

(Projects submitting final reports after 1 January 2014 must use this format.)



LIFE Project Number
LIFE08 ENV/D/000021

FINAL Report – technical part
Covering the project activities from 01/01/2010 to 30/09/2015

Reporting Date
30/09/2015

LIFE+ PROJECT NAME or Acronym
<MAGPlan>

Project Data

Project location	Stuttgart
Project start date:	01/01/2010
Project end date:	31/12/2014 Extension date: 30/09/2015
Total Project duration (in months)	69 months (including Extension of 9 months)
Total budget	3.445.250 €
Total eligible budget	3.445.250 €
EU contribution:	1.722.625 €
(%) of total costs	50
(%) of eligible costs	50

Beneficiary Data

Name Beneficiary	Landeshauptstadt Stuttgart, Amt für Umweltschutz
Contact person	Mr Hermann Josef Kirchholtes
Postal address	Gaisburgstraße 4, 70182 Stuttgart
Visit address	Gaisburgstraße 4, 70182 Stuttgart
Telephone	+49/(0)711/216-88717
Fax:	+49/(0)711/216-88620
E-mail	Hermann.Josef.Kirchholtes@stuttgart.de
Project Website	http://www.magplan-life.eu http://www.sauberes-grundwasser-stuttgart.de

1. List of contents

1.	List of contents	2
2.	Executive Summary (maximum 5 pages)	3
3.	Introduction (1 page).....	8
4.	Administrative Part (maximum 3 pages)	9
4.1.	Description of the Management System.....	9
4.2.	Evaluation of the management system	11
5.	Technical part (maximum 50 pages)	12
5.1.	Technical progress, per task	12
5.2.	Dissemination Actions.....	37
5.2.1.	Objectives	37
5.2.2.	Dissemination: overview per activity	37
5.3.	Evaluation of Project Implementation	45
5.4.	Analysis of long-term benefits	47
6.	Comments on the financial report	49
6.1.	Summary of Costs Incurred	49
6.2.	Accounting system	49
6.3.	Partnership arrangements (if relevant)	49
6.4.	Auditor's report/declaration	49
6.5.	Summary of costs per Action	49
7.	Annexes	50
7.1.	Administrative Annexes	50
7.2.	Technical Annexes	50
7.2.1.	Lists of (i) Key-Words and (ii) Abbreviations.....	50
7.2.2.	Technical Documents – see CD and folder.....	50
7.3.	Dissemination Annexes – see CD and folder	52
7.4.	Final table of indicators	52

2. Executive Summary (maximum 5 pages)

Project Objectives

Overall aim of the project is to improve the groundwater quality in urban areas. Thus an optimal strategy for integral groundwater investigation and efficient remediation of key pollution input was developed und implemented. Results are laid down as an exemplary Municipal Groundwater Management Plan with the final aim to further substantiate the recommendations given by the Common Implementation Strategy for the WFD, guidance documents No. 17, 18 and 26. Major aim of this procedure is to achieve a quantitative overview of contaminant mass flow rates for the whole area under consideration, to localize hot spots in a second step and then subsequently identify the main sources of pollution. Finally risk management strategies and remedial action plans are defined. Test area is the inner city of Stuttgart with a diffuse contamination of chlorinated solvents, located in the centre of the groundwater protection zone of the mineral water resources.

Specific objectives to be pursued:

- Development of a generally applicable concept for integral groundwater risk management at urban scale comprising technical and administrative aspects
- Test and evaluation of innovative investigation technologies for quantitative assessment of fate and behaviour of groundwater pollution plumes by chlorinated solvents in layered and fractured aquifers (3-dimensional)
- Verification of one innovative characterisation technology according to the upcoming EU-ETV (environmental technological verification) scheme
- Test and evaluation of a model based methodology (conceptual and numerical) to define and assess appropriate sets of information for a well-defined decision basis in order to minimise the need for technical investigation measures. Moreover water authorities are enabled to increase efficiency of their administrative actions.
- Quantitative assessment of contaminant mass flow rates, identification of key sources of pollution and related liable polluters in the project area
- Establishment of a Municipal Groundwater Management Plan for the project area as a best practise example
- Compilation of EU-wide applicable recommendations for action for groundwater risk management in urban areas linked to the activities of the WFD Common Implementation Strategy (CIS) - Working Group C activities to develop further guidance for implementation of the GWD
- Rising and securing awareness among the general public and the commercial sector for groundwater protection issues in general and the abatement of groundwater pollution in urban areas

Key Deliverables and Outputs are:

- description of a general concept for integral groundwater risk management at urban scale, combined with the Municipal Groundwater Management Plan as best practise example – documented in our comprehensive project documentation
- test and evaluation of 9 innovative investigation technologies, summarized and laid down in various reports and guidance documents
- technology verification of isotope fingerprinting, laid down in a guidance document
- test and evaluation of a model based methodology (conceptual and numerical), laid down in guidance documents and the comprehensive project documentation

- demonstration of a methodology for quantitative assessment of contaminant mass flow rates, subsequent identification of key sources of pollution and related liable polluters - documented in our comprehensive project documentation
- demonstrator of software application of 3D-visualisation via the software tool MAG-IS
- groundwater flow and transport model for Stuttgart city area including identification, quantification and assessment of pollution plumes – the model as a tool which will be further operated after MAGPlan lifetime
- development and demonstration of a methodology for an efficient evaluation of microbial degradation processes
- 3 public workshops on dedicated technical aspects
- 1 international final conference
- vitreous aquifer mobile exhibition in combination with newsletters, project movies and an online-quiz

The single chapters of this report are to be summarized as followed:

Introduction

A severe problem in many European big cities is a long lasting, widespread groundwater contamination with chlorinated solvents (equivalent to CHC, chlorinated hydrocarbons). In Stuttgart low level concentrations of these substances have been detected even in the local mineral water resources, traditionally used for medical and leisure purposes. Mitigation or remediation is hampered by a large number of possible pollution sources and the impossibility to identify the crucial sites.

MAGPlan tested and demonstrated a new method to overcome this problem. In contrary to the traditional approach of separately investigating single sites, MAGPlan focussed on the areal (or integral) characterisation of groundwater pollution. An iterative approach, building up and stepwise improving a conceptual and a numerical groundwater model simultaneously, helps to understand the system and permits to finally identify the most relevant contaminant sources. Approach and working methodology is in line with GWD requirements and generally transferable to other European cities with comparable challenges.

Administrative Part

MAGPlan is divided in six work packages. Four work packages (WP 1 – WP 4) comprise technical activities. Each of them resulted in the build-up and stepwise update of a conceptual and a numerical model, both of them describing processes of groundwater flow and contaminant transport in three dimensions. Planning for technical steps during WP 1 to WP 4 was done in specific project workshops, usually organized in the initial phase or towards the end of a work package. WP 5 focused on guidance documents in cooperation with the associated beneficiary LUBW. WP 6 included project management and dissemination tasks.

The project management structure foresees the project management of LHS-AfU as a central contact point and project authority. It is closely linked with financial and communication management tasks, each of them continuously supported by an external subcontractor. A close link to the operational level is provided by regular meetings of the working group. They ensured a continuous cooperation with the associated beneficiary

LUBW. A copy of the Partnership Agreement was delivered with our Inception Report in September 2010. Project budget and reporting were annually controlled by the project auditor “Rechnungsprüfungsamt”, especially concerning compliance with LIFE+ specifications, national legislation and accounting rules as well as the cities’ standard procedures.

An amendment request was sent to the Commission on 20/03/2013. With these modifications we reacted to the extraordinary abundance of the data and the need for adjustment of the “vitreous aquifer” concept. Further modifications concerned the necessity to adapt the technical investigation strategy to the state of knowledge by implementing deep drillings. An added value was achieved from an improved reliability of the technical results, merged in the management plan, as well as a more efficient communication concept. With our site review reports we created an innovative tool forming an intermediate step from point investigations to large scale modeling. The modifications resulted in a shift of budget to the category “external assistance”. We also suggested an optimized work plan and extended timetable. Thus the project ended on 30/09/2015 instead of 31/12/2014. The revised grant agreement was signed by the Commission on 04/07/2013.

Technical Progress

The first step in WP 1 (general overview, characterisation of groundwater flow) was the build-up of a data management system based on an extensive data investigation from abundant documents in archives. A conceptual model was established describing groundwater flow conditions, followed by the construction of a numerical groundwater model. Six drillings (MAG 1-MAG 6) helped to improve the knowledge about groundwater flow pathways in deeper aquifers. A drilling from ground investigation works was used to install an additional well MAG 7.

In WP 2 (contaminant load and transport processes) a number of integral pumping tests with accompanying investigations for hydrochemistry, isotopes and tracer substances was done. A conceptual contaminant model was established describing conditions for horizontal and vertical contaminant transport in groundwater. The numerical flow model from WP 1 was extended to a numerical transport model to simulate the migration of CHC plumes.

In WP 3 (contaminant degradation and natural attenuation processes) we constructed 11 additional wells (MAG 8-MAG 18) to improve the knowledge about contaminant transport in deeper aquifers. A large scale tracer test in the immediate upstream of mineral springs was performed. We developed and demonstrated an innovative methodology to verify microbial degradation processes in a comprehensive interpretation of data evaluation, results of field investigations and laboratory methods. We could proof the natural degradation of Trichlorethen (TCE) as a new scientific finding. The numerical model was upgraded to a reactive transport model simulating not only CHC as a sum parameter but also in detail each single component (like PCE, TCE, etc.) with related biologic degradation processes.

WP 4 (remedial options and management plan) focussed on remediation design and management. Based on model evaluations, we identified nine sites with a high pollution input and a definite influence on receptors. Calculations of the numerical model could quantify the distinct contribution of each site and estimate the benefit of various

remediation scenarios. Based on a feasibility study on remediation options we developed a remediation concept for five sites with most urgent need for action. It has been accepted by the City Council and will be implemented from 2016 to 2026.

In WP 5 the associated beneficiary LUBW established two comprehensive guidance documents for a widespread application: the first gives handling instructions how to deal with long lasting hydraulic remediation measures; the second describes methodology and procedure for an integral management of contaminated sites. LHS-AfU presented a guidance document to the City Council as a comprehensive summary of the Groundwater Management Plan.

The Transnational Science and Policy Panel as an international expert committee from municipalities, administrative bodies and researchers accompanied the project, gave us their continuous advice and reflections in addition to our German perspective and provided the link to the WFD Common Implementation Strategy (CIS) working group C for groundwater.

Dissemination

With our vitreous aquifer concept we addressed more than 300.000 visitors. Their sensibility for groundwater protection and especially for the situation of Stuttgart's mineral springs was enhanced. The strata model as its main component visualizes the sequence of layers of different rocks. It allows touching the real rocks and facilitates the understanding of each single stratum.

Our comprehensive project documentation, published as a book, was presented to the technical community on our final conference. A clearly structured overview on 267 pages, supported by targeted graphic illustrations, gives an insight for the non-involved technical expert. It describes the applied methodologies and technical tools and gives a comprehensive evaluation of all findings for the final outcome Municipal Groundwater Management Plan.

Evaluation of Project Implementation

MAGPlan implemented a new method to meet requirements of GWD, on the scale of big cities, very frequently concerned with diffuse groundwater pollutions like in Stuttgart. The methodology of integral groundwater investigation and remediation derives factors on a holistic scale instead of separately investigating and evaluating a large number of single sites. Thus technical investigations can be planned efficiently and costs can be reduced to the necessary minimum. With this approach, we finally managed to select 9 from 182 sites for a further investigation and remediation need. The principle of this methodology is transferable to other cities and may be replicated to tackle comparable challenges, as many European cities are facing similar situations.

Based on an exemplary comparison of quantitative objectives and results achieved we can show that the targets could be achieved or proposed numbers are even exceeded. The project amendment enabled us to optimize the whole process and to distinctly improve our public relations performance.

Analysis of long-term benefits

Measures of the Groundwater Management Plan have been authorized by the City Council and will start implementation in 2016. As expected, we will achieve a definite reduction of abundant contaminant loads. This will lead to a definite improvement of groundwater and mineral water quality, especially for the deep aquifers.

The integral remediation concept instead of the traditional single site approach distinctly increases the efficiency and saves considerable costs, as it allows a concentration of cost intensive measures on few high priority sites. Of specific importance for this expected benefit is the knowledge about microbial degradation processes. By a combination of data evaluation, numerical model simulations and laboratory tests we could demonstrate that natural CHC degradation takes place. Exploiting these processes for remediation design will distinctly increase the effectiveness.

MAGPlan developed and demonstrated multiple innovative methods and strategic instruments to tackle urban groundwater contamination as occurring in many big cities within the EU. These tools and instruments are transferable to other big cities with comparable challenges. Replicability is ensured, as they have been laid down and described in our guidance documents. As the reaction of many international experts participating in our workshops and on the final conference showed, there is a tremendous need for such instruments and innovative concepts. An English project summary, giving a comprehensive overview about the most important features, methods and findings, is in preparation.

To test the application of groundwater management plans in functional urban areas LHS-AfU is participating in an INTERREG application, together with 11 partners from Poland, Czech Republic, Italy, Slovenia and Croatia. The decision about the acceptance of this proposal is awaited for April 2016.

3. Introduction (1 page)

A severe problem in many European big cities is a long lasting, widespread groundwater contamination with chlorinated solvents (equivalent to CHC, chlorinated hydrocarbons). Due to their fate and behaviour in the environment threshold values for trichloroethene (TCE) and tetrachlorethene (PCE) are listed in annex 2 of the Groundwater Directive (GWD). Mitigation or remediation is very often hampered by a large number of possible pollution sources and the impossibility to identify the crucial sites.

GWD application focusses on a large scale evaluation to assess a good chemical status of groundwater bodies. However for a comprehensive assessment of groundwater pollution at urban scale there is still a lack of strategic concepts and working tools. Merely a first outline is given by the *Common Implementation Strategy for Water Framework Directive, Guidance Document No. 17*. It presents a framework how point source pressures could be monitored with respect to their influence on receptors. But in order to predict groundwater quality trends and developments and to design potentially required remediation measures, contaminant plumes and large scale pollutions up to the scale of the entire city districts have to be described.

Low level concentrations of chlorinated solvents have been detected in Stuttgart's local mineral water resources, traditionally used for medical and leisure purposes. The "Muschelkalk" mineral water aquifer is part of a complex geologic sequence of multi-layered fractured and porous aquifers. Stuttgart as a demonstration example shows point source pressures, i.e. chlorinated solvent contaminations of single hot spots and their influence on receptors (i.e. mineral springs). Huge amounts of time and financial resources have been spent for single site investigations but, although single pollution sources could be detected, most frequently it was not possible to evaluate their influence on contaminant concentrations in relevant receptors.

Therefore MAGPlan developed and applied a different approach. Instead of the traditional single point source characterisation it focussed on the areal (or integral) characterisation of groundwater pollution. An iterative approach, building up and stepwise improving a conceptual and a numerical groundwater model simultaneously, helped us to understand the entire system with its driving forces and enabled us finally to identify the most relevant contaminant sources. The Municipal Groundwater Management Plan as a final output defines handling priorities and provides preliminary remediation concepts for five sites with a top priority need for action. Having been authorized by the City Council the Groundwater Management Plan prescribes binding measures for the period 2016 to 2026.

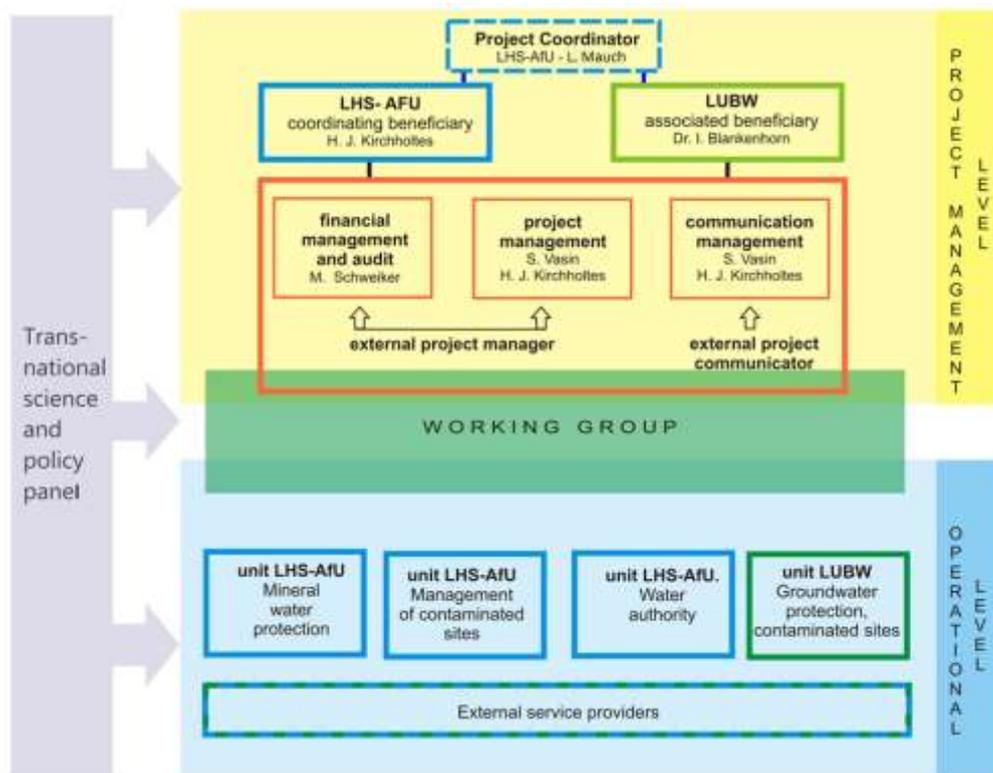
In the long term, we expect a definite improvement of Stuttgart's groundwater and mineral water quality. Approach and working methodology are transferable to other European cities with comparable challenges. Our continuous contact and knowledge exchange with the WFD - CIS (Common Implementation Strategy) working group "groundwater" ensures that our concepts, results and findings will be applied in the framework of GWD implementation and its update.

A number of innovative investigation technologies and strategic instruments were applied as "best practise" examples. Experiences are laid down in various guidance documents to be applicable and transferable for comparable challenges in other European big cities.

4. Administrative Part (maximum 3 pages)

4.1. Description of the Management System

MAGPlan is divided in six work packages. Four work packages (WP 1 – WP 4) comprise technical activities. Each of them resulted in the build-up and stepwise update of a conceptual and a numerical model, both of them describing processes of groundwater flow and contaminant transport in three dimensions. WP 5 produced guidance documents in cooperation with the associated beneficiary LUBW. WP 6 included project management and dissemination tasks. Planning for technical steps during WP 1 to WP 4 was done in specific project workshops, usually organized in the initial phase or towards the end of a work package. The project management structure (see organogram below) foresees the project management of LHS-AfU as a central contact point and project authority. It is closely linked with financial and communication management tasks, each of them fundamentally supported by an external subcontractor. A close link to the operational level is provided by regular meetings of the working group. They ensure a continuous cooperation with the associated beneficiary LUBW.



The **Project Management of LHS-AfU** (Action 6.1) in close interconnection with the associated beneficiary LUBW pursued tasks as follows: operating and conducting tendering procedures, concluding contracts with external service providers, organizing project meetings and workshops, presenting the project at conferences and in the general public. The external project manager gave general support and prepared technical specifications for tendering procedures, recommendations for assignment, compiled activity reports, prepared and moderated project meetings and workshops. Furthermore he was a consulting instance for all kind of questions, concerning technical issues, LIFE+ program matters or tendering procedures. He was involved in technical project work, thus assuring quality of work and target control for time and financial requirements.

During project lifetime, meetings took place as listed below:

- 29 meetings of the working group
- 11 technical workshops with the complete project team
- approximately 25 meetings of project management and/or dissemination teams
- at least 50 technical meetings of the operational level LHS-AfU
- four workshops of the Transnational Science and Policy Panel

A copy of the **Partnership Agreement** was delivered with our Inception Report in September 2010.

The **Financial Management** (Action 6.2), alike supported by the external project manager, compiled financial reports and payment claims, and conducted negotiations with external subcontractors, checked and payed external invoices. For target-performance comparison an excel-tool was established giving comprehensive information about status of technical measures, awarded contracts, budget and time situation. This tool was updated regularly, every two months at least.

Project budget and reporting were annually controlled by the project auditor “Rechnungsprüfungsamt”, especially concerning compliance with LIFE+ specifications, national legislation and accounting rules as well as the cities’ standard procedures.

Project Monitoring (Action 6.3)

Project monitoring tasks, operated by the project management team in close cooperation with the external project manager, were:

- target-performance comparison every two months in the course of project meetings
- short monitoring reports every six months (alternating with technical activity reports)
- three extensive monitoring reports with contents as follows: description of technical work and public relation activities, evaluation of project status in concerns of technical, time and financial requirements, description of problems and their possible solution, evaluation of LIFE+ “output indicators”, evaluation of project structures and their efficiency.

Project Communication and Dissemination (Actions 6.4 – 6.11)

The project communication manager, supported by an external subcontractor, organized information events for the general public, launched publications in the local press, and produced flyers and brochures. Main investment for dissemination was a vitreous aquifer explaining the complex hydrogeologic structure in the project area in an illustrative way. For detailed information see Chapter 5.2.

Amendment Request

An amendment request was sent to the Commission on 20/03/2013. Main technical modifications resulted in an improved reliability of the technical results and a shift of budget to the category “external assistance”. We suggested an optimized work plan and extended timetable, reacting to the necessity to adapt our strategy to a revised state of knowledge. Thus the project ended on 30/09/2015 instead of 31/12/2014. The revised grant agreement was signed by the Commission on 04/07/2013.

Concerning the project management structure, there were no major changes due to the project amendment.

4.2. Evaluation of the management system

Our project management scheme as described in the organigram above proofed its worth and enabled an efficient procedure. Of predominant importance were the regular meetings of our working group, securing a continuous interaction and knowledge transfer between the project management, communication team and the operational level. This regular communication ensured consciousness of the operational team for time and financial restrictions, when planning their next technical steps. The project management, being informed about the latest state of technical knowledge, could evaluate objectives against achieved results. Ideas and concepts for the next communication steps were discussed and evaluated by the whole project team.

A regular check of technical and financial status was done between project management and financial teams. Tendering and accounting procedures ran frictionless according to pre-established standards.

This regular cooperation also helped us to tackle and overcome technical problems and corresponding time delays. The realization of some deep drillings in densely populated urban areas with many crossing underground lines and multiple involved administrative stakeholders was a really hard task. In all cases we finally succeeded but this involved an extremely time-consuming procedure. The duration of two tracer tests in the MAGPlan area was distinctly longer than according to planning– this lengthened the time scale for these measures distinctly, although, on the other hand, the longer performance provided us with essential new findings.

Despite these unforeseeable circumstances, we managed to keep the project running and achieve our final targets in the predefined time frame.

This continuous working group, meeting every two months approximately, was accompanied (in mostly yearly intervals) by the Transnational Science and Policy Panel as an international expert group. The members of the committee gave us their critical input and challenged the further procedure. Discussions in this extended working group gave us important impulses, focusing not only on the specific situation in Stuttgart, but evaluating the EU-wide applicability of concepts and findings. The panel also included a member of the WFD - CIS (Common Implementation Strategy) working group “groundwater”.

The partnership with the associated beneficiary LUBW worked frictionless. In their role as an environmental competence authority, supporting the ministry and other administrations with their expertise, they are responsible for setting environmental quality standards in Baden Württemberg. In technical terms, both partners benefitted from this cooperation. The representatives of LUBW were enabled to integrate specific aspects and requirements of practical implementation in their guidance document. The operational team of LHS-AfU was enriched by a conceptual, objective view on their technical work. There were no significant deviations from the arrangements contained in the partnership agreement.

The cooperation with our external monitor, who visited us yearly, was very fruitful. She gave us her support and clarified upcoming questions with the LIFE commission. On 09/01/2013 the LIFE unit visited us in Stuttgart in preparation of our amendment request. The head of LIFE unit, Mr. Herve Martin, accompanied our final conference.

5. Technical part (maximum 50 pages)

5.1. Technical progress, per task

Work Package 1: General Overview, Characterisation of Groundwater Flow

Action 1.1: Data Update, Conceptual Model

Technical data originating from the years 1984 to 2010 were collected from the whole project area by investigating multiple archives. Documents like building ground expertise, monitoring records of mineral springs, investigation reports of contaminated sites, groundwater abstraction protocols, data from building projects (especially Stuttgart 21), etc... were searched for relevant information. Evaluation was done for:

- geological buildup (8.000 drillings)
- piezometric groundwater levels (1.400 groundwater observation wells)
- flow properties of aquifers (1000 pumping tests)
- hydrochemical and contaminant situation (25.000 chemical analysis, 813 potentially contaminated sites)
- groundwater levels (864 point measurements, already collected in autumn 2009)

The conceptual model was defined in its first version. This implied definition of hydro geologic units with thickness and relevant hydraulic parameters, model boundaries and boundary conditions, definition of necessary data amount to be sampled (from archives or via field investigations).

External service providers were involved for data collection, data management; also they gave their technical expertise for buildup of the conceptual and groundwater model.

Results

Project specific database established, thematic maps of groundwater level distribution and conceptual model report (updates in Action 1.7, see deliverable there).

Problems occurred / modifications compared to proposal

None

Action 1.2: Project Meeting, Initial Report

A “Kick-off” meeting “targets and strategies” was held in Stuttgart on 01/02/2011. Besides the complete project team technical experts from LHS-AfU and currently involved external service providers were invited.

Based on a general presentation of the project idea and a description of results achieved so far, the workshop focused on a definition and discussion of project targets and respective technical tasks. We also discussed our communication strategy for an efficient and far-reaching dissemination and developed ideas and visions for an implementation of the vitreous aquifer concept.

An initial project report summarized the results of the data management in Action 1.1.

Results

Initial project report (see Progress Report No.1, Annex 1a), workshop protocol

Problems occurred / modifications compared to proposal

None

Action 1.3: Installation of Monitoring Wells

Drilling measures for six new observation wells were done between May and July 2011. They were positioned in areas with lacking knowledge of vertical flow mechanisms between shallow and deep aquifers. Their drilling depths were as follows:

	Depth [m]	Aquifer
MAG 1	33,20	Lower Keuper
MAG 2	64,00	Lower Keuper
MAG 3	62,25	Lower Keuper
MAG 4	77,35	Lower Keuper
MAG 5	28,30	Lower Keuper
MAG 6	49,50	Lower Keuper

Altogether approximately 315 drilling meters were done. Sample taking and short well tests were performed in the course of drilling.

In September 2011, a ground investigation offered the opportunity to build an additional well. The well with a drilling depth of 19 m was called MAG 7.

Results

Seven new wells completed (instead of six proposed), final documentation (see Mid-Term-Report, Annex 8.4.1)

Problems occurred / modifications compared to proposal

None

Action 1.4: Single Site Investigations

As a major result of the data update of Action 1.1, 21 highly contaminated sites could be distinguished with a prevalent need for further investigation and evaluation. For these, 19 individual site review reports were compiled, partly summarizing two individual sites in one report. These reviews comprise a comprehensive description, graphical illustration and interpretation of all available data and working hypothesis, based on current state of knowledge. As an intermediate step from point investigation to large scale modeling, they proved to be building bricks for the extensive conceptual model.

Results

19 individual site review reports (see Progress Report No. 2, Annex 10.2.1)

Problems occurred / modifications compared to proposal

None

Action 1.5: Groundwater Monitoring

An extensive groundwater monitoring campaign with a sampling of 355 wells and springs spread all over the MAGPlan project area was organized and performed from autumn 2011 to March 2012. Three sampling teams worked simultaneously.

Water distraction times to assure a representative sample quality varied between 20 minutes and two hours. On-site measurements were reported in a sampling protocol compiled for each individual well.

Samples were taken to an analytical laboratory for standard hydro-chemical and contaminant (CHC) analysis. Coincidentally part of drawn samples was used to perform required special analysis for isotopes (see Action 2.1) and tracer analysis (see Action 2.3). So there were three different laboratories involved. Bundling sampling activities in this Action saved time and financial resources.

The first part of the groundwater monitoring campaign, with a measurement of groundwater levels in 864 piezometers, was performed already in autumn 2009, previous to MAGPlan.

Results

Groundwater levels from 864 wells, results of chemical analysis from 355 wells, groundwater contour maps see Action 1.6, Documentation see Mid-Term-Report, Annex 8.4.2

Problems occurred / modifications compared to proposal

None

Action 1.6: Buildup of 3D-Visualisation

Abundant data from field investigations are generally allocated to distinct horizontal and vertical locations. To allow a spatial interpretation for the conceptual model, it was necessary to interpolate and present them in clearly arranged two-dimensional, layered maps. With the help of an external subcontractor maps we produced as follows:

- 12 maps showing distribution of hydraulic conductivities
- 5 maps showing the state of elution for gypsum strata in their spatial distribution
- 1 geologic map (strata layering and distribution)
- 11 groundwater contour maps
- 1 map showing difference of hydraulic potential between different aquifers
- 26 distribution maps for hydrochemical parameters, groundwater age, tracer substances, etc.

Results

56 maps for parameter distribution in eight groundwater storeys (digital version see Annex 7.2.2).

Problems occurred / modifications compared to proposal

None

Action 1.7: Data Management, Update of Conceptual Model

The project specific data base was updated in regular intervals according to results of new field investigations partly with the help of external service providers.

The conceptual model, having been defined in its basic dimensions in Action 1.1, was further extended and elaborated on base of recent results and findings. Its main target was to provide understanding for the extremely complex geologic conditions in Stuttgart, with

eight different aquifer strata, a large number of fault zones and additional karst formations. Description and quantification of the main driving factors concerning horizontal and vertical flow regimes gave the fundament for the subsequent buildup of a numerical groundwater model.

Results

Updated data base, thematic maps see Action 1.6, conceptual hydrogeologic model report (see Mid-Term-Report, Annex 8.4.3), Report: Hydraulic Characterization of Stuttgart's aquifers (see Annex 7.2.3)

Problems occurred / modifications compared to proposal

None

Action 1.8: Buildup and update of groundwater model

Buildup of the numerical groundwater model with 17 vertical model strata and 6.450.764 active model cells started in April 2011. From the very beginning numerical modelers were in a continuous discussion and permanent knowledge exchange with the conceptual model authors. Especially the function of fault zones with their possible vertical interaction between aquifers was an important factor to be discussed.

Calibration was performed on basis of a measurement of groundwater levels in 864 wells (see Action 1.5).

Results

Calibrated groundwater flow model, described in final documentation: "Numerical Model for Groundwater Flow" (see Annex 7.2.4)

Problems occurred / modifications compared to proposal

None

Action 1.9: Project meeting, Summary report groundwater flow

A final workshop for WP 1 took place on 28/02/2012. Results of WP 1 were presented and measures for WP 2/WP 3 discussed. Participants were the operational and project management teams of LHS-AfU and LUBW, external service providers for project management and communication, external service providers currently involved.

A comprehensive Summary Report (extensive and short version in English), describing and evaluating measures and activities from WP 1 was delivered in February 2012 and updated in December 2014.

Results

Summary Report WP 1 and workshop protocol, see Annex 7.2.5

Problems occurred / modifications compared to proposal

None

Work Package 2: Contaminant Load and Transport Processes

Action 2.1: Integral Pumping Tests, Additional Features of Hydraulic Characterization, Isotope Fingerprinting

IPTs were performed as follows:

- seven IPTs in MAG 1-MAG 7, lasting four days each, performed in August 2011. During each IPT, the water level was observed in two adjacent wells. Water samples were taken in regular intervals and investigated in different laboratories for hydrochemistry, contaminant parameters, isotopes and tracer substances. The IPTs were evaluated for an assessment of hydraulic aquifer properties.
- one extensive IPT, lasting two weeks, performed in July 2011:
Well P 172 is located in Stuttgart city center, in the immediate vicinity of a fault zone and of predominant importance to understand groundwater flow processes between contaminated sites located in Stuttgart-South and the main station. The IPT lasted two weeks with corresponding observation of eleven surrounding wells. Water samples were taken in regular intervals and investigated in different laboratories for hydrochemistry, contaminant parameters, isotopes and tracer substances. The IPT was combined with the application of two additional features of advanced pumping test technology:
 - High-speed-measurements performed with a special gauge, measuring pressure variations in a frequency of 100 measurements per second. These gauges were installed in the pumped well and three observation wells to cover the earliest time response of pressure to pumping
 - Long-term logging of pressure variations due to natural influences like earthquakes, earth tides and air pressure fluctuations, installed in one observation well and running for two years with a measurement frequency of one value per second. Results were collected and evaluated monthly

IPT data were evaluated to specify hydraulic aquifer parameters. The development of CHC concentrations versus time in the pumping wells during each IPT was used to delineate the spatial contaminant distribution and quantify emitting contaminant loads. Newest technologies with a very high measurement resolution (100 values per second) provided the possibility to characterize the fractured aquifer “Upper Muschelkalk” in detail with its hydraulic features and groundwater flow properties.

Results

Evaluation of aquifer properties, spatial extent of contaminant plumes, laid down in reports: Hydraulic Characterization of Stuttgart’s aquifers (Annex 7.2.3), final documentation MAG 1-MAG 7 (see Mid-Term-Report, Annex 8.4.1)

Problems occurred / modifications compared to proposal

None

Action 2.2: Technology Verification Isotopic Fingerprinting

Isotopic Fingerprinting is a key method for identification of source-plume-relationships and degradation pathways of CHC. As such it is an important part of the investigation program in MAGPlan. As this method is still struggling for broad acceptance, EU-ETV technology verification offered an option to overcome this barrier. The general target of

verification EU-ETV is to enhance market entrance for providers of new innovative environmental technologies. The EU ETV pilot program was launched in 2011; first verification bodies were in full operation since December 2012.

To initiate the procedure a kick-off-meeting took place in Stuttgart on 06/05/2013 with three vendor laboratories and two members of DHI group, a Danish service provider for technology verification. Attending vendors showed to be very different in their attitude, market ambitions and targets. Although both beneficiaries took intensive efforts, enhanced by convincing arguments from representatives of DHI group, it was finally not possible to achieve a consensus. Considering the expenses to be expected, there was eventually no willingness of service providers to participate in verification costs.

As our originally intended realization via EU-ETV could not be followed, we had intensive discussion and finally found another way to realize this target. In cooperation with selected experts from University of Tuebingen, we established a comprehensive compendium to be used as guidance for administrations and service providers. Based on an initial research it describes and evaluates currently applied procedures and gives recommendations for a standardized working method. This covers field sampling, analytical performance as well as quality standards for a technical correct interpretation of results. Frequent mistakes and related strategies to avoid them are shown. The practicability, laid down in the guidance document, has been evaluated in a test series between commercial laboratories on samples from a representative MAGPlan location.

Results

Verification of innovative technology by establishing a guidance document (see Annex 7.2.6)

Problems occurred / modifications compared to proposal

Technical procedure: Instead of following the EU-ETV-procedure we reached the target of technology verification by establishing a generally applicable guidance document providing standards for performance. Introducing a new method for quality control of laboratory results it secures a better reliability. Thus, although the product is different, we could meet the aims of EU-ETV verification.

Time: Due to this altered procedure, we were not able to keep the scheduled timeframe: On the one hand, the EU-ETV program started their operation in December 2012, distinctly later than expected. On the other hand we needed some time to look for feasible alternatives and partners to realize them. Finally, the set-up of the guidance document in several steps and the cooperation with involved parties was very time-consuming.

Budget: Budget for this Action was distinctly lower as proposed. The verification of this innovative technique by Tuebingen university, having an own scientific interest in this matter and thus exploiting their own resources, could be done at a lower price as the originally planned, cost-intensive EU-ETV procedure.

Action 2.3: Anthropogenic Tracer Tests

Sampling for tracer analysis (CFC and SF6) was jointly done with the activities of Actions 1.3, 1.5 and 2.1 – evaluation of results was done in course of the conceptual model reports of Actions 2.5 and 3.5

Results

Analytic results as input parameters for the reactive transport model

Problems occurred / modifications compared to proposal

None

Action 2.4/Action 2.6: Build-up and Update Numerical Transport Model

Based on the validated groundwater flow model (Action 1.8), a numerical transport model was developed and further on calibrated by tracer data (Tritium, SF6). In a next step, the summarized CHC concentration (no differentiation between single components) was integrated as a transport variable. The calibration was done on base of temporal concentration curves ranging from 1960 to 2010. As a result, the model was able to depict the overall input and release of contaminant loads since 1960 in a plausible magnitude.

Results

Calibrated numerical flow and transport model, depicting contaminant transport in different aquifers, described in final documentation: “Numerical Model for Contaminant Transport” (see Annex 7.2.4)

Problems occurred / modifications compared to proposal

None

Action 2.5: Data Management, Update of Conceptual Model

The project specific data base was updated in regular intervals according to results of new field investigations partly with the help of external service providers.

In addition to the conceptual groundwater flow model established in Action 1.7, a conceptual contaminant model was established and gradually updated by new findings. Laid down in an extensive report it describes abundant data and results concerning CHC concentrations, general hydrochemistry, isotopic fingerprinting results, tracer analysis like CFC and SF6 in a comprehensive evaluation and the aim to derive an understanding of the whole system. Thus working hypothesis could be derived for:

- the identification of contaminant sources
- the geometry and delineation of contaminant plumes
- vertical interactions between different aquifers
- the age of contaminants

Results

Updated data base, conceptual contaminant model (including numerous thematic maps) laid down in extensive report (see Progress Report No.2, Annex 10.2.3)

Problems occurred / modifications compared to proposal

Costs for this Action are higher as proposed, as the amount of data recovered from archives had been significantly larger than expected. Consequently build-up of the conceptual model with corresponding evaluation was also extremely complex and time consuming. Correspondingly parts of the work had to be delegated to external service providers, as available staff resources were not adequate to the amount of efforts required.

Action 2.7: Project Meeting, Summary Report Contaminant Load and Transport

The final project workshop WP 2, comprising the whole MAGPlan-team including selected external service providers, took place on 25/09/2012. The meeting focused on a general overview about major contaminant plumes and their delineation and discussed indicators for local vertical exchange processes derived from distribution of hydrochemistry. Although the numerical model was able to plausibly reproduce the overall contaminant balance, the detailed reproduction for essential areas and critical sites still showed a lot of inconsistencies. This required an intensive discussion for selected areas in subsequent meetings.

A Summary Report for this Work Package (one extensive and one short version in English) was presented on 30/09/2012 and updated on 31/07/2015 (also downloadable from project website).

Results

Summary Report Contaminant Load and Transport (see Annex 7.2.7), Meeting Protocol 25/09/2012, List of Participants, Meeting Protocol 25/07/2012 with Detailed Action Plan WP 3 (see Progress Report No. 2, Annex 10.1.1).

Problems occurred / modifications compared to proposal

None

Work Package 3: Contaminant Degradation and Natural Attenuation Processes

Action 3.1: Installation of Monitoring Wells

This Action was realized in two steps. 284 drilling meters for wells MAG 8 – MAG 12 were done in 2012 and 2013. Another 279 drilling meters were done in 2014 and 2015 (MAG 13-MAG 18). An overview is given below:

	Depth [m]	Screened Aquifer
MAG 8	91,5	Upper Muschelkalk (two different depth horizons)
MAG 9	27,6	Lower Keuper
MAG 10	34,0	Lower Keuper
MAG 11	70,2	Upper Muschelkalk
MAG 12	61,0	Upper Muschelkalk
MAG 13	49,9	Lower Keuper
MAG 14	49,0	Lower Keuper
MAG 15	48,0	Lower Keuper
MAG 16 N	71,8	Upper Muschelkalk
MAG 17	40,2	Medium Keuper
MAG 18	20,2	Medium Keuper

These 563 drilling meters answered key questions concerning:

- following of flow paths, especially through deeper groundwater storeys
- delineation of contaminant plumes
- verification of the connection between specific contaminant sources and the mineral springs
- detection and delineation of contaminant sources for remediation planning.

The drillings were accompanied by hydraulic tests and depth specific samples in the open boreholes. MAG 8 was screened in two different horizons of “Upper Muschelkalk” to evaluate depth specific aquifer properties and contaminant distribution pathways.

MAG 16 was originally planned near Stuttgart’s main station. Due to a great number of crossing lines in a few meters depth, whose penetration was not allowed, this proved to be unfeasible. These lines had not been known from available plan documents. Extensive excavation around two potential drilling points did not lead any further. A photo-documentation may be seen from Annex 10.2.2 in Progress Report No 3. So we gave up the intention of drilling in this area.

Investigating the downstream of contaminant site Rümelinstraße 24-30 with drilling MAG 13-15 identified the need for another deep drilling along the eastern site boundary. MAG 16N, penetrated in the mineral water aquifer “Upper Muschelkalk” helped to complete the conceptual understanding and explained mechanisms of vertical contaminant transport in this area in the immediate upstream of the medicinal mineral springs.

The construction quality of MAG 13, MAG 17 and MAG 18 was controlled by an investigation campaign by specified geophysical methods. No major defects could be detected. The application of these innovative methods proved to be an appropriate method to control the quality of wells on occasion.

When drilling MAG 17, a very deep water table could be detected, which allowed pumping tests in the open borehole. After well construction, this piezometer fell dry.

Although all drilling results were used and evaluated by MAGPlan, the financing of the drillings happened partly on behalf of the municipal budget.

Results

Eleven wells completed (instead of 10 proposed). Documentation in reports (Annex 7.2.8).

Problems Occurred / Modifications Compared to Proposal

Time schedule:

A delay of several months was caused due to the necessary relocation of drilling point MAG 16.

Action 3.2: Additional Investigations

This Action comprised a bundle of activities, as described in detail below:

- **Sampling Campaigns in August/September and November/December 2012**
Two sampling campaigns with corresponding chemical analysis were initiated in 2012. The first one took place in August/September 2012 and covered 18 wells in the south of Stuttgart; samples were analyzed for tracer substances. The second campaign was performed in November/December 2012 and included a sampling of 25 wells as well as one short pumping test in two separate aquifer horizons of one observation well. Samples were analyzed for standard parameters, isotopes and tracer substances.
- **Integral Pumping Tests in MAG 8 to MAG 12**
IPTs were performed in MAG 9, MAG 10, MAG 11 and MAG 12 in June and July 2013. Design was done on base of well performance tests in advance. Pumping time in each well took four days with additionally several observation days before and after the tests to watch development of water levels. Water samples were taken in regular intervals and investigated in different laboratories for hydrochemistry, contaminant parameters, isotopes and tracer substances.

IPTs were accompanied by a special online analysis of CHC contaminants, providing the possibility to observe concentration development at once without having to wait for laboratory results. Thus decisions for possible modifications or alterations of pumping performance could be taken on the spot.

In MAG 8 a packer was installed to test two different aquifer horizons. The first IPT in this well was performed in July 2013. It gave indications that hydraulic parameters differed from our pre-assumptions, resulting in a groundwater yield higher than anticipated. Also CHC traces were detected in the lower aquifer. Therefore a second integral pumping test in MAG 8 was necessary.

The second pumping campaign was undertaken in October/November 2013 with longer duration and higher pumping rates. Again the well was equipped with a packer, so the upper and lower aquifer horizon could be tested separately. Based on this variation of pumping rates we were able to gain well-founded hydraulic data for both aquifer horizons. Covering a distinctly wider distraction zone CHC results of the first test were confirmed.

- **Extensive Field Tracer Test in Upstream Zone of Mineral Springs**

To investigate aquifer and contaminant transport properties and delineate flow paths in the immediate upstream of the mineral springs, a large scale tracer test was started in 2013. Design of the test was based on results of a former test performed in 1998 and 1999. To avoid a staining of mineral spa water, we chose the invisible tracer substance Natrium-Naphthionat. A predefined amount was induced into MAG 11 on 22/08/2013. Subsequent sampling was performed on eleven downstream wells and mineral springs.

The tracer could be detected in three downstream locations – but its transfer took distinctly longer than anticipated. This helped to improve our conceptual understanding and track flow paths on a new basis. Findings have also been integrated in our numerical groundwater model.

Although essential conclusions could already be drawn, we want to finalize the test according to the predefined procedure. We therefore decided to lengthen the test until September 2015 on behalf of municipal budget.

- **Detailed Investigation of Drilling Cores**

A detailed investigation of selected drilling cores from Upper Muschelkalk was done by University of Erlangen. The aim is to understand properties of the rock matrix like porosity and elasticity which are critical for groundwater flow conditions. The tests were done by special ultrasonic measurements. The results were mathematically transferred to magnitudes of permeability thus allowing a plausibility check to the numerical model's assumptions.

- **Application of Cl-CSIA**

The Compound Specific Isotope Analyses for Carbon Isotopes (C-CSIA) is a meanwhile established and widely applied method. It delivers satisfactory results in most cases. But sometimes complicated constellations require an additional tool.

We therefore applied a combination of C-CSIA and a new method, called Cl-CSIA, on some test samples. This method, still in the state of development and applied only at universities, uses the fractionation of chlorine- instead of carbon-isotopes. Cl-CSIA is a promising tool for a better characterization of plumes and identification of sources. The practical implementation however is still limited due to the high detection limit of 50 µg/l. This is not sufficient for plume characterization.

Confirming and expanding the results of former C-CSIA investigations we could verify the existence or non-existence of biological degradation. Furthermore it was possible to define primary signatures as characteristic isotopic fingerprints for specific contaminant sources.

Results

Documentations for:

Integral Pumping Tests MAG 8 – MAG 12 (see Progress Report No. 3, Annex 10.2.3)

Extensive Field Tracer Test (Annex 7.2.9)
Detail Investigation of Drilling Cores, Report (see Progress Report No. 3, Annex 10.2.4)
Application of Cl-CSIA, Report (see Progress Report No. 3, Annex 10.2.5)

Problems Occurred / Modifications Compared to Proposal

Time schedule:

This Action took longer than anticipated due to the extending duration of the large scale tracer test.

Action 3.3: Contaminant Degradation Tests

The existence of microbial degradation processes and the knowledge of pathways are essential for a comprehensive understanding and remediation planning. Conclusions for our groundwater model are drawn from a combined interpretation of hydrochemistry and isotopic fingerprinting results. Microbial laboratory tests are a tool to finally verify these assumptions.

We originally planned to perform tests along predefined transects of four major contaminant plumes, running from contaminant sources to mineral springs. The procedure was tested in two piezometers, one for aerobic and one for anaerobic conditions. On base of results we modified the original concept and led our focus on aerobic degradation processes especially the investigation of frame conditions like nutrients availability, inhibiting factors, etc. Twelve groundwater samples were taken from three different areas to be tested in three test campaigns under different nutrient and mineral conditions.

Results could confirm the essential assumptions of microbial degradation zones, laid done in milieu mapping maps (see Action 3.5). Especially important was the verification of natural TCE degradation occurring near the main station and explaining the definite reduction contaminant loads in this area. The final report for this Action was completed on 01/04/2015.

Results

15 tests (2 anaerobic and 13 aerobic) tests performed for the evaluation of an aerobic/anaerobic natural attenuation potential in distinct areas, final documentation see Annex 7.2.10

Problems Occurred / Modifications Compared to Proposal

Time: This Action took distinctly longer than anticipated. This is mainly due to the fact, that we had not realized the necessity for a well-founded investigation concept to achieve results for a regional understanding. Compilation of this concept and its later modification and also the two step procedure with preceding reference phase took much more time than originally anticipated.

Budget: Budget for this Action was distinctly lower as proposed. At the time of our proposal, this innovative technique was still in the state of methodological development. Meanwhile, although mainly practiced in research institutes, there are also some commercial service providers abundant. This fact enabled a distinct cost reduction in comparison to the original assumptions.

Action 3.4: Technology Verification of Contaminant Degradation Tests

Canceled, see Amendment Request

Action 3.5: Update of Conceptual Model, Data Management

The project specific data base was updated in regular intervals according to results of new field investigations partly with the help of external service providers.

The conceptual model report, as provided in Action 2.5, was updated by additional elaborations as follows:

- Comprehensive evaluation of isotope fingerprinting results
- Comprehensive evaluation of all historic or current integral pumping tests within the MAGPlan area
- Specific mapping of groundwater milieu conditions and isotopic fingerprinting results was, delineating zones of different microbial degradation conditions. It served as a preparation for Action 3.3 and served as input for the numerical groundwater model.
- Comprehensive evaluation of tracer substance (SF 6 and CFC) investigations

Results

Updated data base, upgraded conceptual contaminant model, laid down the following documentations:

Summary Report Isotope Fingerprinting, Annex 7.2.11

Summary Report Integral Pumping Test Evaluation, see Progress Report No.3, Annex 10.2.7

Report Milieu Mapping, see Progress Report No.3, Annex 10.2.8

Evaluation of CFC distribution for two selected areas, Annex 7.2.12

Evaluation of SF6 spatial distribution, Annex 7.2.13

Problems Occurred / Modifications Compared to Proposal

Time schedule: This Action took longer than anticipated, as its evaluations were partly based on results from Actions 3.2 and 3.3.

Budget: Costs for this Action are distinctly higher as proposed. This is due to our initial underestimation of efforts for technical work. In this Action, we evaluated WP 3 evaluations for a consistent interpretation with findings from WP 1 and WP 2. This process as well as the “translation” for the numerical model afforded a lot of time and financial resources. Major elaborations had to be delegated to external service providers, as available staff resources were not adequate to the amount of efforts required.

Presentation of conceptual contaminant model: A comprehensive and holistic evaluation of all results has been done in the framework of our final project documentation (Action 6.6). Therefore, within Action 3.5, we decided to only add additional single evaluations to the conceptual model report from Action 2.5 instead of compiling a completely new comprehensive report.

Action 3.6: Update of Groundwater Model, 3. Model Run

The numerical contaminant transport model of Action 2.4/2.6 was expanded and equipped with additional elements. Transport velocities were simulated on base of groundwater flow additional sorption and retardation factors for specific contaminants. Simulation was done not only for the sum of CHC, but for each of the components (PCE,

TCE, etc.) as a single parameter. As a further step, based on the mapping of milieu degradation conditions (Action 3.5), microbial degradation processes were integrated into the model. The model now delineates between zones of aerobic, anaerobic or lacking degradation. Degradation rates as input parameters were estimated on base of plausible assumptions and calibrated versus occurring concentration differences. Delineation and allocation of these zones were discussed in frequent working sessions, securing a compliance with the conceptual model understanding.

This numerical transport model was updated by results of current isotopic fingerprinting, forensic and IPT data. The current field tracer test (Action 3.2) with its actual measuring results was replicated and depicted correctly.

Results

Fully operational multispecies reactive transport model as described in Final Documentation: “Numerical Model for Contaminant Transport” (see Annex 7.2.4)

Problems Occurred / Modifications Compared to Proposal

Time schedule:

This Action took longer than anticipated, as its evaluations were partly based on results from Actions 3.2 and 3.3.

Action 3.7: Project Meeting, Summary Report Degradation and Natural Attenuation

The final WP 3 workshop took place on 26/09/2013. Current working hypothesis about predominant hydraulic structures and flow paths were drawn from results of recent IPT's in MAG 8 to MAG 12 (Action 3.2). Recommendations for targeted further investigations were derived from remaining knowledge gaps. An Action plan for WP 4 was drafted and finally established in subsequent sessions. It concentrated on six to seven key sites with a suspected major influence on receptor. Its target was to fill remaining knowledge gaps and to establish the preconditions for remediation planning.

The final report for WP 3 was delivered on 13/04/2015.

Results

Action plan for WP 4, focusing on presumable remediation areas, workshop protocol (see Progress Report No. 3, Annex 10.2.10), summary report contaminant degradation and natural attenuation, see Annex 7.2.14

Problems Occurred / Modifications Compared to Proposal

Time schedule:

Due to lengthened execution times in Actions 3.2 and 3.3 compilation of the final report was delayed until April 2015.

Work Package 4: Remedial Options and Management Plan

Action 4.1: Preselection of Remediation Methods

Feasibility Study

An extensive study on base of literature research investigated possible remediation techniques, their frame conditions and possible restrictions, risks to be observed, former reference projects, magnitude of costs. The methods were evaluated for their applicability in Stuttgart with respect to underground conditions and possibilities of operation in a densely populated urban environment.

Identification of Critical Sites

21 sites with a high contamination potential had been characterized in detail by single site reviews (Action 1.4). Further evaluation was now done in cooperation between conceptual and numerical model to evaluate the risk of a contamination transfer into deeper groundwater storeys. Thus nine critical sites could be identified with a definite risk of emission into the aquifers Unterkeuper and Oberer Muschelkalk.

Results

Feasibility study remediation methods (Annex 7.2.15), final documentation: “Numerical Model for Contaminant Transport” (see Annex 7.2.4)

Problems Occurred / Modifications Compared to Proposal

Further evaluations on base of numerical model calculations for an integral remediation concept were done within Action 4.5 and not, as originally intended, within Action 4.1. This enabled us to take in account additional findings of field investigations and conceptual model evaluations acquired in Actions 4.2 and 4.3.

Action 4.2: Additional Investigations

This Action comprised a bundle of activities to gain additional knowledge required for the evaluation of remedial options and contaminant transport prognosis, as described in detail below:

- **Integral Pumping Tests**

For a further characterization of hydraulic properties and contaminant transport parameters eight IPTs were performed. Design was done on base of well performance tests in advance. Pumping in each well was accompanied by several days of observation before and after the tests to watch development of water levels. Water samples were taken in regular intervals and investigated in different laboratories for hydrochemistry, contaminant parameters, isotopes and tracer substances. We have summarized the key data in the table below:

well	MAG 12	Br 7	B 8	MAG 13	MAG 14	MAG 15	MAG 16 N	MAG 18
Date of IPT	23.04.-01.05.2014	09.04.-16.04.2014	15.10.-25.10.2014	23.09.-29.09.2014	09.09.-15.09.2014	16.09.-22.09.2014	23.03.-01.04.2015	11.08.-20.08.2014
aquifer	mo (Trigonodus)	mo (Trigonodus)	mo (Trigonodus)	ku (Lingula)	ku (Lingula)	ku (Lingula)	mo (Trigonodus)	mgh (Mittlerer Gipshorizont)
pumping rate [l/s]	10	8	3,7	2	0,75	1,5	6,7	0,0026
pumped water volume [m ³]	6.930	4.863	3.175	733,75	274,05	526,19	4.004	1,9
number of observation wells	9	9	3	12	12	12	16	2
analysed parameters								
hydrochemistry	x	x	x	x	x	x	x	x
CHC-concentration	x	x	x	x	x	x	x	x
CHC-isotopes	x	x	-	x	x	x	x	-
tracer substances: SF ₆ , FCKW	x	x	x	x	x	x	x	-
stable isotopes: ¹⁸ O/ ² H	x	-	x	x	x	x	x	-

As MAG 17 had fallen dry after well construction, it could not be investigated by an IPT. IPT data were evaluated to specify hydraulic aquifer parameters. Furthermore, the development of CHC concentrations versus time in the pumping wells during each IPT was used to delineate the spatial contaminant distribution and quantify emitting contaminant loads. The evaluation of IPTs MAG 13-MAG 18 was done within the framework of specific site assessments (Action 4.3), providing important input about the delineation of contaminant source zones.

- **Thermoflow-Investigation**

Usually monitoring wells are investigated by pumping the whole screened areas, thus receiving average values for hydraulic permeability and chemical concentrations for a complete depth interval. A special innovative method, designed to get depth specific data was applied in two wells of Upper Muschelkalk (MAG 8 and P 174) in March 2014. The method, called Thermoflow, works by a depth-specific measurement of groundwater temperature, which is inversely proportional to the velocity of groundwater flow. In both wells, depth zones of different flow properties could be detected and delineated.

- **Sampling Campaign Rosensteinpark**

A sampling campaign for tracer substances (CFC) in the immediate upstream of the mineral springs was done on 25 wells from 05/03 to 11/03/2014. It helped to verify a correlation between the contaminated site Mittnachtstraße 21-25 and the low concentrated mineral springs.

- **Tracer Test in the City**

To trace groundwater flow pathways in the downstream of well P 172 near the old castle, a further tracer test was done, using the invisible, chemically inert gas SF₆. In August 2014, the substance was induced in well P 172 into three different depth horizons. Sampling campaigns in the subsequent months measured ten downstream piezometers and also included selected mineral springs. The well MAG 8, which is screened in two different depth horizons, was additionally investigated by a packer test, allowing a depth specific sampling in both horizons.

The tracer transport took distinctly longer than anticipated; a last sampling campaign (on behalf of MAGPlan) was done in May 2015. As the results show, flow paths near the old castle are distinctly influenced by a west-east-running fault structure. It causes a separation into two flow paths: a major one in northwestern and a minor one, passing the fault in northern direction. This principle could be reproduced in the numerical model. This knowledge of predominant flow paths was of primary relevance for the holistic remediation planning as done in Action 4.5.

Results

Evaluation of remediation concepts on base of findings, documented in reports as follows:

Documentations of IPT performance and evaluation: MAG 12 and Well 7 Dinkelacker (see Annex 7.2.16), B 8 (see Annex 7.2.17), MAG 13-15 (see Annex 7.2.17), MAG 16N (see Annex 7.2.18), MAG 18 (see Annex 7.2.22)

Documentation Thermoflow (see Progress Report No.3, Annex 10.2.12)

Documentation Sampling Campaign Rosensteinpark (see Annex 7.2.20)

Documentation tracer test SF6 (see Annex 7.2.21)

Problems Occurred / Modifications Compared to Proposal

The necessary relocation of MAG 16 as described in Action 3.1 caused a delay of several months. This delayed the subsequent investigations accordingly. Also, as explained above, performance time of the tracer test was distinctly longer than anticipated.

Action 4.3: Conceptual Remediation Model, 3D-Visualisation

Conceptual Remediation Model

In preparation for the Groundwater Management Plan and based on elaborations of Action 1.4, we described each of the nine critical sites in an extensive report, hereby focussing on remediation aspects. The feasibility study from Action 4.1 helped us to evaluate different remediation options for each of the nine sites. This concept, developed in a first draft in September 2014, was continuously improved up to its final state as a framework remediation concept, presented to the City Council as a part of the Groundwater Management Plan in July 2015.

Update of Conceptual Contaminant Model

The Conceptual Contaminant Model from Action 3.5 was further updated by specific evaluations for the crucial areas, based on results from drillings MAG 13 to MAG 18 and corresponding field investigations. An updated comprehensive evaluation of isotope fingerprinting results was done on base of current results. Important aspects of these specific elaborations are described below:

Site assessment Rümelinstraße 24-30:

The former tank farm with an emission of approximately 130 g of CHC per day is located in Stuttgart North, in the direct upstream of the medicinal mineral springs. A hydraulic safety measure was initiated in 2010, but its efficiency is not satisfying, as there is still a definite emission into deep groundwater storeys. All investigation results from this site, together with results of the drillings MAG 13-15 as well as MAG 16N, were fed into a comprehensive conceptual site model. This helped to achieve a better understanding of the driving mechanisms. Obviously the migration of contaminants into deeper aquifers takes place along an existing fault structure near the eastern site boundary. So part of the contaminated water sinks into deeper aquifers before it can be entrapped by the running remediation measure. Thus the next steps will focus on a relocation and optimization of the current measure with the aim to increase its efficiency significantly.

Site assessment Rotebühlstraße 171:

The former dry cleaner with an emission of approximately 100 g CHC per day is situated in Stuttgart South. The location of the contaminant source could be detected around an old operation well which was presumably used for waste disposal. A hydraulic safety

measure initiated in 2010 led to a definite reduction of emitting contaminant loads, but it could not cover the whole contaminant downstream. In order to optimize the remediation and improve the delineation of the primary contaminant source the drillings MAG 17 and MAG 18 were done. As the measured concentrations show, they catch part of the contaminant plume, but not its bulk fraction. Still it has been possible to distinctly narrow the possible downstream migration corridors.

Comprehensive evaluation of fingerprinting results:

This expertise finally verifies the relationship between specific contaminant sites and the relevant receptors on base of measured isotope signatures. Isotope measurement results from WP 4 helped to update and finalize important findings about contaminant degradation processes in the project area.

3D-Visualisation

Dynamic Online Visualization

For an efficient communication within the technical project team it is important to visualize results of the numerical model in a transparent manner, enabling participants to understand the whole system and not only giving detail extractions. We therefore developed the online visualization tool MAG-IS. It works on base of google maps and shows modelling results two- or three-dimensional. For each single strata graphic illustrations informing about aquifer properties, contaminant concentrations, microbial degradation zones, etc. can be switched on or off by demand. The tool also enables to evaluate the quality of calibration by showed measured versus calculated time concentration curves for selected wells. It is also possible to create vertical profiles on demand to get a spatial understanding of strata buildup, hydraulic potentials and contaminant distribution. The application of this tool is documented in a users' manual.

Static Visualization

Data sets gathered from data acquisition and field investigations were interpolated and presented in maps, cross-sections and graphical illustrations. They were regularly updated during project lifetime. Several semi 3D-elaborations were done in course of our final project documentation (see Action 6.6). A block diagram was produced for the vitreous aquifer and used for the second newsletter and strata model.

Results

Conceptual remediation model – first draft (final version see Action 4.5, framework remediation concept), 41 maps for parameter distribution, 3D and semi 3D images laid down for a conceptual understanding,

online visualization tool as an interdisciplinary communication platform, laid down in reports as followed:

Conceptual contaminant model: Site assessment Rümelinstraße 24-30 (see Annex 7.2.22)

Site assessment Rotebühlstraße 171 (see Annex 7.2.23), Comprehensive evaluation of isotope fingerprinting results (see Annex 7.2.24)

Dynamic online visualization – manual MAG-IS (see Annex 7.2.25)

Static visualization – maps and images (see Annex 7.2.2)

Problems Occurred / Modifications Compared to Proposal

Time: The necessary relocation of MAG 16 as described in Action 3.1 caused a delay of several months. This delayed the corresponding investigations and subsequent investigations accordingly.

Budget: Costs for this Action are distinctly higher as proposed. This is due to our initial underestimation of efforts for technical work. In Action we further extended the elaborations from conceptual model by additional evaluations, based on multiple data and laboratory results obtained from investigations. During WP 4 we finally managed to describe and understand the whole system. Valuable technical discussions were done on the presentation of specific aspects. Both new graphical illustrations and a modification of existing maps for a more transparent description were needed. Results have been laid down in our final project documentation.

All this work implied tremendous manpower efforts – which we had underestimated in advance. Major parts had to be delegated to external service providers, as available staff resources were not adequate to the amount of efforts required.

Presentation of conceptual contaminant model: A comprehensive and holistic evaluation of all results has been done in the framework of our final project documentation (Action 6.6). Therefore, within Action 4.3, we decided to only add additional single evaluations to the conceptual model report from Action 2.5 instead of compiling a completely new comprehensive report.

Action 4.4: Project Meeting, Summary Report Remedial Options

Two project workshops were held in autumn 2014 to prepare the necessary decisions for the Groundwater Management Plan, fix the strategic procedure and prepare cornerstones for the final project documentation (see Action 6.6).

On 17/10/2014 participants were asked for their personal statement about the next necessary steps: targets, necessary prognosis/scenarios to be calculated, way of documentation, remaining open questions. Furthermore the key data for each single of the nine priority sites were finally checked and discussed between conceptual and numerical modellers. On 07/11/2015 we found a way to describe the key systems and driving processes most efficiently by identifying three core areas influencing different receptors.

The final report for WP 4 was delivered on 31/08/2015.

Results

Workshop protocols, Final report remedial options see Annex 7.2.26

Problems Occurred / Modifications Compared to Proposal

Budget for this Action was distinctly lower as proposed. The original intent of this report was a comprehensive overview and summary of the pollution situation. This has now been done in our final project documentation (Action 6.6). So this report could concentrate on a mere summary and description of WP 4 measures.

Action 4.5: Groundwater Management Plan, Monitoring Network

The Groundwater Management Plan delivers the fundament for a future protection of municipal groundwater and mineral springs in Stuttgart. Based on results of a comprehensive evaluation, nine sites with a primary remediation need could be identified (Action 4.1).

By adhering to legal standards of water legislation and meeting the requirements of mineral water protection, the municipality agreed to define handling priorities for different receptors. They determine the sequence of Action as shown below:

priority	affected receptor	criteria and decontamination target
1	medicinal springs and spas	site affects receptor directly, decontamination goal is the complete elimination of a possible input into „Upper Muschelkalk“
2	lower-concentrated mineral springs, limestone groundwater in „Upper Muschelkalk“	concentration in receptor Σ CHC < 5 µg/l single species < 1 µg/l
3	groundwater above „Upper Muschelkalk“ (higher aquifers)	emission and immission from contaminant sources Σ CHC < 20 g/d Σ CHC < 10 µg/l

The first priority addresses the medicinal mineral springs. Here the emission of all sites with an influence on this receptor has to be reduced to zero. The next priority refers to the remaining lower-concentrated mineral springs and general groundwater resources in the mineral water aquifer “Upper Muschelkalk”. For this priority specific remediation targets have been defined. The third priority refers to all groundwater above the “Upper Muschelkalk”. For each individual site, the priority with the strictest requirements is valid.

Scenario calculations of the numerical model

By extrapolating the current situation for the upcoming 50 years, the numerical model elaborated prognosis for different theoretical scenarios. This helped to define the sequence of action and allocate a handling priority to each specific site. Calculated theoretic scenarios were:

- continuous emission from contaminant sources, but all running remediation measures switched off
- continuous emission from contaminant sources, but running remediation measures continued
- optimization of remediation to reduce the overall contaminant emission by 50%
- optimization of remediation to reduce the overall contaminant emission by 100%

For each of these calculated scenarios the effect on the receptors was evaluated. Besides calculating a hypothetic emission of all nine priority sites, the model did separate runs for each single site, assuming an emission only from this selected site (and switching off the emissions from all other sites). This procedure enabled us to evaluate:

- the influence of each single priority site on a specific receptor
- the efficiency of running remediation measures
- the effect of an optimization of remediation to reduce emissions by 50% or 100%
- the separation between most urgent and urgent measures.

On this basis different handling priorities could be defined as shown below:

Site	Priority
Rümelinstraße 24 - 30	priority 1
Dornhaldenstraße 5	priority 2
Rotebühlstraße 171	priority 2
Nesenbachstraße 48	priority 2
Mittnachtstraße 21 - 25	priority 2
Prag-/Löwentorstraße	Definition of priority on base of further investigation results
Johannesstraße 60	priority 3
Rotebühlplatz 19	priority 3
Wolframstraße 36	priority 3

Remediation Framework Concept

The remediation framework concept evaluates and recommends possible remediation methods for handling priorities 1 and 2. Based on a comprehensive site description and a summary of investigation results, a characterization of contaminant sources and quantification of contaminant loads is done. Microbial degradation processes, if abundant, are described and their influence estimated. For each site, possible remediation options are described and evaluated for their applicability on base of a predefined catalogue of criteria. One preferable method is recommended for each site in combination with cost estimation. Most frequently it is recommendable to combine an already running hydraulic extraction measure with an innovative method like for example a microbial remediation. To test the feasibility of innovative methods, pilot test should be done in advance. Measures are planned in the timeframe from 2016 to 2026.

Monitoring Network

For an efficient control of remediation success, it is necessary to control and survey the future development of contaminant concentrations in the downstream of contaminant sources. In this way it can be controlled whether the effect of performed remediation measures coincides with the prognosis of the numerical model, or whether modifications of the concept are necessary. For this reason a monitoring program has been established

for the nine priority sites. It defines control criteria, observation wells and sampling depths and intervals for each contaminant site.

Results

Strategic planning document, laid down in documents as follows (see Annex 7.2.27):

- Remediation framework concept
- Monitoring program
- Comprehensive description in final project documentation (Action 6.6)

Problems Occurred / Modifications Compared to Proposal

None

Work Package 5: Guidance and Best Practise

Action 5.1: Assessment of Groundwater Pollution Plumes

A guidance document „assessment and evaluation of long-lasting-hydraulic remediation measures” was established by LUBW. The guidance defines instruments for a methodic and technical procedure guiding the assessment of pollution plumes’ relevance and proportionality of their remediation. It also establishes a procedure for an evaluation of remediation efficiency with recommendations for a possible optimization on the one hand and a risk assessment on the other hand. Compilation was based on expertise from sources of regional and national level as well as Stuttgart experiences from WP 1.

Results were discussed with technical and administrative experts in a project workshop in November 2011. The final guidance document, based on recommendations of this workshop, was compiled in January 2012. In June 2012 1.000 paper versions were produced and distributed to:

- federal, regional and municipal environmental administrations
- private industry
- universities and research associations

in Germany, Austria and Switzerland. The guideline can be downloaded from MAGPlan and LUBW websites. An English short version is available. The Distribution list may be seen from Progress Report No.2, Annex 10.3.4.

Results

Guidance document (see Mid Term Report, Annex 8.3.3)

Problems Occurred / Modifications Compared to Proposal

Costs for this Action were higher as proposed. The guidance was developed in a two-step procedure with an initial data collection and the final compilation of the guidance document based on results of a workshop. This involved two different service providers. Such a procedure, implying higher costs, had not been anticipated in the proposal, but it proofed its worth.

Action 5.2: Integral Groundwater Remediation Concept and Tools

Groundwater risk management and remediation in inner city areas, where multiple plumes occur overlying each other, should be preferably done on base of integral investigation and conceptual modelling. To widen acceptance and applicability for this method, LUBW established a guidance document.

It is divided in two parts. Part one, based on abundant experiences from MAGPlan and previous projects, gives clear instructions for the methodic procedure and work steps to be followed. The overall strategy is visualized by a comprehensive flow chart. For each work step recommended methods are described. Realization is possible on base of current legal/administrative practice. Part two focuses on advanced and innovative tools and methods, shows their potential, gives recommendations for their application but also describes obstacles to be overcome for a wider application.

Two main expert workshops, one initial and one based on a draft version were organized, accompanied by numerous meetings of the working group, reconsidering specific details with participating experts. In November 2014 900 paper versions were printed. 263 prints were sent to representatives of public administrations, private engineers, libraries, universities and research associations (see distribution list in the Annex). 150 prints were distributed on the MAGPlan final conference, 100 prints on the “Dienstbesprechung Altlasten”, a conference of Baden Württemberg environmental agencies. 120 prints were made available to the “Fortbildungsverbund” for their technical seminars and approximately 250 prints remained for free distribution via Stuttgart municipality and LUBW.

The guideline can be downloaded from MAGPlan and LUBW websites. An English short version is available.

Results

Guidance document (see Progress Report No.3, Annex 10.1.1), Distribution list, see Annex 7.2.28

Problems Occurred / Modifications Compared to Proposal

None

Action 5.3: Groundwater Management Plans and Best Practice

To present the Groundwater Management Plan to the City Council, a guidance document was prepared. It summarizes the most important decisions and describes necessary measures for the five sites of priorities 1 (medicinal mineral springs) and 2 (mineral springs and Upper Muschelkalk aquifer). The plan foresees measures from 2016 to 2026 with total costs of 13,5 Mio Euro. The guidance document was presented to the City Council and accepted on 23/06 (environmental board) and 01/07/2015 (administrative board).

In preparation of its final establishment two expert workshops were launched on 23/02 and 24/03/2015.

Results

Guidance document (see Annex 7.2.29) for City Council, protocol of expert workshops (see Annex 7.2.30), protocol City Council 01/07/2015 (see Annex 7.2.31)

Problems Occurred / Modifications Compared to Proposal

None

Action 5.4: Transnational Science and Policy Panel

The TSPP consists of selected national and international experts with long-lasting technical, scientific and administrative experience. Participating nations (besides Germany) were: Austria, Switzerland, France, the Netherlands, Belgium, Italy, Croatia, Slovenia and Hungary. The MAGPlan experts benefited from the input of these experts related to issues as follows:

- scientific supervision, plausibility control and independent check of current results and working hypothesis
- contribution of new technical ideas and scientific concepts

- report of experiences from comparable projects
- check of necessity, adequacy and technical feasibility for planned strategies and methods
- check of feasibility from an administrative point of view
- dissemination of MAGPlan concept and results in national and international scientific forums
- link to the CIS groundwater implementation group by attending representative

Furthermore the TSPP served as a communication platform to exchange new findings with other thematically related EU projects. Meetings of the TSPP took place in 2011, 2012, 2014 and 2015. Each single event was documented in a separate report.

The last TSPP took place directly following our final conference. We collected statements for a final evaluation of the MAGPlan concept. Participants emphasized the pioneer role of MAGPlan. They will contribute to a wider distribution and application of the developed methods and tools.

Results

Members of the TSPP gave us guidance and advice to the project. Important impulses focused not only on the specific situation in Stuttgart, but evaluated the EU-wide applicability of concepts and findings. The panel also included a member of the WFD - CIS (Common Implementation Strategy) working group “groundwater”. The workshops have been documented in reports as follows:

1. TSPP (see Progress Report No. 1, Annex 2d), 2. TSPP (see Progress Report No. 2, Annex 10.2.10), 3. TSPP (see Progress Report No. 3, Annex 10.2.17), 4. TSPP (see Annex 7.2.32)

Problems Occurred / Modifications Compared to Proposal

As a non-EU participant, we invited Mr. Christoph Wenger from the Swiss national environmental authority BAFU. He presented the network Chloronet as a platform for the exchange of expert information and promotion of experience in the area of CHC polluted sites. Although established in Switzerland, this platform is also active in Germany, Austria and France.

5.2. Dissemination Actions

5.2.1. Objectives

The dissemination plan as set up in the project proposal pursued objectives as follows:

- raise awareness and enhance sensibility for matters of groundwater protection in the public opinion
- provide an understanding for geologic issues, consistency of strata, underground buildup and preconditions for groundwater flow and contaminant transport
- secure a broad support for an efficient protection of Stuttgart's mineral springs from harmful influences
- give ideas for handling options in everyday life to contribute to the protection of ground- and mineral water

5.2.2. Dissemination: overview per activity

Dissemination measures have been attributed to Actions 6.4 – 6.11. Most of the measures were in charge of our external service provider for project communication, assigned in January 2011. A summary presentation of dissemination measures, visualizing essential activities in a chronological order, is given in Annex 7.3.3. A summary table listing all performed dissemination activities is provided in Annex 7.3.4.

Action 6.4: Project Website

Our project website (www.magplan-life.eu or www.sauberes-grundwasser-stuttgart.de) was initially established and activated in September 2010. In March 2011 it was equipped with a new design. A further optimization and technical adaption of its functionality was done in 2015, in course with the publication of the online-quiz. The website was continuously updated according to current state of knowledge. Visitor numbers ranged around 300 per month; from May to September 2015 approximately 900 visitors could be counted per month. In comparison to the proposal's objective of 500 visitors per month, we achieved only 60 %. But in the months approaching project end, this objective was distinctly exceeded. The website will be kept open until 2020.

Results

MAGPlan website in operation, continuously updated, 300 visitors per month with an increase of 600 visitors between May and September 2015

Problems Occurred / Modifications Compared to Proposal

None

Action 6.5: Installation of Notice Boards

Several mobile notice boards informing about the project were installed in course of ongoing field activities.

In addition to that, we placed temporary advertisements in frequented stations of Stuttgart's local traffic, using digital info screens installed at departure platforms. Continuously changing their performance, they inform waiting passengers about current news but are also a platform for multiple advertisements. MAGPlan spots were published from 19/05 to 24/05/2014 in course of an upcoming drilling campaign and also from 15/06 to 20/06/2015 to inform about the online quiz.

Results

Mobile notice boards installed during ongoing field activities, two one-week advertisement campaigns in public stations, see summary presentation, Annex 7.3.3

Problems Occurred / Modifications Compared to Proposal

None

Action 6.6: General Public Involvement and Vitreous Aquifer

In January 2011, an external service provider for project communication was selected and assigned. In a first step, they established a communication strategy with related timetable, based on provided specifications of the LIFE unit. It defines targets and issues to be communicated and sketches the formal frame (locations, dates) to place the media. A time plan was set up, defining measures, time frames and responsibilities. It was presented in our initial project workshop on 01/02/2011 and served as a discussion basis to substantiate future activities. This communication strategy has been updated regularly until the end of the project.

Also in 2011 a small leaflet was produced in German and English language to give a general project introduction. It was distributed on public events like the press event on occasion of drillings MAG 1 to MAG 6. A MAGPlan folder was provided to visitors on the first Science and Policy Panel and following events.

In autumn 2011 we produced our first project movie. It gives a general introduction about MAGPlan's motivation, way of procedure and expected results, but also introduces into the geological conditions of groundwater flow and contaminant transport. A three dimensional animation explains the most important processes. It was published on MAGPlan and LUBW websites, on Regio TV and provided to visitors on numerous events.

In 2012, equipment for exhibitions like MAGPlan roll-ups, counters and information booths with an interactive working station to show MAGPlan movie and website were produced and used on the 20th LIFE anniversary, celebrated in Stuttgart on 4th May 2012 and following events.

In 2013, several Give-Aways like MAGPlan pens, bags, USB-Sticks and writing pads were produced and distributed on numerous events.

In 2013, the MAGPlan strata model was produced. When discussing our vitreous aquifer concept in detail, we found this innovative and very efficient way to transfer technical issues to specified target groups. The model visualizes the strata sequence and allows touching the real rocks and understanding of each single strata with its special geological characteristics and groundwater flow behavior. Drilling cores, starting from ground surface to the mineral bearing aquifer, were prepared especially for this exhibition object. Drawers to be opened give more information about technical details and show graphical and photographic presentations. A monitor, integrated into the model, shows the project movie. In combination with our block diagram (Action 4.3), it is an ideal platform to transfer technical issues to non-experts.

The strata model was officially opened to the public in Stuttgart Town Hall by Mayor Hahn on 21/02/2014, followed by a press conference with many journalists. In the following months it was exhibited in Stuttgart Town Hall, Leuze mineral spa and the environmental office and also on several public relation events (see presentation schedule below).

Two newsletters, summarizing technical issues for the general public, were produced in 2013 and 2014. As a public information brochure, they explain our technical work in a generally understandable way by vivid graphical illustrations. Handed out on multiple events and distributed in the framework of strata model exhibitions, they proved to be a valuable instruments to explain project matters to non-technical visitors in a fast and easy way.

In 2015, we created and published an online quiz for the young target group. It is directed to the young, technically-oriented clientele, was produced to be played on smartphones and may be downloaded from the MAGPlan website. An animation gives an overview and quick summary of the project and is followed by 12 questions to be answered in a multiple choice procedure. In a playful way they pick up issues like properties of CHC, groundwater flow, protection of mineral spas, etc. Handling options are shown to integrate the protection of ground- and mineral water in everyday life. We plan to further extend the quiz and introduce on schools as a teaching instrument. Annex 7.3.5 gives an overview about counted visitors (up to 80 per day). As the curve shows, the temporary advertisement placed in Stuttgart's stations between 16/06 and 20/06/2015, caused a distinct increase of visitor numbers.

A comprehensive project documentation, published as a book on 267 pages, was compiled by the whole project team in 2014 and 2015. It is directed to the expert community in order to secure the transferability of concepts and findings. Clearly structured text passages, supported by targeted graphical illustrations, give a comprehensive view for non-involved experts. The compendium is structured as follows: motivation and historical background, methods and tools, conceptual and numerical model, Groundwater Management Plan, public relations. Summarizing paper prints and electronic versions, approximately 1.000 copies are in distribution via booksellers, libraries, universities and the authors themselves.

A second project movie was produced in 2015 and presented on the final conference. It describes outcome and results of the project, its major findings and resulting consequences in an appealing, understandable way. Defining essential contaminant sources and plumes, it describes driving mechanisms and processes and finally introduces the Groundwater Management Plan with its remediation frame concept. The movie is available on the MAGPlan website.

The local and regional press reported about the project in regular intervals, mainly on occasion of events like new drillings, opening of the strata model, the final conference, etc. A summary press review may be seen from Annex 7.3.6.

Presentation Schedule

The following table shows major events and exhibitions, directed to the general public with related numbers of visitors.

Date	Event	Way of Exhibition	Number of Visitors (approx.)
04/05/2012	Europe's Day, 20th LIFE Anniversary, Stuttgart	exhibition booth, information counter, MAGPlan movie	2.000
14/11/2012	Student's Information Day at Stuttgart University	exhibition booth, information counter, MAGPlan movie	180
14-15/03/2013	ITVA Symposium	exhibition booth, information counter, MAGPlan movie	450
03/05/2013	Europe's Day, Stuttgart	exhibition booth, information counter, MAGPlan movie, 1. Newsletter	2.000
23/05/2014	Europe's Day, Stuttgart	strata model, 2. Newsletter	2.000
21/02 – 23/05/2014	exhibition in Stuttgart Town Hall	strata model	200 per day, ca. 12.000 visitors in 3 months
23/05 - 16/12/2014	exhibition in Leuze Mineral Spa, Stuttgart	strata model, 2. Newsletter	2000 per day, approx. 280.000 visitors in 7 months
since 17/12/2014	exhibition in the Environmental Office – entrance area	strata model	50 per day, approx. 9.000 visitors in 9 months
07/02/2015	Open day in Stuttgart's Town Hall	strata model, block diagram, Newsletters	7.000
08/05/2015	Europe's Day, Stuttgart	MAGPlan Newsletters, general information, roll-up	2.000

In Summary more we managed to reach more than 300.000 visitors, raising their awareness for groundwater protection and securing a broad support for an efficient protection of Stuttgart's mineral springs.

Results

More than 300.000 visitors on numerous events, final project documentation published as a book, two newsletters (in summary 5.000 printed copies, representing the brochure “abatement of groundwater pollution in Stuttgart”), online-quiz (operable from the website), online quiz - statistic evaluation of visitor numbers(Annex 7.3.6), communication strategy, MAGPlan leaflet, two MAGPlan movies, strata model, etc. (see summary presentation and table of dissemination measures, Annex 7.3.3 and Annex 7.3.4), second project movie (Annex 7.3.10).

Problems Occurred / Modifications Compared to Proposal

None

Action 6.7: Workshops and Technical Seminars

Two national seminars and one international workshop took place during MAGPlan lifetime:

1. A combined training seminar with EU-project FOKS (<http://projectfoks.eu/>) was organized on 08/03/2012 in Stuttgart. FOKS shows some technical similarities to MAGPlan especially in terms of applied methods but focused on small scale questions in a significantly smaller investigation area. The seminar was directed to regional consulting engineers by presenting successfully applied methods and techniques from both projects. Approximately 80 visitors attended the seminar.
2. The „Fortbildungsverbund Altlasten Baden Württemberg“ launched a technical seminar: “Integral groundwater investigation and MAGPlan” on 15/07/2014. With the general aim to inform about methods and legal procedures of the integral approach, it focussed especially on MAGPlan. The stepwise procedure towards our final Groundwater Management Plan was described with all its elements, methods and tools. Approximately 30 visitors attended the seminar.
3. An international workshop with 21 technical and administrative experts from Germany, Austria, France, Belgium, Italy, Poland, Serbia, Slovenia and Croatia took place in Stuttgart’s Town Hall on 07/10 and 08/10/2014. We had an intensive discussion about the Groundwater Management Plan concept, its way of compilation with involved parties and decisions to be taken. The transferability of the concept to European neighbour countries with comparable challenges was evaluated. Based on best practise results we discussed strategies to implement GWD requirements under different conditions. Finally we defined necessities for a future need and developed some ideas for common future initiatives.

Results

Three workshops/training seminars with respective documentation, for a comprehensive overview with related documents (list of participants, agenda, photographs, presentations) see Annex 7.3.7.

Problems Occurred / Modifications Compared to Proposal

None

Action 6.8: Technical Publications, Presentations at Conferences

Annex 7.3.8 gives a list of all presentations and publications done during MAGPlan lifetime. Since the last progress report we visited events as follows:

Conference Presentations:

- poster-presentation of groundwater modelers on the international conference “Integrated Hydrosystem Modelling 2015” at University of Tuebingen from 07/04 to 10/04/2015. The conference had approximately 60 participants
- presentation of the groundwater management plan on the international conference “Aquaconsoil” in Copenhagen from 08/06 to 12/06/15. On this conference, with approximately 750 participants, we found a lot of interested comments and could also acquire participants for our final conference.
- presentation of the online visualization tool MAG-IS on the “Intergeo” fair from 15/09 to 17/09/2015 in Stuttgart. The fair had approximately 17.000 visitors.
- presentation of the LUBW guidance document: “Integrated Management of Contaminated Sites” on a meeting of Baden Württemberg environmental agencies on 22/10 and 23/10/2014
- presentation of the LUBW guidance document: “Integrated Management of Contaminated Sites” on a conference of German federal administrations from 22/06 to 24/06/2015

Technical Publications:

Announcements for the Final Conference (see Action 6.11) were done in the journals “Altlastenspektrum” and “af-info” (journal of the Altlastenforum) in spring 2015.

Results

At least 16 conference presentations, at least 7 presentations in technical journals, for a comprehensive overview with related documents (list of participants, agenda, photographs, presentations) see Annex 7.3.8.

Problems Occurred / Modifications Compared to Proposal

None

Action 6.9: After Life Communication Plan

This Document in German and English language has been added in Annex 7.2.2

Results

After Life Communication Plan in German and English language, see Annex 7.2.3

Problems Occurred / Modifications Compared to Proposal

None

Action 6.10: Layman's Report

A Layman's Report on 12 pages, each of them divided in German and English sections, has been added in Annex 7.3.1. A download is available from the MAGPlan website.

Results

Layman's Report in German and English language, see Annex 7.3.1

Problems Occurred / Modifications Compared to Proposal

None

Action 6.11: Final Conference

Our Final Conference took place on 02/07 and 03/07/15 in Stuttgart's "Haus der Wirtschaft". To inform about the event, we contacted multiple national and international technical agencies and administrative institutions, asking to activate their networks and eMail distribution lists, as listed below:

- Fortbildungsverbund Baden Württemberg
- Altlastenforum Baden Württemberg
- Städtetag Baden-Württemberg
- Landkreistag Baden-Württemberg
- Ingenieurtechnischer Altlastenverband e.V. (ITVA)
- AKASG (Arbeitskreis der Altlasten-Sanierungsgesellschaften der Länder)
- Technical journals: "Grundwasser", "Altlastenspektrum" and "af-journal"
- Bayerische Wasserwirtschaftsverwaltung Regensburg, LFU Bayern
- Common Forum of Contaminated Land
- CIS Working Group Groundwater
- CHC network "Chloronet" from Switzerland
- Danish Regions - Mr. Christian Andersen
- ENWAT Doctoral students of University of Stuttgart (involved in the field of environment and water issues)

Selected representatives were invited by a personal letter. Also we used attended technical meetings and conferences in the preceding months to announce the event.

The conference with approximately 150 visitors attending was opened by Mayor Matthias Hahn and Hervé Martin from the Directorate-General for the Environment of the European Union. The head of Stuttgart's Environmental Department, Dr. Hans-Wolf Zirkwitz, accompanied and moderated the event. The technical part was subdivided in five thematic sections:

- legal and technical framework for integral management of groundwater contamination
- integral investigation in MAGPlan
- numerical modelling and visualisation
- the management plan and best practice guidances
- integral approaches: current developments and projects

Conference languages were German and English with simultaneous translations for both. The visitors appreciated the well-structured and clearly understandable way of

presentation despite technically highly demanding issues. As the positive feedback of many international guests made apparent, MAGPlan with its prototype “Groundwater Management Plan” plays a pioneer function for comparable challenges in many European cities.

The strata model was presented as a permanent exhibition project. Paper prints of the MAGPlan book and LUBW guidance were distributed to all visitors.

An evening barbecue as a social event was arranged in the beergarden Bad Cannstatt, just in the vicinity of Stuttgart’s mineral spas.

Results

Approximately 150 visitors attended, presentations (available online), photographs, agenda, list of participants (see Annex 7.3.9), MAGPlan-book and LUBW guidance distributed to all visitors

Problems Occurred / Modifications Compared to Proposal

Costs for this Action were higher as proposed. Originally we planned to organize this event in Stuttgart’s Town Hall. Due to time constraints and conflicts of availability for the two days needed we had to choose another venue. The external “Haus der Wirtschaft” as an equivalent, representative venue for the final conference implied rental fees and a higher organization effort.

5.3. Evaluation of Project Implementation

Methodology applied

MAGPlan implemented a new method to meet requirements of GWD, on the scale of big cities, very frequently concerned with a diffuse pollution like in Stuttgart. The principle of this methodology is transferable to other cities with a comparable contamination problem.

The methodology proved to be much more efficient as the traditional single site approach. By deriving driving factors on a holistic scale, thus expressing recommendation for targeted investigations to close knowledge gaps, expenses for technical investigation measures could be reduced to the necessary minimum. This happened by an iterative-adaptive approach, establishing a conceptual model and a numerical site model in parallel with a regular mutual plausibility check. With this approach, we finally managed to select 9 from 182 sites for a further investigation and remediation need.

Still, as the most frequent investigation need was directed to deeper aquifers, single measures showed to be very expensive and could not have been handled within the normal municipal budget. Also it proved to be extremely challenging and time-consuming to find drilling locations in densely populated inner city areas. We had underestimated the effort to obtain the necessary admissions from administrations and involved proprietors. Also, as with MAG 16, crossing lines in the underground prevented us from drilling in the predefined location.

Despite our long lasting and well-founded work and a distinct improvement of our “understanding puzzle”, knowledge gaps remain in certain areas, where a detailed interpretation fails due to missing investigation results. Still these are locally restricted problems and do not touch the understanding of the whole system.

We took the risk to apply innovative investigation and applied special evaluation methods; results very often led us further, but also very often further steps were necessary to achieve the acquired results. This explains why we head distinctly higher evaluation efforts than originally assumed, especially for the conceptual contaminant model.

Our public relations activities helped to increase the understanding for groundwater contamination issues in the general public. A specific challenge, though, was to take into account the contemporary activities on the large railway building project Stuttgart 21. This project, also touching groundwater issues, was disputed controversially in the public. We learned to tackle the situation by distinctly explaining to involved target groups, that there was no practical interference with MAGPlan. In the long run we had a very positive feedback, especially when exhibiting our strata model.

Comparison of results achieved against objectives:

The following table compares objectives of the revised proposal with achieved quantitative results on some examples:

Task	Foreseen in the revised proposal	Achieved	Evaluation	Action
Construction of wells	16	18	target exceeded	1.3/3.1
Number of visitors on public events	35.000	more than 300.000	target distinctly exceeded	6.6
Conference presentations	3-5	at least 16	target distinctly exceeded	6.8
Publications in technical journals	3	7	target distinctly exceeded	6.8
Compilation of guidance documents	3	3	target achieved	2.2,5.1,5.2,5.3
Test and evaluation of innovative techniques	3	9	target distinctly exceeded	2.1, 2.3, 3.1,3.2, 3.3
Number of microbial degradation tests	15	15	target achieved	3.3
MAGPlan – book	0	1	additional achievement	6.6

Effects of Project Amendment

Realization of the amendment enabled us to optimize the whole process and to distinctly improve our public relations performance. The main aspects are described below:

- The improved public relations concept with our vitreous aquifer exhibition allowed us to introduce more than 300.000 visitors on various occasions in the world of groundwater protection in urban areas. We managed to increase their awareness and sensitivity for the necessity to protect Stuttgart's mineral springs from harmful influences. The young, digital community was efficiently addressed with our online-quiz.
- The adapted time schedule with a prolongation of nine months allowed us to:
 - more efficiently structure the project
 - intensify data evaluation efforts
 - even more carefully plan field measures on base of abundant data
 - put our focus on an investigation of deep aquifers with time-consuming but very valuable deep drillings
 - finally lay down the whole procedure in a comprehensive publication to instruct the technical community
- the modified concept of 3D-visualisation allowed us to produce the platform MAG-IS as a valuable instrument for technical discussions.

5.4. Analysis of long-term benefits

1. Environmental benefits

a. Direct / quantitative environmental benefits:
not applicable

b. Relevance for environmentally significant issues or policy areas:

Our continuous contact and knowledge transfer with the CIS working group ensures that project findings are considered and included in the GWD implementation process as well as in the coming update for 2019. We were also in continuous contact with the COMMON FORUM on Contaminated Land, which is a network of contaminated land policy makers, regulators and technical advisors from Environment Authorities in European Union member states and European Free Trade Association countries.

2. Long-term benefits and sustainability

a. Long-term / qualitative environmental benefits:

The improvement of groundwater quality in Stuttgart, induced by the measures defined in the Groundwater Management Plan will be sustainable. Financing and realization of these measures is secured, as they were admitted by the City Council. As expected, we will achieve a definite reduction of abundant contaminant loads. This will lead to a definite improvement of groundwater and mineral water quality, especially for the deep aquifers. In the long term, it will secure the pureness of Stuttgart's mineral spas.

b. Long-term / qualitative economic benefits:

The integral remediation concept instead of the traditional single site approach distinctly increases the efficiency and saves tremendous costs. Of specific importance for this expected benefit is the knowledge about microbial degradation processes. By a combination of data evaluation, numerical model simulations and laboratory tests we could demonstrate that natural CHC degradation takes place. A completely new scientific finding is the verification of Trichlorethene (TCE) degradation. Including these processes and their benefits into remediation planning and design will save huge amounts of time and money.

c. Long-term / qualitative social benefits:

Stuttgart's mineral springs are a source of health protection and relaxation, either as drinking or as bathing water. As such, they are an important tourism factor and part of Stuttgart's identity. The measures defined by MAGPlan ensure a preservation of this treasure for future generations.

d. Continuation of the project actions by the beneficiary or other stakeholders:

As fixed and authorized by the City Council, Stuttgart will start to realize the measures as defined in the Groundwater Management Plan from 2016.

3. Replicability, demonstration, transferability, cooperation:

Within MAGPlan, we developed multiple new methods and strategic instruments to tackle urban groundwater contamination as occurring in many big cities within the

EU. As the reaction of many international partners participating in our workshops and on the final conference showed, there is a tremendous need for such instruments and innovative concepts. Most of the international guests were highly interested in cooperating and using our findings for their specific challenges.

Here are some examples for methodic innovations, developed and implemented in MAGPlan:

- the milieu mapping of biologic degradation zones based on an evaluation of hydro chemic data in combination with time development curves and isotope fingerprinting results
- the hereon based simulation of microbial degradation processes in the numerical transport model by assuming and calibrating different degradation rates
- the combination of conceptual evaluations and microbial degradation tests. Thus the verification of naturally occurring TCE degradation could be introduced as a new finding into the scientific community.
- the visualization of numerical modelling results by the online-tool MAG-IS
- scenario calculations in the numerical model to anticipate the effects of a hypothetic remediation, to evaluate the effect of each single site on the whole system and finally to define remediation priorities
- the Groundwater Management Plan as a municipal handling instrument pathing the way to implement GWD requirements in cooperation with multiple stakeholders
- the strata model as a multimedia demonstration object to transfer challenges of groundwater protection to the general public

All these tools and instruments are transferable to other big cities with comparable challenges. They have been laid down and described in our guidance documents.

To secure the international transferability, the most important features, methods and findings will be comprised in English language. A translation and further adaption to specific conditions in single countries will be done by members of the transnational Science and Policy Panel.

To test the application of groundwater management plans in functional urban areas LHS-AfU is participating in an INTERREG application, together with 11 partners from Poland, Czech Republic, Italy, Slovenia and Croatia. The decision about the acceptance of this proposal is awaited for April 2016.

4. Best Practice Lessons

Our best practice experience has been laid down in documents as follows:

- Guidance isotope fingerprinting (Action 2.2)
- Guidance: assessment and evaluation of long-lasting-hydraulic remediation measures (Action 5.1)
- Guidance: integral groundwater remediation concept and tools (Action 5.2)
- Guidance: Groundwater Management Plan, presentation to the City Council (Action 5.3)
- MAGPlan book (Action 6.6)

5. Innovation and demonstration value

The applicability of the following technology innovations could be tested and implemented in MAGPlan. As a demonstration example they have been documented in technical reports:

- microbial degradation tests (Action 3.3)
- isotope fingerprinting (C-CSIA and C-Cl-CSIA, Actions 1.5, 2.1, 3.2, 4.2)
- tracer substance investigations (Actions 1.5, 2.3, 3.2, 4.2)
- high speed well measurements (Action 2.1)
- large scale tracer tests (Actions 3.2, 4.2)
- 21 integral pumping tests applying innovative evaluation methods (Action 2.1, 3.2, 4.2)
- thermoflow method (Action 3.2)
- investigation of drilling cores (Action 3.2)
- geophysical well control (Action 3.1)

6. Long term indicators of the project success

Remediation success in Stuttgart

To control the development of contaminant concentrations as a consequence of projected remediation measures, a monitoring network will be installed and observed in regular intervals. The observed development in the receptors will show whether the expectations are met. In case they are not, additional measures will be taken to modify and adapt the remediation procedure.

Application of guidance documents

The assessment of contaminated sites in Baden-Württemberg is generally accompanied by LUBW. Consequently they are able to observe to what extent their guidance documents are used for practical implementation. In the recent years, they watched several public stakeholders making practical use of the guidance “assessment and evaluation of long-lasting-hydraulic remediation measures” (Action 5.1).

6. Comments on the financial report

- 6.1. Summary of Costs Incurred
- 6.2. Accounting system
- 6.3. Partnership arrangements (if relevant)
- 6.4. Auditor's report/declaration
- 6.5. Summary of costs per Action

7. Annexes

7.1. Administrative Annexes

The following administrative documents have been delivered with the Inception Report:

- Partnership agreement
- Certification of the finance authority about impossibility of input tax deduction
- Confirmation of first level control “Rechnungsprüfungsamt”
- Certification of civil servants working for the project

7.2. Technical Annexes

7.2.1. Lists of (i) Key-Words and (ii) Abbreviations

WP	Work Package
LUBW	Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg
LHS-AfU	Landeshauptstadt Stuttgart, Amt für Umweltschutz
WFD	Water Framework Directive
GWD	Groundwater Directive
CIS	Common Implementation Strategy
TSPP	Transnational Science and Policy Panel
IPT	Integral Pumping Test
CHC	volatile chlorinated hydrocarbons
WP	work package
PCE	perchloroethene
TCE	trichloroethene
SF6	sulfur hexafluoride
CFC	Chlorofluorocarbons
EU-ETV	european technology verification
C-CSIA	Compound Specific Isotope Analyses for Carbon Isotopes
Cl-CSIA	Compound Specific Isotope Analyses for Chlorine Isotopes
BBodschV	Bundesbodenschutzverordnung

7.2.2. Technical Documents – see CD and folder

A print of all technical annexes (on top of those already presented in previous reports) would cover at least 1.000 pages. To avoid too much paper consumption, we have delivered the documents in digital form and provide a print for most important documents and deliverables:

No.	Title	digital on CD	printed
7.2.2	Maps for parameter distribution (Action 1.6/4.3)	x	-
7.2.3	Report: Hydraulic Characterization of Stuttgart's aquifers (Action 1.7/2.5)	x	-
7.2.4	Final Documentation: “Numerical Model for Groundwater Flow” (Actions 1.8/2.4/2.6/3.6/4.1/4.5)	x	-
7.2.5	Summary Report Groundwater Flow and workshop protocol (Action 1.9)	x	x

7.2.6	Guidance Document Isotope Fingerprinting (Action 2.2)	x	x
7.2.7	Summary Report Contaminant Load and Transport (Action 2.7)	x	x
7.2.8	Wells MAG 8-MAG 18 – Documentation of Installation (Action 3.1)	x	-
7.2.9	Documentation of extensive field tracer test (Action 3.2)	x	-
7.2.10	Documentation of contaminant degradation tests (Action 3.3)	x	-
7.2.11	Summary Report Isotope Fingerprinting (Action 3.5)	x	-
7.2.12	Evaluation of CFC distribution for two selected areas (Action 3.5)	x	-
7.2.13	Evaluation of SF6 spatial distribution (Action 3.5)	x	-
7.2.14	Summary Report Degradation and Natural Attenuation (Action 3.7)	x	x
7.2.15	Feasibility study remediation methods (Action 4.1)	x	-
7.2.16	Documentation of IPT performance and evaluation: MAG 12 and Well 7 Dinkelacker (Action 4.2)	x	-
7.2.17	Documentation of IPT performance and evaluation: IPV B 8 (Action 4.2)	x	-
7.2.18	Documentation of IPT performance: MAG 13-15 (Action 4.2)	x	-
7.2.19	Documentation of IPT performance: MAG 16N (Action 4.2)	x	-
7.2.20	Documentation Sampling Campaign Rosensteinpark	x	-
7.2.21	Documentation tracer test SF6 (Action 4.2)	x	-
7.2.22	Site assessment Rümelinstraße 24-30 (Action 4.3)	x	-
7.2.23	Site assessment Rotebühlstraße 171 (Action 4.3)	x	-
7.2.24	Comprehensive evaluation of isotope fingerprinting results (Action 4.3)	x	-
7.2.25	Dynamic online visualization – manual MAG-IS (Action 4.3)	x	-
No.	Title	digital on CD	printed
7.2.26	Final Report Remedial Options, workshop protocols (Action 4.4)	x	x
7.2.27	Groundwater Management Plan with Documents: Remediation Framework Concept, Monitoring Program (Action 4.5)	x	x
7.2.28	Distribution list of Guidance Document (Action 5.2)	x	x
7.2.29	Guidance document for City Council (Action 5.3)	x	x

7.2.30	protocol of expert workshops (Action 5.3)	x	-
7.2.31	protocol City Council 01/07/2015 (Action 5.3)	x	x
7.2.32	Short Report: Fourth Science and Policy Panel (Action 5.4)	x	-

7.3. Dissemination Annexes – see CD and folder

No.	Title	digital on CD	printed
7.3.1	Layman's Report (Action 6.10)	x	x
7.3.2	After Life Communication Plan (Action 6.11)	x	x
7.3.3	Summary Presentation of Dissemination Measures (Action 6.4-6.11)	x	x
7.3.4	List of performed dissemination activities (Action 6.4-6.11)	x	-
7.3.5	Online quiz – statistic evaluation of visitor numbers (Action 6.6)	x	x
7.3.6	Press Review (Action 6.6)	x	-
7.3.7	Technical Seminars and Workshops – comprehensive overview with related documents (Action 6.7)	x	-
7.3.8	Technical presentations on conferences, publications in technical journals - comprehensive overview with related documents (Action 6.8)	x	-
7.3.9	Documents final conference: presentations, agenda, photographs, list of participants	x	-
7.3.10	Second project movie - video	x	-

7.4. Final table of indicators

- Provided as an Excel File on CD