Those are the most common and are caused by change or addition of knowledge in the domains the ontology is modeling.
- **Changes in the explicit specification**: Those will occur when ontology is translated from one knowledge representation language to another. The languages differ in their syntax but also in their semantics and expressivity, so it is not easy to preserve the semantics during translation.

3.1.2 Logical (rule-based)

Logical and rule-based approaches to ontology validation and quality evaluation use rules which are built in the ontology languages and rules users provided to detect conflicts in ontologies.

As an example, if two objects in the ontology are said to be different from each other, the ontology cannot say that they are the same, or when two classes are said to be disjoint of each other the ontology cannot have statements that mention an instance as being member of both classes. Users can also identify properties that are considered in conflict in the domain (e.g. define that property “motherOf” conflicts with property “marriedTo”).

3.1.3 Metric-based (Feature-based)

Metric-based techniques to evaluate ontologies offer a quantitative perspective of ontology quality. These techniques scan through the ontology to gather different types of statistics about the knowledge presented in the ontology, or ask the user to input some information that is not included in the ontology itself.

There are several techniques that have adopted this approach. This techniques can be found in (Tartir, S., Arpinar, I.B., Sheth, P.) that provide an analysis over the different metric-based techniques enumerated:

- In (Supekar K., Patel C. and Lee Y., 2004) they propose a model for evaluating ontology schemas that contains two sets of features: quantifiable and non-quantifiable. This technique is based on crawling the web to search for ontologies and use the user information to return the most suitable one.
- OntoMetric (Lozano-Tello A. and Gomez-Perez A., 2004) is a hierarchical framework that consists of 160 characteristics spread in ontology, language, development methodology, building tools and usage cost dimensions.
- AKTiveRank(Alani H., Brewster C. and Shadbolt N., 2006): this technique finds a set of related ontologies to a set of terms entered by the user. It uses an aggregation of the values of class match, density, semantic similarity and betweenness to select the most suitable ontology.
- ODEval(Corcho O. et al., 2004): a tool that automatically detects possible syntactical problems in ontologies.
- In (Mostowfi F. and Fotouhi F., 2006) they define eight features to measure the quality of ontologies.
- oQual(Gangemi, A., Catenacci, C., Ciaramita, M., Lehmann, J., 2006): evaluation of ontologies on three dimensions: structural (32 features regarding syntax and formal semantics), functional (5 qualitative measures regarding the intended meaning of the ontology) and usability profiling (focused on the annotation context).
- OntoClean(Guarino, N. and Welty, C., 2004): a user of this technique would assign a set of 4 features (Rigidity, Identity, Unity and Dependence) to each class in the ontology and use them to identify problematic areas.
- OntoQA(Tartir, S., Arpinar, I.B., Moore, M. et al., 2005): framework that defines the quality of a populated ontology as a set of 5 schema quality features.

3.1.4 Summary

Based on the techniques mentioned in the previous section, several points of weakness has been found. Mainly, the issues found are related with the ontology construction phases and with the information given to the user (use of the ontology). Detailed issues found are:

- Require the user to provide the ontology: might be problematic for a novice end-user who is not aware of ontologies available for his domain.
- Working only with schemas: might miss problems and ignore knowledge available in the knowledge base of a populated ontology.

- Target developers (rather than end-users): it is important to provide end-users with tools they can use to select an error-free ontology that best fits their applications
- Are feature-based: possibly due to the fact that a combination of metrics can provide insights about an ontology from different perspectives leading to a better understanding of the nature of the ontology

Table 4 provides a summary of the techniques described above and compares them on whether they target developers on end-users, whether users have to provide information to the technique, and whether it targets the schema or both the schema and the knowledge base.

Technique	Appoach	Users		Automatic/ manual	Evaluation	
		Developers	End-users		Schema	Knowledge base
Plessers and De Troyer	Evolution	✓		Manual	✓	
Haase et al.	Evolution	✓		Manual	✓	
Arpinar et al.	Logical	✓		Manual	✓	✓
Swoop	Logical	✓		Automatic	✓	
OntoMetric	Metric	✓		Manual	✓	
Mostowfi and Fatouhi	Metric	✓		Automatic	✓	
oQual	Metric	✓	✓	Manual	✓	
OntoClean	Metric	✓		Manual	✓	
OntoQA	Metric	✓	✓	Automatic	✓	✓

Table 4 "Comparison of different ontology evaluation techniques (table 5.1 of (Tartir, S., Arpinar, I.B., Sheth, P.))"

Source: adaptation of table 5.1 of (Tartir, S., Arpinar, I.B., Sheth, P.) excluding techniques that crawl ontologies from the internet, as we will work on our own ontology rather than using an existing one.

3.2 Validation method

The validation method that will be used to evaluate the ontology created within WatERP is a metric-based method. A first classification of the areas to be evaluated has been done based on (Hehagias D.D., Papdimitriou, I., Hois, J. et al.)(Staab & Studer, Handbook on Ontologies, 2009). As a result we will consider the following areas (layers) which are detailed in the next sections: vocabulary layer, architecture layer, semantics layer, application layer and usability layer.

The general idea of the method is to obtain a score for the defined layers of the ontology that could be compared with other ontologies or future versions of the same ontology. Each layer contains specific items to be evaluated. Some of those items can be automatically evaluated (thus obtaining a completely objective measure) but some others will have to be empirically evaluated following a best practices guide (thus the result may be influenced by the evaluator's criteria).

There will be different evaluators depending on the nature of the item to be checked: Most of items will be checked by an ontology expert but there are some others that will be checked by a water domain or meteorology domain expert (e.g. governance category of the vocabulary layer). Other items are measured in time of ontology exploitation. Usually, ontology is used over an application or web platform using Protégé software only for ontology construction. Over ontology exploitation environment it is also interesting to validate usability metrics to measure and identify potential mistakes related to the visualization and information manipulation.

The output of the ontology evaluation will be a report containing the values of the metrics classified for each category and some graphs to facilitate the comparison against other ontologies or against other entities of the same level within the ontology. As an example, it could be useful to have a diagram of the scoring of the ontology in each layer:

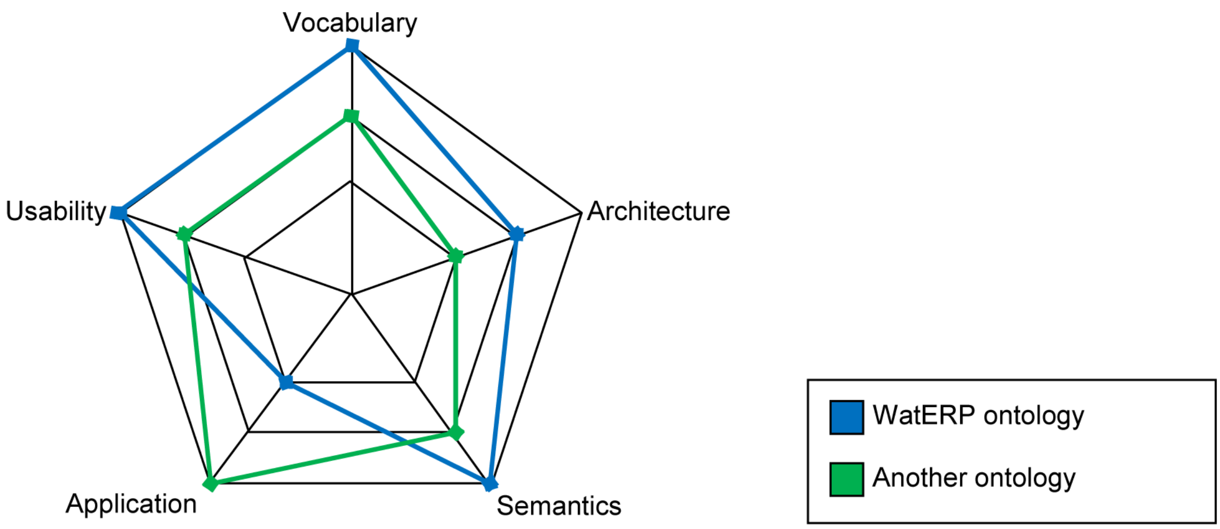

Figure 1 "Example evaluation diagram"

3.2.1 Vocabulary layer

The vocabulary layer includes criteria relevant to the syntactic elements of ontologies. The following items will be considered in this layer. Notice that those are good practices, therefore an empirical evaluation must be done.

Category	Item description	Metric
Naming criteria	All concepts are named as single nouns and use CamelCase notation (e.g. MyNewConcept)	Pass / Fail (if fail, point out which ones are incorrect)
	All properties are named as verb senses and use mixedCase notation (e.g. hasProperty)	
	Common and descriptive prefixes and suffixes are used for related properties or classes (when possible)	
	Inverse properties have been provided (when it makes sense). E.g. <Father> <hasChild> <Janie> would be expressed inversely as <Janie> <isChildOf> <Father>	
	All concepts and properties have a definition.	
Syntax	Words and definitions are clear (and use comments and annotations to clarify when needed)	
Governance	Terms used make sense and are correct in the specific knowledge domain (water management domain in the WatERP case)	

Table 5 "Vocabulary layer evaluation items"

3.2.1 Architecture layer

The architecture layer includes criteria that characterize the structural attributes of ontologies. The items considered in this layer are described in the following table. Those metrics will be obtained automatically.

Category	Item description	Metric
Structure	**Schema relationship richness**: The diversity of relations and placement of relations in the ontology. An ontology that contains many relations other than class-subclass relations is richer than a taxonomy with only class-subclass relationships.	Ratio of the number of relationships (P) defined in the schema, divided by the sum of the number of subclasses (SC) (which is the same as the number of inheritance relationships) plus the number of relationships. $RR = \frac{\lvert P \rvert}{\lvert SC \rvert + \lvert P \rvert}$
	Attribute Richness: The number of attributes (slots) that are defined for each class can indicate both the quality of ontology design and	Average number of attributes (slots) per class. It is computed as the number attributes for all classes (att) divided by the

	the amount of information pertaining to instance data. In general we assume that the more slots that are defined the more knowledge the ontology conveys.	number of classes(C). $$AR = \frac{\lvert att\rvert}{\lvert C\rvert}$$
	Class importance: the percentage of instances that belong to classes at the subtree rooted at the current class with respect to the total number of instances. Although this measure might not be exact, it can be used to give a clear idea on what parts of the ontology are considered focal and what parts are on the edges.	Number of instances that belong to the subtree rooted at Ci in the KB (Ci (I)) compared to the total number of instances in the KB (I). $$Imp = \frac{\lvert C_i(I)\rvert}{\lvert I\rvert}$$
	Class relationship richness: this is an important metric reflecting how much ofthe propertiesin each classin the schema is actually being used at the instances level. It is a good indication of the how well the extraction process performed in the utilization of information defined at the schema level	Number of relationships that are being used by instances Ii that belong to Ci (P(Ii,Ij)) compared to the number of relationships that are defined for Ci at the schema level (P(Ci,Cj)). $$RR_c = \frac{\lvert P(I_i, I_j), I_i \in C_i(I)\rvert}{\lvert P(C_i, C_j)}$$
	Readability: this metric indicates the existence of human readable descriptions in the ontology, such as comments, labels, or captions. This metric can be a good indication if the ontology is going to be queried and the results listed to users.	Sum of the number attributes that are comments and the number of attributes that are labels the class has. $$Rd = \lvert A, A = rdfs{:}comment\rvert + \lvert A, A = rdfs{:}label\rvert$$
Reasoning	Check ontology consistency using a reasoner (e.g. Pellet, HermiT, FacT++, RacerPro…)	Pass / Fail (will pass if reasoner does not throw any consistency error)

Table 6 "Architecture layer evaluation items"

The metrics defined for the items in the "Structure" category is a subset of the metrics defined in OntoQA ((q) method of section 3.1.3), whose complete catalogue can be found at (Tartir, S., Arpinar, I.B., Moore, M. et al., 2005).

The decision of using OntoQA instead of another method is based on the following criteria:

- Works on populated ontologies. Thus, it uses knowledge represented in the instances to gain a better measure of the quality of the ontology.

- It uses simpler techniques compared to other tools, so it does not require a lot of training as user involvement is minimal.
- The metrics describe quantitatively certain aspects of the ontology rather than giving only a qualitative (e.g. good/bad) output.
- We have the values of the metrics already calculated for some other ontologies (Tartir, S., Arpinar, I.B., Sheth, P.) so we can compare them against the results of the same metrics on our ontology.

3.2.1 Semantics layer

The semantics layer includes criteria relevant to the semantic elements of ontologies. These concern those attributes whose goal ir to conceptually describe the structural elements defined within each ontology. The following items will be considered in this layer. Notice that those are good practices, therefore an empirical evaluation must be done.

Category	Item description	Metric
Consistency	Check that there are no formal contradictions in axioms definition. In this part, axioms are checked semantically and must follow expert knowledge about the field. Avoidance of semantically axioms inconsistencies assure quality in the ontology.	Pass / Fail
Expressiveness	Check that ontology language and structure used is coherent and kept along iterations	Pass / Fail
Granularity	Check that the granularity level used in the ontology is reasonable. Above all it shall be checked that the elements have not reached the instance level (e.g. "magnesium" should not appear. That hierarchy should stop at "chemical element" level).	Pass / Fail
Comprehensiveness	Check that the extent of the target domain is covered. This will be achieved by establishing a relation between the identified elements in the pilots and the elements of the ontology.	Pass / Fail (will pass if all elements could be related)

Table 7 "Semantics layer evaluation items"

3.2.1 Application layer

The application layer refers to the applicability of the ontology in a given application domain. The following items will be considered in this layer. Notice that those are good practices, therefore an empirical evaluation must be done.

Category	**Item description**	**Metric**
Ontology querying	Ontology querying is performed using SPARQL language (it can be used in OWL and RDF ontologies). This metric is focused on evaluate the competency question that are more related with a querying over the information instantiated in the ontology. Information retrieved from the querying should be clear, according with result expected and also must follow a coherent response time (close related with ontology size and depth).	Pass / Fail
Competency questions	One of the ways to determine the scope of the ontology is to sketch a list of questions that a knowledge base based on the ontology should be able to answer, competency questions. A list of competency questions for each pilot case will be prepared in the scope of WP1 (e.g. What is the current state of reserves? How much water needs to be released from the reservoirs? And from which ones?) with the expected answers. In this step, the competency questions to be validated are related to those that are necessary to generate A-Box (specific ontology scenario including instances) in order to obtain extra knowledge or recommendations based on the constructed scenario.	Pass / Fail (fails if the answer was not the expected one, in such case the question will be pointed out)

Table 8 "Application layer evaluation items"

3.2.1 Usability layer

The usability layer defines those quality measurements that are required in order to ensure that the resulted ontologies satisfy a set of usability standards. The following items will be considered in this layer. In the "metric" column, "Impact" stands for the impact of the error found, "Frequency" stands for the level of frequency between "LOW", "MEDIUM" and "HIGH", and "Persistency" should be answered with "Yes"/"No".

Category	**Item description**	**Metric**
Visibility and system state	This item is focused on the visibility of the ontology towards user (in an application or web page, etc). This metric tries to evaluate user interaction with the ontology. Aspects like response time, informational feedback and	Impact Frequency

	visualization elements should be evaluated.	Persistency
Standards	All elements of the ontology follows the standards and main conventions defined. Also results and presentation information must follow these considerations.	Impact Frequency Persistency
Errors	The ontology and the application that exploits the ontology must avoid the error appearing.	Impact Frequency Persistency
Error Recovery	In case of appear some errors during the ontology exploitation. The errors must be showed with a clear language, and understandable.	Impact Frequency Persistency
Responsiveness	The system must be response in an appropriate time (for the querying and for the knowledge inference)	Impact Frequency Persistency
Feedback	Feedback to the user must be appropriate. The user should be informed about actions and interpretations during ontology exploitation.	Impact Frequency Persistency

Table 9 "Usability layer evaluation items"

4. Results

This chapter shows the results of applying the evaluation and validation processes to the knowledge base. Methodologies exposed in chapters 2 and 3 will be used to test that on the one hand the data supplied by the pilot sites' stakeholders is suitable for the WPs needs and on the other that the elements of the knowledge base designed within the WatERP project is aligned with the user's needs or requirements.

Although the Work Package 1 main outputs are not mature enough to start the holistic validation stage, some documentation regarding the data supplied by the pilots has already been released and we will take advantage of that situation to do a preliminary validation. Unfortunately, the situation for the taxonomy and the ontology is not the same, thus we will not be able to do any validation at this time.

It is important to remark that the validation procedure will be performed in every iteration of the ontology construction and it will be documented in further iterations of this deliverable document to consolidate the progress of WP1.

4.1 Pilots' data validation results

Pilots' data has been evaluated based on information found on documents (INCLAM, 2013), (ACA, 2013) and (SWKA, 2013) and other documents and presentations available in the WatERP project repository with the following result:

Category	Item	Availability	
		ACA	SWKA
Geographical and demographic	Geographical situation and environment	Yes	Yes
	Description of land use	Yes	Yes
	Population coverage/people supplied	Yes	Yes
	Water supply chain roles (e.g. bulk water supplier, water authority, etc.)	Yes	Yes
	Institutional framework (which are the actors involved in which activity, property of each institution, etc)	Yes	Yes
Institutional and financial framework	Actors involved in which activity	Yes	Yes
	Organization type and legal status of each actor	Yes	Yes
	Institutional hierarchy	Yes	Yes
	Responsibilities matrix	Yes	Yes
	Financial framework	Yes	Yes
Water use	Water use sectors, uses and users.	Yes	Yes
Infrastructure	Water supply system diagram	Yes	Yes
	Water sources (including capacity, storage capacity and number of	Yes	Yes

	wells)		
	Treatment plants (including type of treatment)	**Yes**	**Yes**
	Desalination plants (including capacity)	**Yes**	**Not app**
	Reservoirs/tanks (including volume, area, hydroelectric turbine, etc.)	**Yes**	**Yes**
	Pumping stations (including number and capacity)	**Not app**	**Yes**
	Pipeline system	**Not app**	**Yes**
Data collection	Information about ground water (including sensors/meters, units and frequency)	**Yes**	**Yes**
	Information about regulated water (including sensors/meters, units and frequency)	**Yes**	**Yes**
	Information about produced water (including sensors/meters, units and frequency)	**Yes**	**Yes**
	Information about flows (including sensors/meters, units and frequency)	**Yes**	**Yes**
	Information about water consumption (including sensors/meters, units and frequency)	**Yes**	**Yes**
	Information about energy consumption (including sensors/meters, units and frequency)	**No**	**Yes**
	Information about meteorology (including sensors/meters, units and frequency)	**Yes**	**No**
Systems	Information about the information transmission to the systems	**Yes**	**Yes**
	Hydraulic/hydrologic models	**Yes**	**Yes**
	Data flow diagram	**Yes**	**Yes**
	IT systems architecture and list of used software	**Yes**	**Yes**
	Available interfaces to export/import data with specification of storage type (DB, file, etc.), format and access policy	**Yes**	**Yes**
Historical data	Water flows (including frequency and availability)	**Yes**	**Yes**
	Drinking water supply (including frequency and availability)	**Not app**	**Yes**
	Output of water works (including frequency and availability)	**Yes**	**Yes**
	Water consumption (including frequency and availability)	**Yes**	**Yes**
	Population (including frequency and availability)	**Yes**	**Yes**
	Population prediction (including frequency and availability)	**Yes**	**Yes**
	Water consumption statistics/trends (including frequency and availability)	**Yes**	**Yes**

Table 10 "Result of the preliminary evaluation of pilots' data"

As a conclusion, the following data has been identified to be missing and it will be needed to interview the implied stakeholders to complete the knowledge base:

- ACA should provide information about the energy consumption, including sensors/meters, units and frequency.
- SWKA should provide information about the meteorological data they use or receive, including sensors/meters, units and frequency.

4.2 Knowledge base validation results

A result over the ontology is not considered at this stage because of early stages of the WatERP project. First version of the taxonomy and functional model exists. In case of the taxonomy, it has been based on the main information collected from demonstration objects and also is an enhancement of CUASHI ontology defined for the water field including also links with SWEET ontology and Semantic Sensor Network ontologies (developed by W3C) similarities. Furthermore, the first version of the taxonomy is aligned with the functional models and current standards schemas such as WaterML.

Regarding functional models a first version has been developed taking also into account decision processes or behavioral processes inferred from pilots. These behavioral models based on the pilots are under revision and also have been taken into account in the taxonomy generation.

As a conclusion of the status of the knowledge base that includes taxonomy, functional models and ontology, we have decided to wait to obtain a more stable version of each of these elements before starting the validation. In the next iteration of the knowledge base more relevant results over knowledge base validation will be presented.

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