Requirement Analyses of Data Management and Data Model

Deliverable 1.3.1 – SMART MOVE

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Management of Highly Variable Water Resources in semi-arid Regions - Israel (ISR), Jordanien (JOR), Palästinensische Gebiete (PSE); Teilprojekt 5: Geodateninfrastruktur zum nachhaltigen Datenmanagement

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Table of Contents

List of Acronyms 4
Abbildungsverzeichnis .... **Fehler! Textmarke nicht definiert.**
Tabellenverzeichnis .... **Fehler! Textmarke nicht definiert.**

0 Disclaimer 7

1 Preface 7

1.1 Introduction 9

1.1.1 Background 9
1.1.2 Work Packages 9
1.1.3 Objectives 10

2 DAISY – Assessment of the Data Management in the previous SMART project phases 11

2.1 Objectives and Activities 11
2.2 Results 11

2.2.1 DAISY architecture and roadmap 11
2.2.2 Available Data 12

2.2.2.1 Alphanumerical Data 12
2.2.2.2 Geodata 13

2.2.3 DAISY database structure 15
2.2.4 DAISY Interfaces 15

2.3 Conclusions 15

3 Data Management Requirements 16

3.1 Workshops 16

3.1.1 Timetable Workshops 16
3.1.2 Data Management Use Cases 16
3.1.3 Workshop Conclusions 18

3.2 IWRM Information System 18

3.2.1 Introduction 18
3.2.2 Data Model 18
3.2.3 Implementation of the WEAP Model 20
3.2.4 Conclusions 20

3.3 Spring Early Warning System 22

3.3.1 Introduction 22
3.3.2 Input data 22
3.3.3 System Structure 23
3.3.4 Web Interface 26
3.3.5 Conclusions 26

4 Implementation 27

5 Summary and Conclusions..........28

6 References 30

List of Acronyms

ATB	ATB Umwelttechnologien GmbH
BAUER	BAUER Umwelt GmbH
BDZ	Bildungs- und Demonstrationszentrum für dezentrale Abwasserbehandlung e.V.
BMBF	Bundesministerium für Bildung und Forschung
DAISY	Data and Information System
DWWT	Decentralized wastewater management
EC	electric conductivity
EWS	Early Warning System
GU	Georg-August Universität Göttingen, Geowissenschaftliches Zentrum, Abteilung Angewandte Geologie
ISO	International Organization for Standardization
iWaGSS	innovative Water Governance System
IWRM	Integrated Water Resources Management
KIT-HYD	Karlsruher Institut für Technologie, Institut für angewandte Geowissenschaften, Abteilung Hydrologie
MOVE	Management Of Highly Variable Water Resources
MWI	Ministry of Water and Irrigation, Jordan
OGC	Open Geospatial Consortium
PESSL	PESSL Instruments
PIA	PIA – Prüf- und Entwicklungsinstitut für Abwassertechnik e.V.
SALAM	project on regional water resource management
SEBA	SEBA Hydrometrie
SMART	Sustainable Management of available water resources with innovative technologies
TERENO-MED	Terrestrial Environmental Observations in the Mediterranean
UFZ	Umweltforschungszentrum
WAJ	Water Authority Jordan
WEAP	Water Evaluation And Planning System

List of Figures

Figure 1: Project structure SMART-Move. 9
Figure 2: Data and Information Management System 12
Figure 3: Alphanumerical Data-Interface of Daisy 13
Figure 4: Web-GIS-Interface of DAISY 14
Figure 5: Distribution of bacterial infection curve. 17
Figure 6: The Original WEAP model displays manifold connections within water supply chain. 19
Figure 7: Hydrological parameters as possible key indicators towards bacterial infestation. 22
Figure 8: Schematic Structure of the Early Warning System. 23
Figure 9: Web Interface of the early warning system. 26

List of Tables

Tab. 0: Planned and conducted activities and results in Workpackage 1.3: Data Management………..7
Tab. 1: Timetable of Workshops held within SMART-Move. 16
Tab. 2: Warning levels and actions triggered in consequence. 24

0 Disclaimer

This report represents the project deliverable **D1.3.1** of the SMART-Move Project and should be understood in the context of the full activity of the Workpackage **1.3: Data Management.**

Since the relevant scope, and thus the necessary tasks, changed in parts during the project phase the following table gives an overview of the activities and results this Workpackage:

Tab. 0: Planned and conducted activities and results in Workpackage 1.3: Data Management.

Activity	Planned	Conducted	Results
1.3.1	Requirement Analyses of Data Management and Data Model	Requirement Analyses of Data Management, Integration of Data	D1.3.1: **This report:** Requirement Analyses of Data Management, Integration of Data
1.3.2	Design and implementation of Data Import Interface for large data sets and telemetric sensors of climate and water quality stations	Design and development of ETL-processes to retrieve and load telemetric Sensor data of SEBA and PESSL Stations into a centralized Data Repository. Design and implementation of business logic of the Spring water early warning system	D1.3.2: **Report:** Early Warning System Concept and Technical Description **Software:** EWS-Prototype with focus on backend functionality (ETL and Database)
1.3.3	Design and Realization of an online dataportal and geodata warehouse for measurement data search and export (WEAP). Documentation.	Realization of an online portal with integration of data layers from previous projects. Full realization of Production-Ready EWS with Technical adaption iterations during 1-year testing phase of the EWS at Wadi Shueib springs.	D1.3.3: **Software:** Full realization of Production-Ready EWS Online information portal for project partners.
1.3.4	Capacity Development for transboundary Data Management in the region; Documentation; Training Material;	Adaption of the EWS for Cluster West springs (Auja) Official Inauguration of EWS in Wadi Shueib Jordan EWS Technical Training Workshop with Employees of the WAJ in Jordan	D1.3.4: **Report:** Early Warning System Installation Guide

1 Preface

The central goal of the research and implementation project SMART-MOVE was to integrate innovative technologies and management instruments into the practice of water management cooperation partners from Israel, Palestine and Jordan. In this context, the robustness of the water resource systems against the high variability of the local hydrological system is of special importance.

This document describes the input and contribution of Disy Informationssysteme GmbH within the SMART-Move project. The primary goal of Disy was the development of applicable concepts and modules for a sustainable use of project data beyond the project itself. Herein, the focus was set on prototyping a database-sensor-interface and the application of functionalities for sustainable data usage scenarios.

The input of Disy is directly linked to the input of SEBA who provide a technical connection of modern, cost-effective and low-maintenance sensor technology for continuous in-situ measurements. The remote transfer of data to a back-end database offers the opportunity to have an up-to-date and high-quality data basis for decisions at any time.

Since any data management application should be foremost driven by user requirements, in order to facilitate the practical implementation, it is necessary to assess the shortcomings of current systems. This includes the analysis of the current status of the former SMART data management concerning data availability, location and form as well as the user-driven definition of requirements, business processes and infrastructures of future data management scenarios. Based on the findings of this assessment, the functional and non-functional specification of the SMART-Data Management Model will be generally defined to specify the solution blocks to be implemented (input, output, functions and interfaces).

In the implementation, the focus was then set to the selection of practice-relevant components, technical usability and serviceability within the local water supply infrastructure. Already present systems of the project partners were used to avoid the construction of new standalone software solutions.

With regard to efficiency gains in the long term, the technical possibility to connect with different partner networks is of special importance. Nevertheless, data sovereignty needs to remain with data owners. This aspect is of special concern in the pilot region. Furthermore, administrative offices in charge need to be created or expanded to enable local authorities to connect regularly or constantly to current data measurements. This would further expand the data basis of local authorities without the support of research projects.

1.1 Introduction

1.1.1 Background

The Lower Jordan Valley is characterised by extreme water shortage due to semi-arid climatic conditions, limited water availability and a constantly increasing demand for drinking water. The availability of water resources (e.g. precipitation, groundwater recharge, flood runoff, spring flow) is highly variable in time and space which results in extreme shortages in water supply. Inefficient water uses and pollution of groundwater through untreated wastewater worsen the tight water supply situation.

In addition, the regional geology includes areas of karst rocks with groundwater reservoirs that are extremely vulnerable to pollution by untreated wastewater. Several karst springs, however, are of major importance towards steady water supply. Therefore, efficient monitoring methods at local karst springs are essential to ensure a stable supply with drinking water in the region.

The central goal of the SMART-Move project is to integrate innovative technologies and management instruments into the water management practice of cooperation partners from Israel, Palestine and Jordan. Water technologies and management concepts have to be adapted to regional conditions to improve robustness against hydrological variability.

1.1.2 Work Packages

The SMART-Move workgroup consists of a cooperation from German University and Industry partners with local partners from Israel, Jordan and Palestine. The network represents different fields of expertise to deal with all aspects of the project. It is coordinated by the Department of Applied Geology of the Geosciences Centre at the University of Göttingen, Germany.

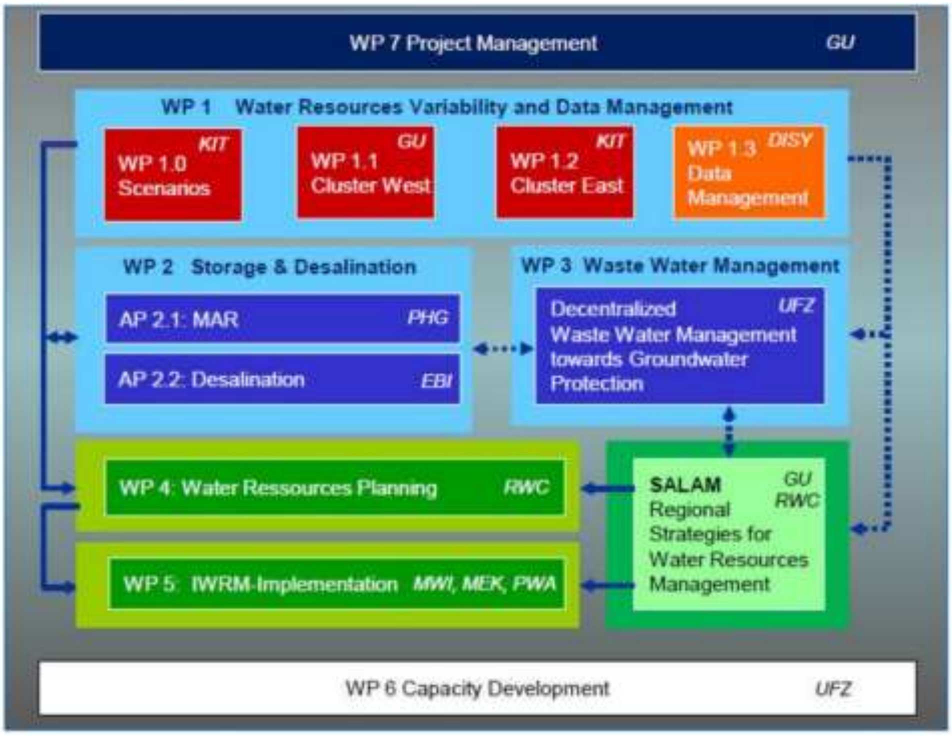

Figure 1: Project structure SMART-Move.

The project is divided into 7 work packages (WP) with an additional subproject, SALAM (Fig. 1). Disy Informationssysteme GmbH contributes to WP1. Main tasks within WP 1 comprise surveys of the hydrological variability within representative catchment area clusters, modelling of hydrological scenarios as well as the installation of a data platform as basis for all further work within and beyond the SMART-Move project.

Based on the existing environmental information system DAISY the main task of Disy is to develop a practical solution for a sustainable data collection during the project phase and for further use. The focus is to implement stable database sensor interfaces and prepare a trans-border data management infrastructure within the region. This includes the design and preliminary implementation of user-friendly and stable methods for data import of existing mass data from tables as well as standard import interfaces for continuous data feed from telemetry stations.

In addition, the data structure should comprise a modular data management solution embedded into already existing or emerging data management structures of the project partners. The data management is designed to enable a cost-effective and sustainable data use. As an extension, an early warning system will be established to monitor bacterial contamination of spring water and ensure stable water supply in a situation of unpredictable water supply.

1.1.3 Objectives

The overall goal of SMART-Move is to develop transferable approaches for an integrated water resource management in the semi-arid pilot region. The availability and management of water resources should be improved through the implementation of new and adapted technologies. Many smaller steps need to be taken to unite concepts from project partners and existing data models.

The following steps were realised to gather all corresponding contents.

- Identification and initial contact to project partners, in particular: WP1 coordinators and partners, contact to further industry partners SEBA and PESSL, person in charge for data management within the pilot region
- Workshops with local partners to identify requirements, work processes, technical and functional infrastructure as well as strategies for future IRWM data management
- Definition of use cases in cooperation with data management stakeholders
- Analysis of existing and target SMART-data management, inventory data, existing data models etc.
- Analysis of the current status of DAISY
- Identification, determination and evaluation of functional, non-functional and technical requirements and conditions
- Development of a data model that transfers existing data from SMART as well as new telemetry data into a standardised format (OGC, ISO)
- Specification of individual modules (input, output, functionality, interfaces) to achieve an overall solution

2 DAISY – Assessment of the Data Management in the previous SMART project phases

2.1 Objectives and Activities

Significant efforts have already been undertaken during the previous phases of the SMART-project (2006-2012) in order to establish a central data repository for project partners, stakeholders and the general public. In these stages the previous SMART partners from the Department Catchment Hydrology of the UFZ Helmholtz Centre for Environmental Research were responsible for the implementation of the central project database DAISY (Data and Information System). Given the currently anticipated evolution of the SMART project from research to implementation it is necessary to assess the established state of data management applications and workflows in the previous phases of the SMART project and identify those parts that seem fit to surpass this transition.

In this regard, the following activities have been undertaken to assess the established state of data management in the SMART project:

- A discussion with the UFZ Helmholtz Centre for Environmental Research-Department Catchment Hydrology group was initiated, regarding the current status and planned fate of DAISY.
- A copy of the database model as database dump (but without data) was provided by the UFZ for analysis purposes. The dump was imported into a development database and the DAISY Database structure was reviewed.
- DAISY data and interfaces were assessed.
- Findings were discussed in the scope of stakeholder interest for future utilization scenarios of the available data

2.2 Results

2.2.1 DAISY architecture and roadmap

From a technical perspective the database and information system components on which DAISY is built are:

- Relational database (Oracle) as primary data store for alphanumerical data
- DAISY-Harvester: a web application to access the alphanumerical data from the database
- A geodata repository (ESRI geodatabase)
- DAISY-WebGIS: a web mapping client based on an ArcGIS Server to access the geodata

The web-based components can be directly accessed through the official UFZ-portal (see Figure).

However, none of the technological components are exclusively used for the SMART project region in the Lower Jordan Valley. This means, that the underlying database model is of a more generic nature and is also used to store data from other projects and regions unrelated to the SMART data (whereas the SMART section of the database extends the general model by introducing some custom tables).

Another important aspect is the fact that the UFZ did not plan to give up on running the DAISY servers (as of January 2016), but on the other hand was planning to merge the DAISY database with the TERENO-MED database[1] as part of a larger system.

Data and Information Management System - DAISY

DAISY is the central database for the BMBF-funded SMART-project and its 2nd phase continuation SMART-2. (Further infos and table of content is → here).

It may provide partner and the public with information and data. Most of the data are from 3rd sources collected and presented within DAISY as a common framework. Additionally, data that are generated within the project will be continuously implemented and updated. The data are in general typified into two groups: alphanumerical data and raster/vector-information.

The data policy of DAISY allows project partners to securely store their data within the database-system. Therefore two security levels are implemented: (a) the public and (b) the project internal including personalised login. Dependent on the type of data and your rights to get access different options are given.

- alphanumerical data: → DAISY-Harvester

- generate thematic queries and maps for the SMART-region: → DAISY-WebGIS

- Raster/Vector datasets incl. metadata for download: → DataLog

The description of the information system and the various possibilities with its web-based interfaces are described as handbook, which is for download
DAISY-Handbook 2.0 (3.3 MB)

A second option is to look at the following explanation sites:

→ DAISY-Harvester Explanation

→ DAISY-WebGIS Explanation

Figure 2: Data and Information Management System[2]

2.2.2 Available Data

2.2.2.1 Alphanumerical Data

The alphanumerical data stored in the Oracle database comprises exclusively measurement data from approximately 8000 monitoring stations of the following categories:

- Climatological stations
- Geology (borehole cores)

[1] http://teodoor.icg.kfa-juelich.de/overview-de
[2] http://www.ufz.de/export/data/2/98648_DAISY-Handbook%202.0.pdf

- Springs
- Streams
- Treatment plants
- Water Bodies
- Wells

The data available at the distinct stations ranges from single measurements to comprehensive time-series of diverse parameters. The most recent data is from 2012. All data is available via the DAISY Harvester, an interactive web interface (see Figure).

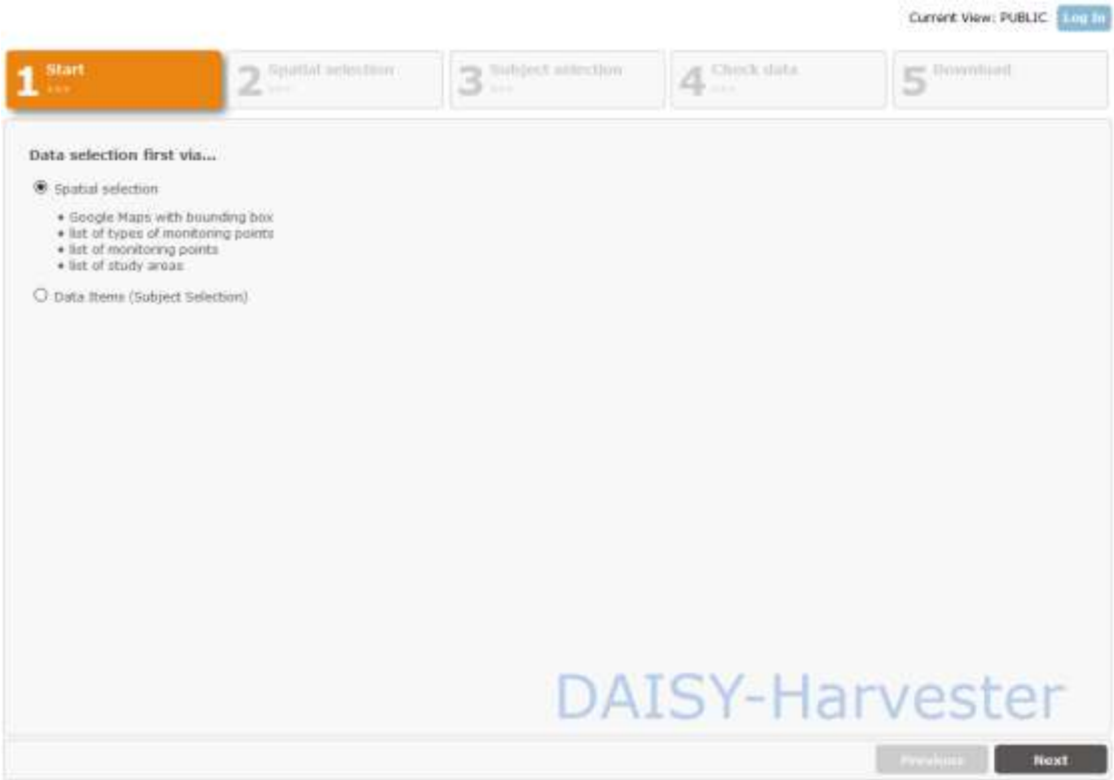

Figure 3: Alphanumerical Data-Interface of Daisy[3]

2.2.2.2 Geodata

The geodata layers stored in the ESRI geodatabase comprise the following categories:

- Administrative Districts
- Bode Intensive Research Site
- Domestic Water Use
- Environmental Hazard Sites
- General Climate
- Geology and Tectonics

[3] https://www.ufz.de/daisy_harvester/

- Infrastructure Hydrology
- Infrastructure
- Land cover
- Relief and Morphology
- Sampling Locations
- Soil
- Springs
- Surface Water bodies
- Surface Watersheds
- Transboundary
- Urban Areas

Each category consists of a set of distinct layers with variable amounts of features and is available via a web map interface (see Figure).

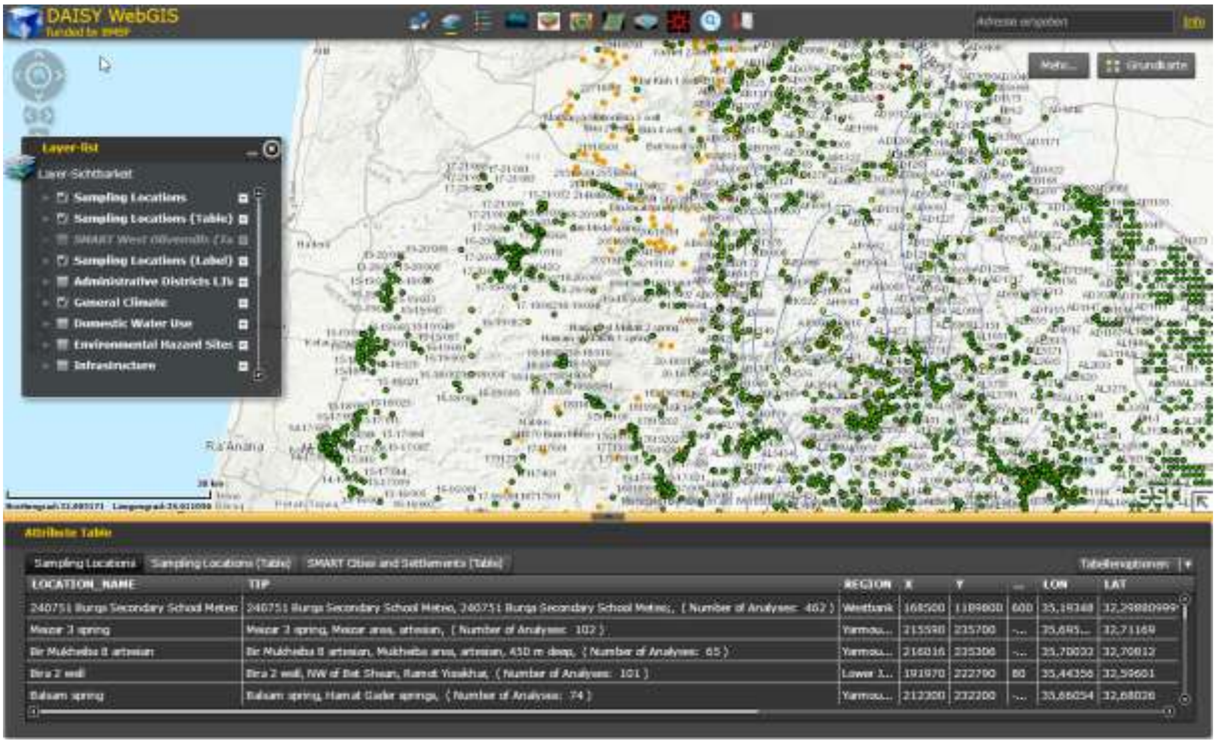

Figure 4: Web-GIS-Interface of DAISY[4]

[4] http://www.ufz.de/webgis-daisy/

2.2.3 DAISY database structure

As mentioned above, the database structure of the DAISY data model for alphanumerical data is part of a larger model beyond the scope of SMART. The analysis of the provided database dump showed, that the schema contains almost 200 tables, whereas only about 10-20 tables are assumed to be required to represent the available alphanumerical data in the above listed 7 categories.

The structure of the ESI geodatabases could not be assessed.

2.2.4 DAISY Interfaces

Besides the web-based user interfaces, the DAISY-system provides a technical ArcGIS REST Services-API[5] to access the available geodata[6]. The data is available as Map Service which allows the integration of the DAISY geodata in other applications as image-based information layer.

There is no technical interface available to access the alphanumerical data.

2.3 Conclusions

Given this setup, a direct transition of the DAISY database into the SMART-Move project was not possible. The concept of DAISY was to connect three countries in the region and establish a common database by recording data considering water supply context. DAISY was aimed to connect different water authorities that have to deal with similar water resource difficulties through its trans-border approach.

However, the data stored was of no relevance for the main SMART-Move-project EWS. Still, the DAISY database turned out to be a helpful source of information for regional geodata. Consequently, the REST-services from DAISY were integrated to the SMART-Move structure.

The interface created for DAISY is of further interest and might be integrated further on. Another follow-up-project worth considering deals with the DAISY-data originating from stakeholders in the region. Enriched with further information and data from other partners, these data would be of special interest for the stakeholders to be re-integrated into their own systems.

[5] https://developers.arcgis.com/documentation/core-concepts/rest-api/
[6] http://www.ufz.de/arcgis/rest/

3 Data Management Requirements

3.1 Workshops

3.1.1 Timetable Workshops

Data management requirements were assessed by project partners and stakeholder consultation during several workshops.

Tab. 1: Timetable of Workshops held within SMART-Move.

Date	Meeting	Participants
2014-06-25	Preparatory Meeting WP1 in Karlsruhe	KIT, Disy, SEBA, BAUER, ATB, BDZ, PIA
2015-04-17	Work Package Meeting: Data Management	KIT, Disy
2015-06-15	Group Session during the Scientific Coordination Meeting in Göttingen	MWI, KIT, GU, SEBA, Disy
2015-08-14	Work Package Meeting: Data Management	KIT, Disy
2016-11-03	SMART-Move Consortium Meeting	Open to all project partners
2016-12-06	Work Package Meeting: Data Management	KIT, GU, Disy
2017-07-06	SMART-Move Consortium Meeting	Open to all project partners
2018-23-04	SMART-Move Consortium Meeting	Open to all project partners

3.1.2 Data Management Use Cases

In order to develop the sustainable prototype of an IWRM planning tool that comprises both currently recorded data and data from former project SMART a stable data flow needs to be established from already existing databases towards the decision support model. The envisioned outcome is an information system prototype that directly supports WEAP water planning.

The initial approach to create an IRWM model is to concentrate on time-series that are automatically prepared to fit into WEAP-modeling. The overall goal is to simplify, speed up and standardize data transfer, data storage and visualization.

Data handling processes mostly comprise transformation of field data into databases and further on into modelling software WEAP. These steps are time consuming and repetitive. The automation of such processes is not only timesaving but may also prevent from data handling failures that occur when workflows are not executed thoroughly. At the same time data handling processes may sort out files that are required for WEAP modelling and transfer them into a readable format. The kind of data detected is of secondary importance as import routines can handle both time series and discrete data values.

In addition to surveys on the existing hydrological system, health issues concerning water supply are of special importance. Local karst springs are repeatedly contaminated through high levels of *E. coli* bacteria and are therefore too risky or unusable for the collection of drinking water. An early warning system for spring water pollution, based on telemetric monitoring, may help to control water usability and stabilize water supply in the region.

A system will be implemented that scans measurement data continuously and triggers a warning signal in case of measured parameters violating predefined threshold events. Possible pollution event scenarios and threshold values need to be calibrated from existing data in advance. The following events were identified to occur simultaneously with increased bacteria infestation through *E. coli*:

- Heavy rainfall
- Increased electric conductivity
- Increased turbidity

All three parameters are easy to detect with telemetric monitoring devices and data may be transferred to a central database.

Further correlations to be determined are the distribution of bacterial contamination in time, possible concentration levels of *E. coli* and during what period of time the affected spring has to be shut down for the use of drinking water (see Figure 5).

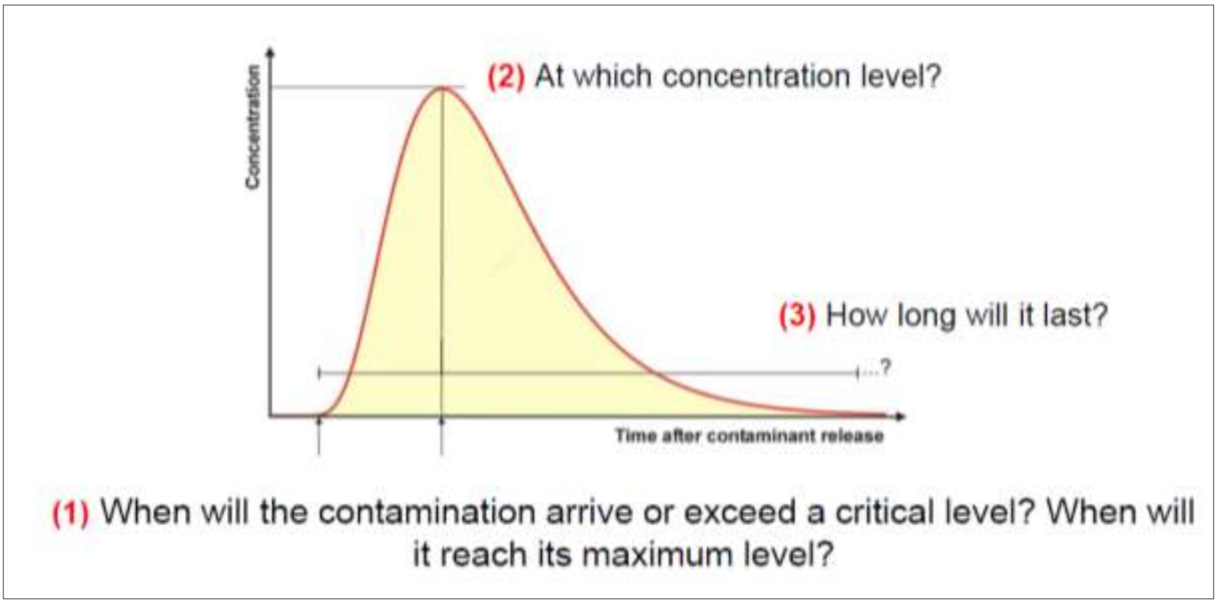

Figure 5: Distribution of bacterial infection curve.

Possible use cases to be considered are (1) increased precipitation values optionally in combination with increased EC and turbidity values as well as (2) an unpredicted increase of faecal bacteria during dry season. Calibration of these use cases is based on existing data and will be re-defined after the installation of monitoring devices.

3.1.3 Workshop Conclusions

The workshops were an important instrument to support communication between partners, both within WP 1 as well as partners of the entire project. In addition, the workshops were aimed to facilitate data exchange. Both conditions were fulfilled. During the workshops project partners discussed the project status and came to joint decisions effecting the further development of SMART-Move.

The most important decisions taken in WP1 were changes in project objectives. These changes were important in order to navigate the common goal to a new direction and to achieve the best possible output for SMART-Move.

In the on-site workshops local project partners were introduced to the implemented monitoring methods. Education on spring monitoring were executed during technical trainings. During a final workshop the database structure constructed by Disy were handed over to the MWI accompanied by a user training on the monitoring system by SEBA.

3.2 IWRM Information System

3.2.1 Introduction

The original aim for the Wadi Shueib IWRM-planning model was to extend the existing WEAP water planning model by the SMART-Move cluster east, including MAR site Deir Alla and the water treatment plant in Zai. This trans-border implementation approach was designed to provide sustainable strategies for water management planning and management to address the region's water supply challenges in a participative way on both sides of Jordan river. This improves the transparency in decision-making and provides a basis for a collaborative management of water resources and negotiations at political level.

Catchment area clusters were developed at a level that is large enough to validate the implementation concept of IWRM and improve the instruments of water management. At the same time these clusters are small enough to allow successful processing within a research project. Finally, both clusters, east and west, cover the whole range of hydro(geo)logical characteristics, land-use management and cultivation to be found within the region which is an important requirement for the generalisation of following results.

Individual water management systems and adapted technologies (e.g. water storage, wastewater treatment, groundwater recharge, brackish water treatment, well systems, storage facilities, etc.) were planned to be implemented as package, in a bundle of IWRM strategies, at the level of the representative catchment area clusters. Already initiated prototype projects (e.g. brackish water desalination) were planned to be continued to completion.

In order to develop a sustainable prototype of such a planning tool, the information flow from the SMART project database towards the decision support model needs improvement. Envisioned outcome was an information system prototype that directly supports WEAP water planning.

3.2.2 Data Model

The Water evaluation and planning system (WEAP) provides the opportunity to describe water flows, to manage water resources and, beyond that, to model future supply challenges. A simple node-edge-model simulates all parameters of current water demand like water supply, runoff, evapotranspiration, infiltration, crop irrigation, stream flow, groundwater flow, or surface storage. These data can be completed by information on water quality, pollution, climatic conditions, land use parameters and socio-economic factors. This way future scenarios in water supply may be monitored and addressed easily, like rising population growth or water needs per capita. Limited water resources become more manageable.

The original aim of KIT was to extent the existing IWRM model (Figure 6) by two further catchment area clusters. Already existing data were to be augmented and provided for further use. To ensure the sustainable data use Disy wanted to provide a database for data collection. At the same time data access would be available for project members and the public via an interface using the software Cadenza. Data management requirements and concept ideas for the output interface from project partners were included in the planning as far as possible.

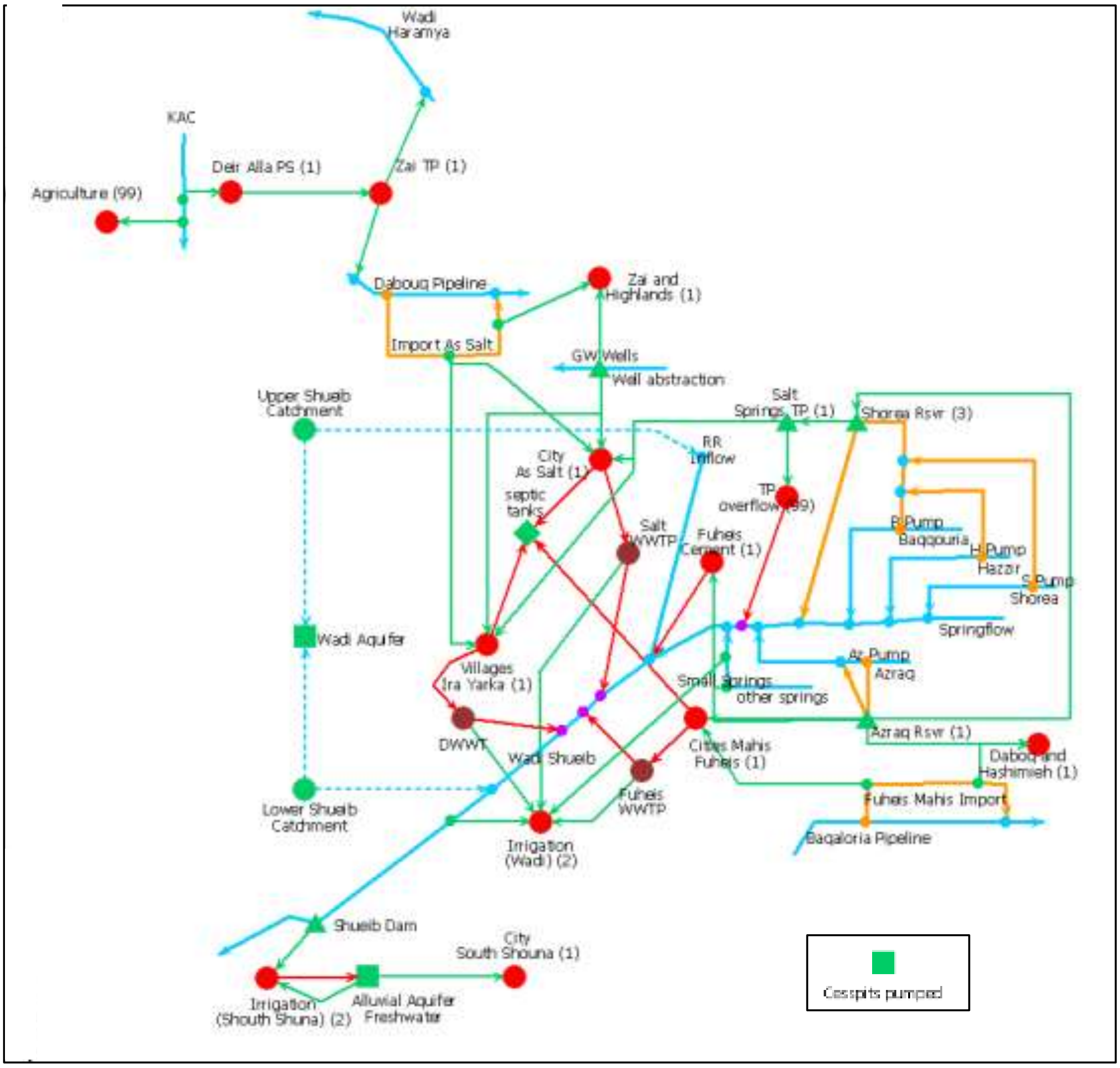

Figure 6: The Original WEAP model displays manifold connections within water supply chain.

Element	Location	Node	Priority	Remark
KAC	Deir Alla	River	no priority	all water coming to Deir Alla will be pumped Zai. If some water will not be pumped to Zai it goes to the agricultural sector to irrigate crop.
Wadi Haramya	Deir Alla	River	no priority	Wadi Haramya receives the brine of the treatment process of Zai.
Zai TP	Deir Alla	Demand Site	1	Zai Treatment Plant receives water from the Deir Alla Pumping station; the water will be treated and then pumped to Amman and As-Salt (via Daqouq pipeline); the brine of the treatment process will be conveyed to Wadi Haramya.
Deir Alla Ps	Deir Alla	Demand Site	1	Water of the KAC will be pumped to the Zai treatment plant (app. 70.000 m^3/y)
Agriculture DA	Deir Alla	Demand Site	99	Water from the KAC will be pumped first to Zai. If there is any surplus of water it goes to the agricultural sector.
City South Shouna	South Shouna	Deman Site	1	Village will be supplied by groundwater abstracted by the local aquifer

3.2.3 Implementation of the WEAP Model

The process of handling data and entering it in the WEAP model is time consuming and repetitive. Therefore, data handling should be facilitated by storing all data in a common database and exporting only those files that are required by WEAP. The model may work with different data like time series as well as single discrete values. In order to organize data flow, it has to be made clear which data sets are going to be included into the database.

The origin of the data used within WEAP may be diverse. Data integrated within the model and dataset requirements were mainly delivered by KIT while Disy organised the data handling. At first a draft of data export functions suitable for WEAP was constructed.

KIT drafted a conceptual Cluster East model that consisted of the schematic WEAP model. This draft was aimed to evaluate the data requirements.

The intended Cluster East WEAP Model comprises:

- Wadi Shueib WEAP Model
- South Shuna Wells and Groundwater Model
- Nodes for Deir Alla and Zai Treatment Plant

The implementation of an automatic data loader would be the next logical step. Therefore, all data have to be in a defined format to realise such an automation process. The output of WEAP may then be stored in the database and be provided online which is beneficial to the stakeholders and for further data access.

3.2.4 Conclusions

During the course of SMART-Move, it turned out that the objective of creating a water balance modelling (WEAP-Model Cluster East) as originally planned by KIT is not going to be finalised. This aim was not pursued in such a manner that specific requirements for supporting software functionalities (like special export functions) would have to be implemented as it was planned in the original project description.

Therefore, in agreement with the project coordinator and the other project partners, the original plan was changed as described in the following. The original implementation of WEAP-export and other functionalities was not continued. All remaining personal resources were shifted to the EWS-task on a cost-neutral basis. At the same time the EWS was to be extended to the western cluster within the project region. Further goals to be implemented by Disy are the connection of the telemetric measuring stations from the western project area and installation of a management for the parameters used in calculation routines of the warning signal. These changes did not result in changes of the financial planning or project schedule.

3.3 Spring Early Warning System

3.3.1 Introduction

Water supply in the pilot region is directly linked to health issues. Local karst springs are frequently contaminated by high levels of bacteria *E. coli* through uncontrolled wastewater dumps. Water use from karst springs is therefore restricted and must be monitored thoroughly. The examination of water samples for *E. coli* on a regular basis is time-consuming and infestation with this bacterium may not be detected in time. Easy detectable parameters that occur concurrently with high levels in bacteria offer an option to install a sustainable monitoring system.

Accordingly, KIT-HYD planned an early warning system for spring water pollution events. The system processes telemetric measurement data from monitoring stations at three local springs in Wadi Shueib: Baqqouria, Hazzir and Shoreia Spring. The early warning system scans measurement data continuously and triggers a warning signal in case of measured parameters violating predefined threshold events.

3.3.2 Input data

A total of 14 hydrological parameters were compared and evaluated with respect to their usability in the early warning system. Every parameter was rated towards its significance in timing and resolution effectiveness as well as its indicator significance. Figure 7 shows a basic result from this comparison.

Parameter	timing & resolution effectiveness	indicator significance
electric conductivity	+++	++
discharge / water level / pumping rate	+++	+++
NO_3	+++	++
pharmaceuticals	o	+++
E. coli / total coliforms[1]	+(+)	+++
turbidity	+++	(+++)
$\delta^{18}O$ / $\delta^{2}D$ isotopes	+	++
pH	+	+
Cl^- & SO_4^{2-}	++	+
major cations	++	+
TOC / DOC	++(+)	++(+)
viruses	o	+++
temperature	+++	+
oxygen demand / redox	+++	+(+)

+++ very good ++ good + moderate o not helpful

Figure 7: Hydrological parameters as possible key indicators towards bacterial infestation.

Through time-series data from several years different events, e.g. heavy rainfalls, were identified to occur simultaneously with increased bacteria infestation through *E. coli*. Finally, the following parameters were proposed to be used in an EWS:

- precipitation

- electric conductivity (EC - possibly in combination with turbidity and/or *E. coli*),
- turbidity
- (*E. coli* in further tests)

The first three parameters are easy detectable by telemetric monitoring devices and data may be transferred to a central database. Further testing for *E. coli* may then be executed selectively when other recorded events suggest higher levels in bacterial infestation.

Data aggregation is carried out continuously. Precipitation data are measured in hourly intervals, all other data are recorded every 15 minutes. The electric conductivity was identified as most suitable parameter especially when data are combined with input from further parameter turbidity.

The data recorded from telemetric stations is scanned continuously and compared to a threshold value. Threshold values include single parameter thresholds as well as the combination of different parameters. In the event of threshold violation, the system will produce a warning signal.

3.3.3 System Structure

The structure of the EWS consists of four steps (see figure 8).

(1) The measurements from telemetric stations are recorded on site and (2) transferred to databases provided by the German cooperation partner PESSL and SEBA. The PESSL Server records precipitation data, SEBA stores hydrological parameters like electric conductivity and turbidity.

(3) These data are then transferred to the SMART server provided by Disy. Within this combined database, the data is evaluated and tested against threshold values that were defined in advance. (4) Threshold violations will then trigger a process that includes an automatically released warning mail to the responsible person of the local water supplier. Together with additional geodata the recorded data is available for project partners as well as the public via a web interface.

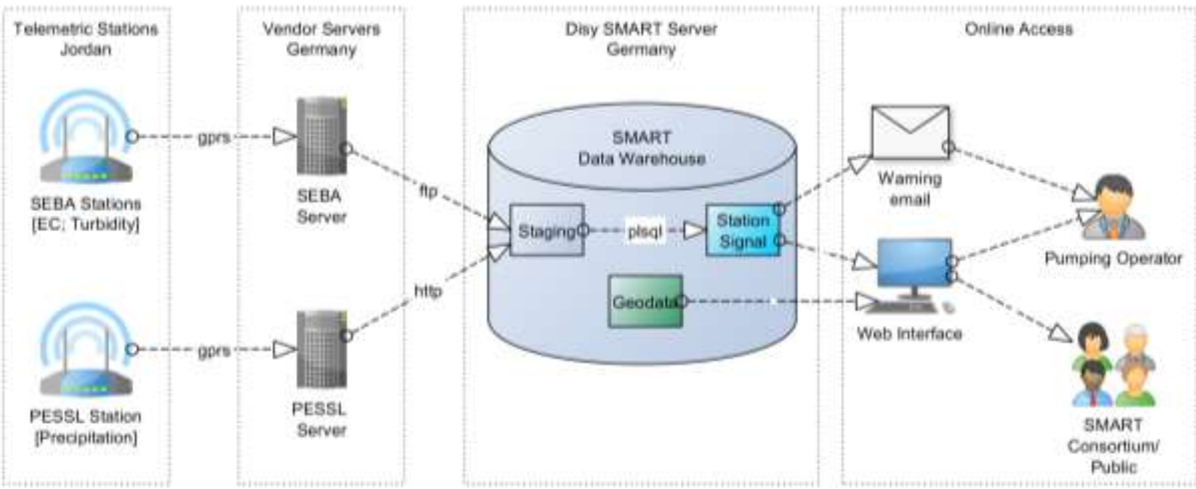

Figure 8: Schematic Structure of the Early Warning System.

Possible pollution event scenarios and thresholds were calibrated from existing data series recorded in the pilot region. Initial warning scenarios were defined from these data. Any further adaptation of threshold values, especially variations in threshold values for each survey station, may be configured while measurements are running. These data were adjusted in cooperation with local water authorities and are configurable for further adaptation.

Three different water pollution risk scenarios were determined in order to define relevant warning levels:

1. Precipitation as single parameter

   Early Warning system at all three monitored springs
2. Combination of turbidity and precipitation

   Individual concept at Baqqouria and Hazzir Spring
3. Combination of electrical conductivity and precipitation

   Individual concept at Shoreia Spring

These parameters were considered individually per station. Further adaption may be taken considering current data recordings. Threshold values to start with are

- Time window for accumulated precipitation (10mm in 12h)
- Turbidity level (5 FTU)
- Variation in EC within time window (30 µS/cm in 24 hours)

Three warning levels were created to distinguish further actions in the event of threshold violations (Table 2). According to the warning level a warning messages may be sent as mail or sms.

Tab. 2: Warning levels and actions triggered in consequence.

Warning Level	Consequence, action initiated
RED	Water supply off for 48 hours Warning message to responsible
YELLOW	1. Warning Level, optionally further attention to other parameters Warning message to responsible
GREEN	Water supply on
GRAY	Station not sending data

Risk scenarios and further actions in detail:

Scenario 1

Parameters considered: Accumulated precipitation values within 12 hours

- Precipitation > 10 mm in 12 h → warning level YELLOW
- Precipitation > 40 mm in 12 h → warning level RED
  - Further action: Warning message to responsible
    Water supply is stopped for 48 hours
  - After 48 hours: if accumulated rain < 10 mm in 12 h
    → Warning level GREEN, water supply on

Scenario 2

Parameters considered: turbidity and accumulated precipitation

- turbidity > 5 FTU → warning level YELLOW
  - Further action: consider accumulated precipitation
- turbidity > 5 FTU **and** precipitation > 10 mm in 12 h → warning level RED
  - Further action: Warning message to responsible
    Water supply is stopped for 48 hours
  - After 48 hours: if turbidity < 5 FTU
    and accumulated rain < 10 mm in 12 h
    → Warning level GREEN, water supply on
- turbidity > 5 FTU **and** precipitation < 10 mm in 12 h
  → warning level GREEN, no further action

Scenario 3

Parameters considered: variation of electric conductivity in 24 hours and accumulated precipitation

- EC variation > 30 µS/cm in 24 h → warning level YELLOW
  - Further action: consider accumulated precipitation
- EC variation > 30 µS/cm in 24 h **and** precipitation > 10 mm in 12 h
  → warning level RED
  - Further action: Warning message to responsible
    Water supply is stopped for 48 hours
  - After 48 hours: if EC variation < 30 µS/cm in 24 h
    and accumulated rain < 10 mm in 12 h
    → Warning level GREEN, water supply on
- EC variation > 30 µS/cm in 24 h **and** precipitation < 10 mm in 12 h
  → Warning level GREEN, no further action

The EWS will be completed by a Cadenza Web installation. This portal will provide access to the measurement and aggregation data for every member of the SMART-Move project.

Further development of the EWS includes a permalink send with the warning message. This permalink provides direct access to current data and may help the responsible person to assess the situation for the affected springs.

3.3.4 Web Interface

The Web Interface (figure 9) offers access to an enormous amount of data concerning the pilot region. Besides climatic and measurement data for each station there is information on the regional geology, hydrological data, landcover and soils. Warning Signals can be displayed in a map offering a quick overview to the current situation. Furthermore, there is data on the infrastructure, administration units and urban areas.

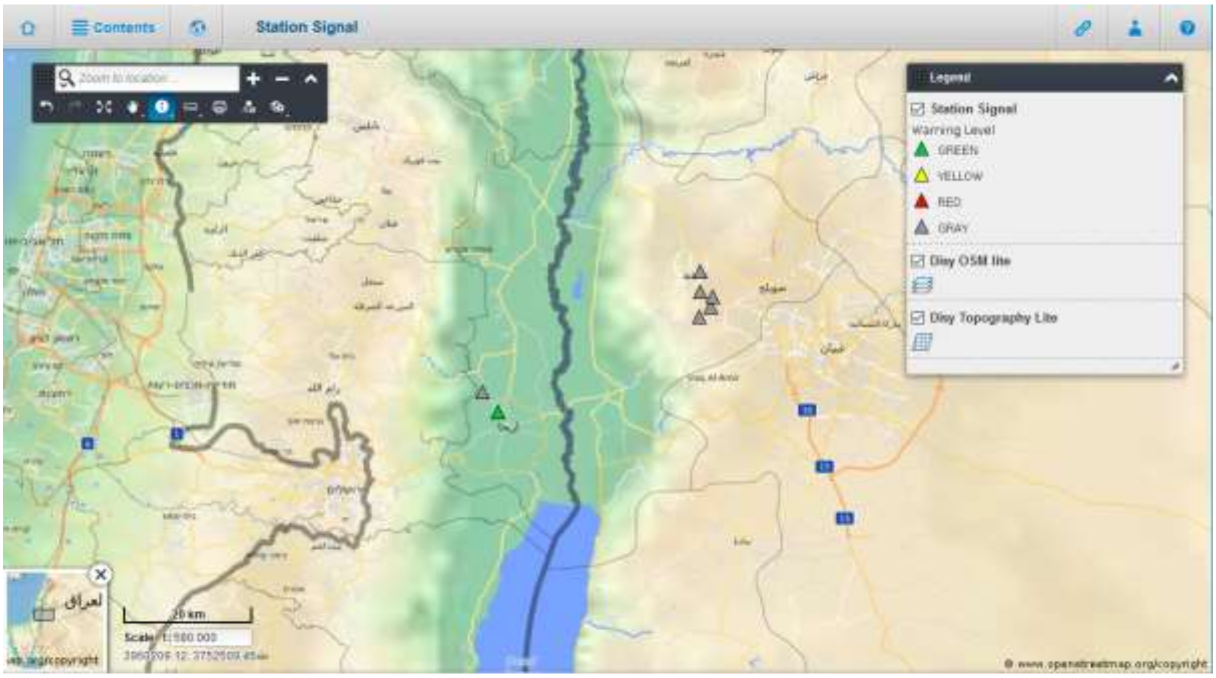

Figure 9: Web Interface of the early warning system[7].

3.3.5 Conclusions

Decreasing water resources in the Lower Jordan Valley region represent a major challenge for the local population and regional ecosystem. The challenge to preserve a reliable water supply in the future depends on a sensible usage of existing water resources.

Major supply challenges in the semi-arid region are the intermittent and highly variable water availability and frequently faecal contamination in groundwater. Karst springs and wells are of major importance to the water supply of local cities As-Salt or Fuheis. Especially after heavy rainfalls these springs are often contaminated by bacteria *E. coli* and therefore not usable as drinking water. Part of this problem is an unsecur wastewater management system.

[7] https://smdb.env.disy.net/cadenza/index.xhtml

A reliable and quick automatic monitoring of bacterial infestation is not possible. Water samples have to be analysed by a laboratory which causes a severe delay in time. This results in an uncertainty of spring water usability for water authorities and temporary shutdown of important water resources.

Through analyses of time-series from several years an empiric correlation of rainfall, increased EC and turbidity together with the increased occurrence of *E. coli* was determined. The most important aspect is that both parameters, EC and turbidity, are easy to monitor at short time steps. This way bacterial infestation becomes manageable.

A warning message on possible bacteria at local springs via e-mail serves as rapid and effective information to responsible persons. Access to current measurements is available via an internet interface allowing further insight to the situation to take a decision considering next steps.

The early warning system cannot prevent pollution of spring water. However, it helps water authorities in Jordan to improve security aspects in the water supply.

The EWS significantly reduces the time required to pass information of contaminated water from spring detectors to water suppliers. Reaction time is reduced from one day to just 15 minutes. This is a great progress in terms of supply security where water supply is scarce. Springs that were formerly not used for water supply due to unsecure information may now be integrated easily. For the water authorities, this is great progress in terms of supply security.

The early warning system is executed in trial operation for the Wadi Shueib since the beginning of 2018.l

4 Implementation

With a focus to the implementation of the EWS, a first step to effectively integrate the survey system in the pilot region was to identify and contact the key users. They were then introduced to the technical options of an early warning system and involved in discussions concerning the different developmental steps. The direct participation of SMART-Move project partners and pilot users was realised during several on-site workshops.

The installations of technical equipment at local springs were executed in cooperation with local authorities. This way the project partners were at the same time educated in the technical structure of the EWS.

Finally, the pilot users had to be educated in operating the EWS. The main step was to integrate the Jordanian pilot users of the WAJ as recipients of warning signals produced when threshold violations occur at surveyed springs.

Responsibility for the technical operation of the EWS was handed over to the pilot users in April 2018 as on-site workshop during a project meeting in Jordan. All technical requirements to operate the early warning system were communicated and handed over. In addition, Disy prepared and handed over a manual on the EWS. At the same time a workshop on the telemetric connection, operational recommendations and a training course for the use of the EWS was conducted by SEBA.

For an independent operation of the EWS in the region the Jordanian partners would have to set up their own data infrastructure corresponding to the one implemented in trial operation. Technical advice how to move the whole system to their own structure was given during the final workshop.

5 Summary and Conclusions

In terms of per capita freshwater availability, the Lower Jordan Valley belongs to the scarcest regions in the world. This territory stretches over three different countries with complex political interactions.

The research project SMART examined different aspects on water availability and sustainable water management in a series of local pilot studies in Israel, Palestine and Jordan. The focus of these studies was set to decentralized wastewater treatment, brackish water desalination, managed aquifer recharge and groundwater protection as well as socio-economic aspects.

During eight years of cooperation, strong connections with governments and stakeholders were established resulting in a very constructive cooperation (see SMART-IWRM final report[8]). The SMART-Move project was designed as follow-up project to further integrate innovative technologies and management instruments into the practice of water management cooperation partners. SMART-MOVE profited from the previous project and already existing connections to partners in the region.

Both projects were designed to approach the severe water supply situation in the region with up-to-date technological capabilities.

Part of the SMART-project was a water resource model for Wadi Shueib. Despite the complexity of the assessed IWRM system and the detail of the sub-catchment scale, the Wadi Shueib WEAP model successfully represents all elements of the preliminary holistic water balance schemes. The study came to the conclusion that WEAP can contribute very well to an IRWM planning process with a focus to water balance and allocation.

Therefore, as a next logical step, the existing model was to be extended to two further regions to implement the IWRM on a greater level within SMART-Move. However, within the course of SMART-Move the project partners decided not to follow the original plan. An early warning system to groundwater safety was implemented and resources were rather used to integrate the western cluster into this system. This way local needs for an enhanced water management system could be fulfilled even more efficiently.

By concentrating on the early warning system, one of the many aspects significant in the context of water supply in the region was considered and implemented in detail. Local karst springs play an immense role in the local drinking water production. Therefore, the hygienic aspects of spring water collection are of special importance to the water supply system.

Jordanian project partners and public profit from a monitoring portal that offers an effective warning system via Web interface and a reliable water supply. The telemetric data transfer is realised with minimal technical effort: only two rainwater collectors and four monitoring probes are operated per supervised spring. The incoming data is processed automatically, this reduces work load for water authorities and speeds up the process of evaluation and decision taking.

Further information on current data of local springs may be accessed via the Web interface at any time. Analyses and data edition may be realised with only a few easy steps. The whole system enables a fast reaction to the current situation. In addition, the early warning system can easily be expanded by further survey stations.

For Disy main benefits were the know-how of dealing with in the field recorded telemetric sensor data and the cooperation with a hardware manufacturer as project partner. Usability and prospects of economic success are given through follow-up projects.

[8] http://www.iwrm-smart-move.de/images/smartmove/final-reports/SMART_II__Final_Report.pdf

On the one hand, Disy deepened its expertise in the field of international research and developmental projects considering IWRM-contents. This enables Disy to further operate in this context. In the meantime, Disy has been granted to participate in the BMBF-project GRoW, a research project that approaches water supply and resource management on a global scale. Disy will participate in the subprojects Trust and iWaGSS which will definitely profit from the experience gained during SMART-Move.

On the other hand, the internationalization of the software products and the corresponding documentation simplifies an international exploitation.

And finally, product enhancements to the Software Cadenza, which were designed as part of SMART-MOVE, have already been rated as interesting by one of the current Disy customers. If there is enough interest on the project results at the prototype stage, Disy Product Management and customer advisors will decide whether these new implementations are going to be financed and integrated into the existing software. The implementation and further commercial exploitation within one year after the end of the SMART-Move project is possible.

As further benefit from SMART-Move there is a scientific publication with participation of Disy resulting from the cooperation:

Felix Grimmeisen, David Riepl, Sebastian Schmidt, Julian Xanke, Nico Goldscheider (2018): Set-up of an early warning system for an improved raw water management of karst groundwater resources in the semi-arid side Wadis of the Jordan Valley. Akzeptiert für: European Geosciences Union General Assembly 2018, Vienna | Austria | 8–13 April 2018.

6 References

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