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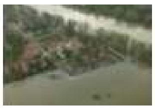
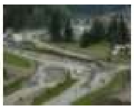
European Flood Risk Management Research

First CRUE ERA-Net Common Call
Effectiveness and Efficiency of Non-structural Flood Risk Management Measures







CRUE Research Report No I-2:

Development of flood risk in mountain catchments and related perception (RISKCATCH)

Prepared by the Joint Project Consortium consisting of

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DISCLAIMER

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ERA-NET CRUE Funding Initiative on Flood Risk Management Research

Risk Assessment and Risk Management: Effectiveness and Efficiency of Non-structural Flood Risk Management Measures

Development of flood risk in mountain catchments and related perception (RISKCATCH)

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Prepared by **Funded by**

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1st CRUE Funding Initiative on FRM research

ERA-Net CRUE is a network of European government departments who directly fund flood risk management programmes and related research actions. In order to tackle the challenge of rising flood risk and to develop effective policies and risk management practices, policy-makers and key stakeholders need a strong evidence base. Evidence-based policy-making is the key to modern, forward-looking strategies for dealing with increasing flood risk. Trans-boundary and trans-national flood risk management issues are becoming more and more important, requiring in particular joint research and development initiatives. The creation and implementation of a European research area in flood risk management – as intended by the CRUE ERA-Net - is an important contribution to an improved trans-national perspective for flood-related research in Europe.

Besides co-ordinating research between Member States, CRUE aims to contribute towards the presentation of research needs with its own trans-nationally based funding initiatives. Common trans-national research calls initiated by the partner countries are a principal activity within the CRUE ERA-Net which can be considered as specific actions to respond to current policy and development needs in Europe. With the launch of the first CRUE common call, a first step toward the integration of flood research in Europe was made.

The topic “Risk Assessment and Risk Management: Effectiveness and Efficiency of Non-structural Flood Risk Management Measures” was selected by six of the CRUE partner countries through an intensive consultation process and is to a great extent based on developments in European flood risk management policy (e.g. EU Floods Directive). In particular, the call was designed to investigate and critically assess the effectiveness and efficiency of non-structural measures in comparison to structural measures and to identify barriers to implementation of these "soft" techniques. The call was an incentive to develop innovative methodological approaches. Moreover, it challenged researchers across Europe to integrate knowledge across different disciplines such as natural and social sciences, and engineering.

Each of the seven successful joint projects within CRUE’s 1st Funding Initiative for FRM research was designed to understand different national approaches to the use and appraisal of non-structural measures, explore what is successful, and what can be improved in terms of efficiency and effectiveness of such measures themselves. The research results presented in this report will provide policy-makers with a better understanding of how FRM as a part of integrated river basin management can deliver multiple benefits, for example reduced flood risk and improved environmental quality.

I feel confident that the outcome of this research will be a valuable contribution to national policy development and the improvement of flood risk-related practice.

John Goudie
ERA-Net CRUE Co-ordinator, Defra, UK

Summary for Decision-Makers

In order to mitigate flood and torrent hazards and to minimise associated losses, technical measures, such as (check) dams and retention basin have been implemented. These measures are supplemented by non-technical mitigation, i.e. land-use planning activities. Therefore, areas affected by dangerous processes have to be indicated. This is commonly done by creating maps that indicate such areas by different cartographic symbols and descriptions. If such hazard maps additionally are intersected with the values at risk exposed, risk maps result. Hence, risk mapping is a common procedure when dealing with natural hazards, even if the methods of map compilation differ. However, only little information is available so far concerning the impact of such maps on relevant stakeholders, i.e., specialists but also people concerned and laypersons. Preceding studies had shown to insufficiently consider individual perception of the target groups, since the traditional approach of graphic semiology does not allow for feedback mechanisms originating from different perception patterns. Reversing this traditional approach by establishing the innovative approach of experimental graphic semiology, and thus taking into account different perception by multiple end-users, different sets of risk maps were created. These small-scale as well as large-scale maps were presented to test persons in order to (1) study reading behaviour as well as understanding and (2) deduce the most attractive components that are essential for target-oriented risk communication. As a result, a suggestion for a map template was made that fulfils the requirement to serve as efficient communication tool for specialists and practitioners in hazard and risk mapping as well as for laypersons. The overall aim of RISKCATCH was to improve the availability of information available to decision makers, local residents, and public authorities, but also to disaster relief organisations and the media.

Socio-economic development in mountain environments and downstream riparian regions is reflected by an increasing usage of areas affected by flooding processes for settlement purpose and economic activities. The intersection of such areas with values at risk results in considerable losses in recent years. In order to mitigate or prevent these losses, combinations of technical and non-technical concepts have been implemented within the framework of integral risk management. Hence, this framework combines constructive measures to mitigate the process with supplementing organisational and passive measures in order to reduce values at risk exposed. However, the efficiency of the latter is not satisfyingly quantified so far, in particular with respect to land-use regulations. To implement land-use regulation, a common procedure applied in most European countries is hazard and risk mapping. By these maps, areas endangered by processes and showing considerable accumulation and concentration of values at risk are depicted; and further utilisation is regulated by certain legal acts or bans.

However, until now only little information is available related to the content and design of such maps, apart from overall principles of map production. These include certain rules and common recommendations, known as graphic semiology. This traditional method relies upon a number of principles and requirements, such as a considerable contrast between illustrated elements, a certain harmony between geometrical features chosen, a generally accepted colour for depicted elements, etc. During traditional map production, the channel of communication is directed from the specialist (cartographer) as a transmitter to the target audience (map reader), the receiver. Due to the linearity resulting from this traditional approach, specific requirements of the target group resulting e.g. from different cultural or knowledge background, are not sufficiently taken into account during the production process. Hence, with respect to natural hazards risk, the impact of information delivered by maps to different stakeholder groups is not sufficiently known so far.

RISKCATCH contributed to this gap by developing a feedback loop in order to account for visual and cognitive perception by the target audience of risk maps. Therefore, a set of 17 complementary but different risk maps was produced for test sites in Austria and Germany, These maps were presented to test persons, including hazard specialists, people concerned, and laypersons, using a video-oculograph, and eye movements were traced. By means of this technique, visual strategies of the test persons were recorded,

and subsequently analysed statistically, spatially, and dynamically. This analysis was complemented by an additional cognitive survey.

As a result it had been shown that the structure of maps influences the visual strategies of the readers. Presumably related to culture and education, textual elements were considerably attractive to the gaze. Furthermore, the central elements of the map have to contrast the background and should be designed in bright and dark colours, respectively. Additionally, the position of various elements in a map, i.e. the title, the legend, and the central figurative element, is of particular importance for the visual comprehension; therefore, map perception is iconographic. The more accessible visual information is the more effective it will be in terms of visual transmission of information. Moreover, particular reading behaviour of specialists, sensitised people and laypersons led to the conclusion that perception is anthropic. Hence, risk maps should be compiled according to these different needs, in particular bearing in mind that approximately 65 % of the observation time of subjects is devoted to less than 25 % of the map surface.

By identifying preferences concerning graphic representation and arrangement, general conclusions were drawn aiming at the development of an optimum risk map to allow for efficient and target-oriented communication of flood risk (Fig. 0-1).

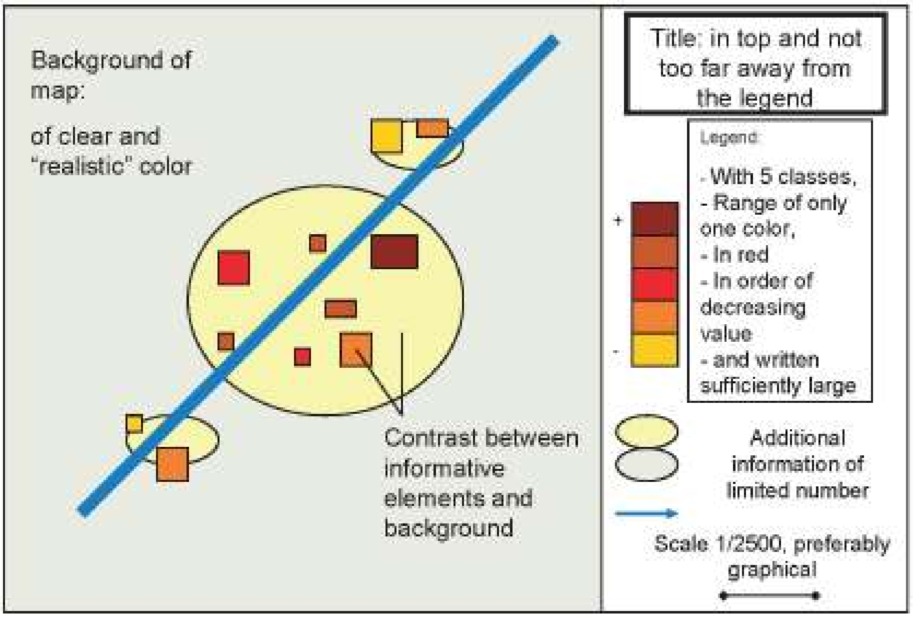

Figure 0-1. Suggestions for the compilation of risk maps in order to allow for efficient and target-oriented risk communication (Fuchs et al. 2008a; Serrhini et al. 2008).

If risk maps were designed according to the RISKCATCH findings, information would be delivered in a visually efficient manner. Consequently, if these requirements were met, risk communication will be enhanced because the level of individual perception and understanding is increased. This deepened insight might result in an increase in both, individual preparedness and public participation, which with respect to flooding and torrent hazards starts with the notion of risk. Therefore, access to information is implicitly necessary. If this information can be delivered target-oriented, i.e. by using the method of experimental graphic semiology, the impact of non-technical measures will be increased, and possible future losses might be reduced to a minimum.

With respect to the European Flood Risk Directive as a supplementary directive to the Water Framework Directive, the results from RISKCATCH will be a useful tool in order to (1) primarily assess flood risk, (2) establish hazard and risk maps, and (3) compile adopted flood risk management plans. In particular with respect to the latter, and being aware that traditional engineering approaches might not be fully sufficient to prevent losses, the results of RISKCATCH will particularly support the management of the consequences of flooding in order to raise flood awareness, and to create resilient communities. Furthermore, the results will be useful to make the abstract terms of residual risk and uncertainties accessible to the public, which is of virtual interest not only for decision makers but also for practitioners in the public administration.

Contents

1 Introduction

"This chapter introduces the topic of risk assessment for natural hazards, in particular with respect to flooding and torrent events in mountain regions and related forelands. Approaches of how to deal with these risks are presented, including technical and non-technical measures. Focussing on the latter, the concept of risk maps is presented. These maps are important in order to deliver information on risks to different stakeholders. It is shown that only little information is available about the necessary information to be included in such maps. This is an artefact of the traditional techniques of map production, where the channel of communication is linear from the transmitter to the receiver. Revising this linear model by experimental graphic semiology, a cyclic feedback loop can be established, and cartographic information can be communicated and delivered target-oriented with respect to specific needs of different user groups. Following this idea, it is shown how RISKCATCH provides added value on different levels and scales."

The historical shift of a traditionally agricultural society to a service industry- and leisure-oriented society led to socio-economic development in mountain environments and downstream riparian regions. This shift is reflected by an increasing usage of alpine areas and related forelands for settlement, industry, and recreation, particularly in the inner Alpine valleys with respect to tourism as well as in the forelands with respect to urbanisation processes. Consequently, a conflict between human requirements on the one hand and naturally determined conditions on the other hand results, leading to an increasing concentration of tangible and intangible assets and to an increasing number of persons exposed to natural processes, which in the case of harm to human life or property are considered as natural hazards. In addition, due to changes in the fluvial regimes, including human impacts on river systems or climate change processes and associated effects on precipitation rates and run-off regimes, the historical grown centres of economy, such as city centres, are endangered or already affected by natural hazard processes.

Traditional approaches to deal with natural hazards in alpine river catchments included the construction of permanent mitigation measures such as (check) dams, and other river engineering activities. Passive mitigation measures such as land-use regulations and hazard mapping supplemented those technical solutions, and provided the basis for the implementation of building regulations. In consequence, the natural processes were influenced and it has to be assumed that the impacts of major events were prevented and minimised, respectively. Subsequently, the risk should have been reduced.

In contrast, due to an increase of settlements and infrastructure in floodplains and torrent catchments in the 20th century, tangible and intangible assets were accumulated in those areas. Hence, a trigger in the opposite direction might have taken place, and considerable loss occurred recently due to torrent processes and flooding.

Non-technical mitigation concepts, above all land-use planning, aim at reducing these losses by establishing building regulations and bans in order to keep endangered areas free of values at risk. One major tool to achieve these regulations are risk maps, which were not only implemented according to national regulations in many countries; the compilation of such maps has also been demanded on the European level, e.g. by the European Flood Risk Directive. Risk maps contain multiple information on different levels, and are key elements with respect to non-technical hazard mitigation strategies. These maps serve as an information basis for multiple stakeholders from official authorities. In addition, they could be used as a tool to strengthen natural hazard awareness of the public concerned, thus they form a risk communication tool. Issues of risk communication are related to the information contained in the maps and to the perception of this information.

However, until now only little information is available related to the content and design of such maps. From a theoretical point of view, the representation and communication of any results from spatially-based analyses in general requires cartographic tools, i.e. maps. These maps are designed based on certain rules and common recommendations, known as graphic semiology (Bertin 1973, 1977). This traditional method relies upon a number of principles and requirements, such as a considerable contrast between illustrated elements, a certain harmony between geometrical features chosen, a commonly accepted colour for depicted elements, etc. (e.g., Imhof 1972; Bertin 1973). During the traditional map production, the channel of communication is directed from the specialist (cartographer) as a transmitter to the target audience (map reader), the receiver. Due to the linearity resulting from this traditional approach, specific requirements of the target group resulting e.g. from different cultural or knowledge background, are not sufficiently taken into account during the production process (see Fig. 1-1). Hence, with respect to natural hazards and risk, the impact of information delivered by maps to different stakeholder groups is not sufficiently known so far.

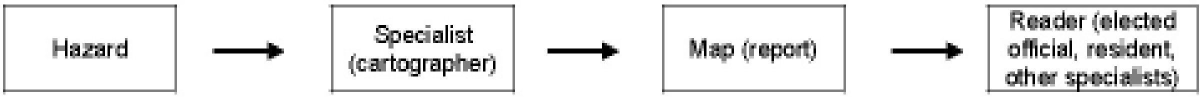

Figure 1-1. Linear model of traditional graphic semiology

Reversing this linear model by establishing a feedback loop, the cyclic system of experimental graphic semiology was developed in order to integrate visual and cognitive perception by the receiver (Fig. 1-2). In doing so, the channel of communication is directed from the receiver to the transmitter, and back to the receiver. As a result, specific requirements of different potential stakeholders can be included in the design of cartographic documents.

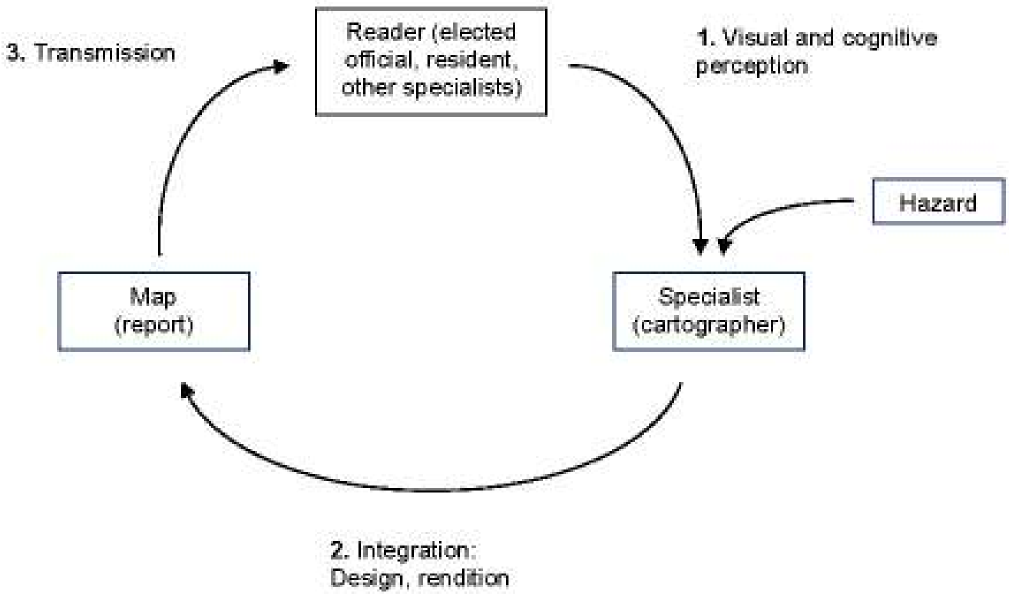

Figure 1-2. Cyclic model of experimental graphic semiology

RISKCATCH aimed at creating added value on different levels and on different scales:

(1) On the general theoretical and conceptual level the interdisciplinary configuration of the project allowed for substantial progress in the discussion on a general risk theory which integrates approaches from both natural and social sciences. Contributions to the refinement of the concept on regional sustainability in mountain environments resulted as an important added value, in particular with respect to the requirements of different stakeholder groups. Furthermore, the added value on the methodological level was most relevant concerning the evaluation of existing

methods and the design of adequate tools for risk modelling and scenario building on a catchment-wide level.

(2) Moreover, added value was created in the field of interdisciplinary mountain research. Focussing on multilevel-analysis (headwater-middle-lower reaches of catchment areas, regional and local consequences) and on explanatory chains from challenges (risks) to responses (sustainability), the project constituted an important and innovative approach for a better and holistic understanding of the specific man-environment-relationship in mountain areas and related forelands. It is expected that the concepts and methods that were developed within the project, as well as the empirical findings provide an outstanding contribution in the frame of the European initiatives in flood management.

(3) Finally, added value was created on the local/regional scale, considering that the empirical outcome of the project provided deeper insight in the causes, interdependencies and consequences of local/regional risk constellations and, consequently, in the conditions, potentials and limitations of local/regional change. In addition to the different findings in the field of interdisciplinary basic research, the project explicitly created added value in the field of applied research, as it aimed, on the one hand, towards the evaluation of local/regional politics and planning strategies and, on the other hand, towards the design of alternative and regionally adapted concepts of sustainable development. These issues directly correspond to the effectiveness and efficiency of non-structural flood management systems.

The overall objective of RISKCATCH was to contribute to a better understanding of how information on risk is delivered and perceived by stakeholders, including specialists familiar with the idea of integral risk management, residents, and laypersons.

2 Objectives

"This chapter provides a concise overview on the scientific and socio-political necessity of RISKCATCH, and shows the embedding of the project in the integral management of natural hazards risk. During the last decades, lots of work has been carried out in order to study and assess the hazard potential. Only recently, quantitative methods for the evaluation of values at risk and vulnerability have been developed. By applying these methods to different areas, and thus merging the information using GIS, hazard and risk maps might be compiled. However, only little information is available so far according to the possible impact of these maps, which seems surprising since they provide an essential base with respect to non-technical flood mitigation. A particular need is deduced for quantifying information related to the perception of risk information by different end-users, apart from specialists familiar with hazard issues primarily people concerned and laypersons."

The underlying concept applied in this work is relied on the theory of risk, which with respect to natural hazards and from an engineering point of view is defined as a quantifying function of the probability of occurrence of a process and the related extent of damage, the latter specified by the damage potential and the vulnerability, see Eq. (1). In general, this function has gained acceptance in accordance with the definition of the United Nations (e.g., Varnes 1984, UN/ISDR 2004).

$$R_{i,j} = f\left(p_{Si}, A_{Oj}, v_{Oj,Si}, p_{Oj,Si}\right) \quad (1)$$

Hence, specifications for the probability of the defined scenario (p_{Si}), the value at risk affected by this scenario (A_{Oj}), the vulnerability of object j in dependence on scenario i ($v_{Oj,\ Si}$), and the probability of exposure of object j to scenario i ($p_{Oj,\ Si}$) are required for the quantification of risk ($R_{i,\ j}$).
The procedure of hazard assessment is methodologically reliable in determining the hazard potential and the related probability of occurrence (p_{Si}) by studying, modelling, and assessing individual processes and defined design events (e.g., Heinimann 1995, 1998; Kienholz & Krummenacher 1995; Hollenstein 1997; Kienholz et al. 2004). So far, little attention has been given to the damage potential (A_{Oj}) affected by hazard processes, particularly concerning spatial patterns and temporal shifts (Keiler et al. 2005; Apel et al. 2006; Büchele et al. 2006; Fuchs et al. 2006; Keiler et al. 2006a; Fuchs & Keiler 2008). Moreover, in particular with respect to dynamic flooding and torrent processes, the concept of vulnerability – though widely acknowledged – did not result in sound quantitative relationships between process intensities and vulnerability values (Fuchs et al. 2007), even if considerable loss occurred during recent years (Fraefel et al. 2004; Oberndorfer et al. 2007). Solely with respect to static inundation a quantification of vulnerability seems to be sound and thus appropriate (Egli 1999; Holub & Hübl 2008). However, the compilation of risk maps always remains a matter of scale, since large-scale assessments of individual torrent fans require a method completely diverse from medium- or small-scale assessments in the mountain forelands.
Thus, there is an emerging need for comprehensive assessments of risk in the upper, the middle and the lower reaches of river basins. Due to the spatial disparities in the relatively small-structured European landscape, regions with different socio-economic distinctions, and thus multiple stakeholder interests, comprise different approaches in dealing with natural hazards and risk.
The RISKCATCH project contributed to the general discussion on the development of risk in mountain catchments. It is not only since the implementation of the European Flood Risk Directive (Commission of the European Communities 2007) that flood risk is subject to intensive research world-wide and in European countries (Kienholz 1977; Plate & Merz 2001; Smith 2001; Kienholz et al. 2004; Wisner et al. 2004; Bryant 2005; Merz et al. 2006). With respect to European regions, a considerable amount of EC- and nationally funded projects have been carried out in order to assess hazards resulting from flooding

(e.g., Armonia, Euroflood, Eurotas, Floodaware, Floodsite and Lessloss). In particular with respect to flood hazards, including torrent processes and hyperconcentrated flows, technical guidelines for a harmonised and reproducible dealing with such threats have been developed and implemented in recent years (e.g., Aulitzky 1994; Heinimann 1998; Borter 1999). These guidelines are based on the respective legal regulations in the affected countries (e.g. Frutiger 1980; Repubblica Italiana 1998; Hattenberger 2006 for an overview). On a catchment scale, the assessment of hazard and risk emerging from flooding results in technical mitigation concepts, such as check dams and retention basins in the upper part, and dams and other river engineering activities in the lower parts of catchments.

Apart from technical reports and planning criteria for mitigation measures, a major result of the above-cited guidelines and regulations are hazard maps, indicating areas that are endangered by a defined design event of the respective processes. The overall aim of such non-technical mitigation concepts is to separate values at risk from hazardous areas by land-use planning activities (even if the efficiency of such measures still remains questionable in practice, above all due to different planning intervals). Hence, an intersection of hazard maps with values at risk exposed is required, resulting in risk maps. Risk maps contain multiple information on different levels, and are key elements with respect to non-technical hazard mitigation strategies. These maps serve as an information basis for multiple stakeholders from official authorities. In addition, they could be used as a tool to strengthen natural hazard awareness of the public concerned, thus they form a risk communication tool. On the European level, such maps are required with respect to flood hazards area-wide until 2013 (Commission of the European Communities 2007). However, apart from procedures of how to compile such maps, only little information is available until now according to the possible impact of these maps. Earlier cartographic research using eye-movement methods has focussed mainly on paper map reading or the processing of static geographical information (e.g., Steinke 1987, Brodersen et al. 2001). So far, methods emerging from social sciences, such as direct or indirect observations including (in-depth) interviews, surveys, or group discussions, are the only available hint (e.g., Slovic et al. 1982; Green et al. 1991; Lave & Lave 1991; Jost 2001; Khaled Allouche & Moulin 2001; Plattner et al. 2006; Laurier & Brown 2008). There is a particular lack of quantifying information on how such maps are perceived by different stakeholder groups, and what elements should be included in order to serve as communication tool and decision support for a future minimisation of flood risk.

To close this gap, risk maps were created for alpine catchments and catchments in the mountain forelands, following common as well as innovative approaches of map production using GIS. These maps were presented to various user groups, including stakeholders from public authorities, experts in cartography and laypersons. Using the method of eye-tracking by means of a video-oculograph, the innovative method of experimental graphic semiology was developed (Serrhini 2000, 2005; Serrhini et al. 2008). By analysing the results, recommendations for the design and compilation of such maps were developed. As a result, the purpose of risk maps in order to serve as a tool for target-oriented non-technical mitigation could be increased.

3 Methodology

"This chapter provides a short survey of the scientific methods applied within the RISKCATCH project. Based on the work flow laid down in the proposal, individual steps necessary for the compilation of risk maps are shown, including process modelling, determination of values at risk exposed, and the assessment of vulnerability. The innovative method of experimental graphic semiology is developed, reversing the traditional linear approach of information delivery by establishing a feedback loop. The underlying experimental protocol is explained, and the necessary analyses of eye movements (statistic, static, and dynamic) are highlighted."

According to the overall framework of RISKCATCH, and as laid down in the proposal, a stepped procedure was chosen (cf. Fig. 3-1) applying different methods, the work included

- an analysis of the status quo using data sets from recent events and existing modelling results,
- a comparison and assessment of different scenarios in land use development, development of values at risk, and vulnerability,
- an evaluation of these data in order to assess the temporal development of risk, and to compile different but complementary risk maps,
- and perception studies on these risk maps in order to enhance risk communication and to provide target-oriented information, using experimental graphic semiology.

First, torrent processes in the upper reaches of mountain catchments and flooding processes in the lower reaches were assessed in order to defined design events (Section 3.1). Second, risk maps were created according to these design events. Therefore vulnerability (Section 3.2) and values at risk (Section 3.3) were assessed. The compiled risk maps were quantitatively evaluated with respect to communication purposes using the method of experimental graphic semiology (Section 3.5). These individual methodological steps were carried out in close collaboration between the project partners in order to assure the exchange of ideas and data, and to efficiently coordinate necessary further steps with respect to the project progress. To establish a continuous dialog and coordination, information and communication technologies were used such as Skype conferencing.
Since the preparation of risk maps is a matter of scale, large-scale analyses were carried out for individual torrent fans in the mountain catchments, and medium- or small scale studies were carried out in the catchment areas situated in the mountain forelands. This procedure mirrors the current situation in large areas of European mountain regions since the values at risk are distributed accordingly. One major focus of RISKCATCH was to compare the results obtained by this in order to provide the most precise and accurate information on risk. Moreover, according to the European Flood Risk Directive, risk maps providing the basis for risk management plans will be compiled in the near future, thus, the RISKCATCH results might aim to the necessary discussion on suitable methods to be used area-wide.

3.1 Process analysis

During the last years the characteristics of floods and land use patterns in the flood plains changed fundamentally. These changes are affected by climatic developments, land use changes, river and channel development and training, and also by mitigation measures, enabling building in formerly endangered areas and reducing the natural detention and profile for runoff.
Following the idea of integral risk management, complementary datasets were used in order to analyse the processes in the test sites, including data on previous events (event documentation, geomorphic evidence, etc.), as well as empirical and numerical modelling.

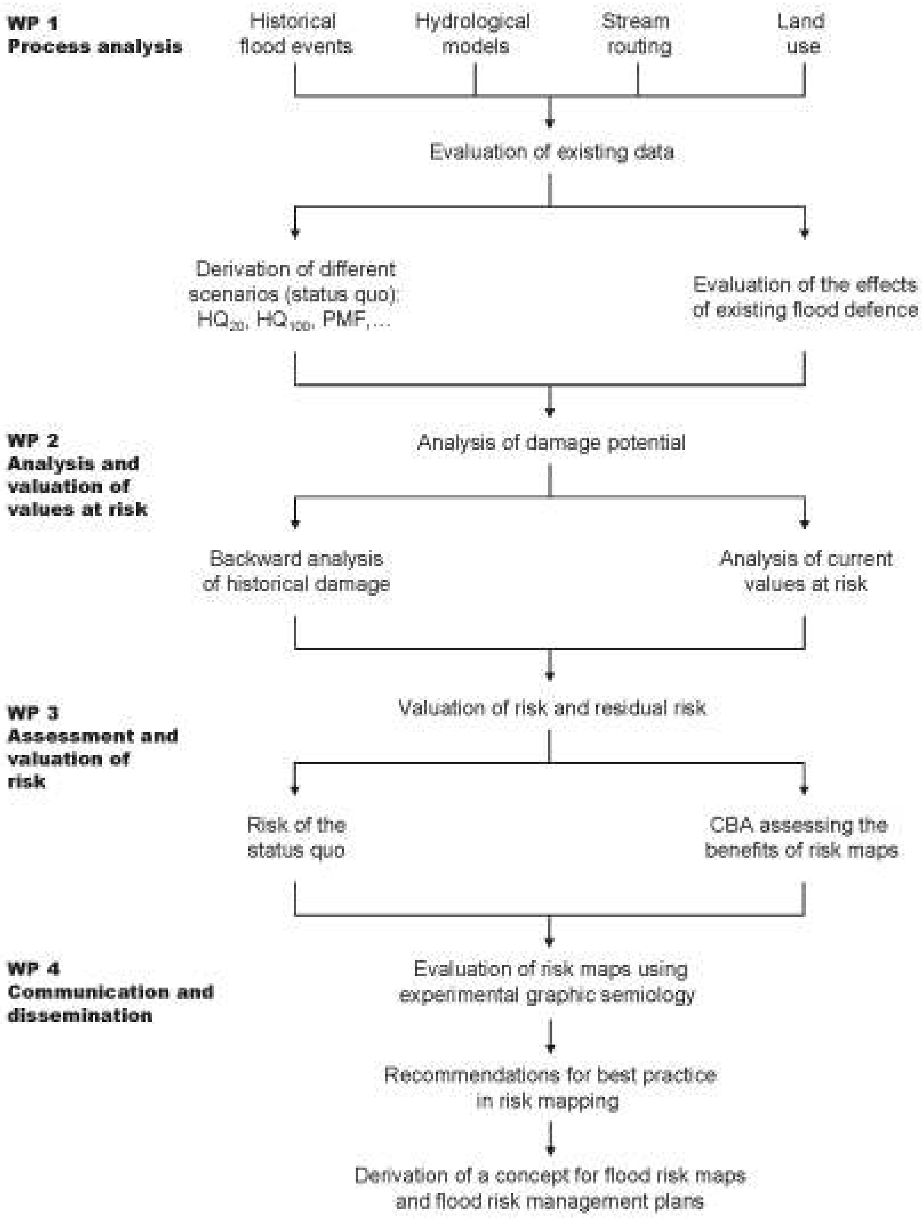

Figure 3-1. Chart of the work flow that provided the basis for RISKCATCH

Based on scenario technique the results of the process analyses were used in the subsequent steps of risk analysis to contrast different past and estimated future developments in flood risk management.

3.1.1 *Large-scale analysis (Austria)*

In order to compile large-scale and object-based risk maps in upper parts of mountain catchments, two test sites in Austria were chosen, (1) Wartschenbach and (2) Vorderbergerbach, see Fig. 3-2.

Figure 3-2. Test sites for large-scale analysis in Austria

The Wartschenbach catchment is situated in the Eastern Alps in the community of Nußdorf-Debant in the Drau valley, next to the city of Lienz, Austria, between 670 m and 2,113 m a.s.l. The geology is dominated by para-gneiss and mica schist; and covered by glacial deposits. Due to the considerable amount of unconsolidated material, and due to the steep gradient of 30-40 %, the catchment is susceptible to erosion processes, in particular debris flows. Several damaging torrent events are recorded in the event registry, major losses occurred in 1995 and 1997 (2 events).
The Vorderbergerbach catchment is the right tributary to the Gail river in the Carnian Alps, which represent the border to Italy in the Southern part of Carinthia, Austria. The catchment area covers 26 km^2 between 690 m and 1,560 m a.s.l. Lithologic, the basin is comprised from limestone and Ordovician shale, and covered by deposits from the Wurmian glaciation. Several damaging torrent events are recorded in the event registry causing damage in the village of St. Stefan-Vorderberg located on the fan the most recent event in 2003.
For the Austrian part, a set of large-scale process analyses was carried out based on an object-based assessment of the hazard. The modelling of the Wartschenbach test site was carried out by a re-calculation of the well-documented torrent event of 16 August 1997 by using the software Flo-2D. The modelling of the Vorderbergerbach test site was also carried out by using FLO-2D, and calibrated by the well-documented event of 29 August 2003. The originally planned assessment of a third catchment (Enterbach, Tyrol) could not be carried out within the timeframe of RISKCATCH due to a lack of suitable data.
Resulting flow depths and accumulation heights were used as proxies for process intensities in order to allow for the assessment of vulnerability and risk. Therefore, a GIS-based real estate appraisal based on a method described in Keiler et al. (2006b) was undertaken, and a vulnerability function for torrent processes was developed (Fuchs et al. 2007).

3.1.2 *Small-scale analysis (Germany)*

In order to compile medium- and small-scale risk maps in lower parts of mountain catchments, two test sites in Southern Germany were chosen. Vils and Rott are two tributaries of the Danube. The Vils river has a catchment size of about 1450km² and a length of the main river reach of 120 km. The catchment of the Rott river is 1200km² large, and its length is about 100 km. Both catchment areas are located in the tertiary hilly landscape, which is dominated by agricultural land use. Rural structures, settlements with scattered buildings and intensive agricultural use are determining characteristics. However, during the last two decades there was a remarkable increase in industrial and commercial use of land in potentially inundated areas. Prosperity and possibilities concerning workplaces were followed by creation and repressing of settlement areas behind dikes. As a consequence of these developments natural processes are able to affect increasing values at risk in those areas.

Three representative areas with different characteristics in the two catchment areas were taken into account to develop and analyse different approaches of non-technical in comparison to technical risk management and evaluate different processes (Fig. 3-3):

- Kleine Vils/City of Geisenhausen,
- Lower Vils, and
- Lower Rott.

The Kleine Vils is representative for the upper parts of the catchment. The City of Geisenhausen is one of the urban areas, which are mainly situated in the upper and middle part of the catchments. The Lower Vils (Untere Vils) is an example for intensive agricultural land use and small settlements with scattered building patterns located in the wide and open flood plains of the lower river reach. Especially in this area, technical interventions such as dikes, bypasses and detention structures modified the structure and land-use pattern of the former flood plain. The Lower Rott (Untere Rott) is representative for settlement areas and industrially/commercially used areas in the lower reach. Since it is situated close to larger cities and has highway access, industrial zones and commercial areas developed during the last decades in the flat and open flood plain of the Rott.

Figure 3-3: Test sites for small-scale analysis in Germany (Note: The map illustrates the contours of the Federal State of Bavaria in Southern Germany)

Hazard information was derived from the hydrodynamic model HYDRO_AS-2D for design events of different probabilities (HQ_{10}, HQ_{100}, HQ_{1000}). HYDRO_AS-2D is a 2-dimensional stream flow and water level calculation package which is based on the Finite Volume Method. A 2-dimensional hydrodynamic flood routing was performed based on the Surface Water Modelling System (SMS) developed by the Environmental Modelling Research Laboratory at Brigham Young University. The 2-dimensional stream flow equation is derived through the integration of the 3-dimensional stream flow equation, the Reynolds- and Navier-Stokes equations for incompressible fluids over water depth, and by using the assumption of a hydrostatic pressure distribution. It includes algorithms to solve complex situations such as weirs or pipes situated in the stream channel. Based on laserscanning data and topographic information, a DTM was compiled as a basis for the sets of Finite Volume calculations. As water depth is the relevant indicator for the intensity of an event, it was extracted from the modelling results, and other factors such as transport processes, flow velocities and shear stress were not taken into account. As shown in Fig. 3-4, different classifications of water levels were used for the definition of hazard category, and thus hazard mapping. As hazard maps provide the basis of risk maps, this classification scheme figured out to be crucially because it determined the possibility to derive and calculate resulting damages. In contrast to previously published material by LAWA (2006) and MUNLV (2003), a more technical-oriented classification scheme was used based on relevant levels of flooding heights and concentration of potential damage in buildings.

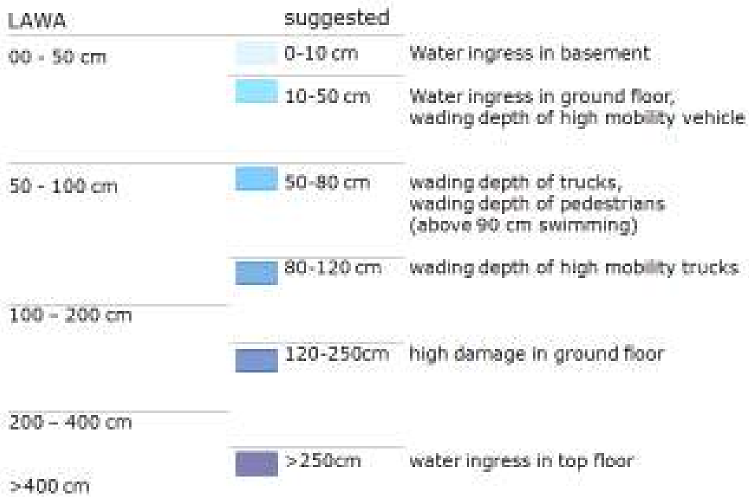

Figure 3-4: Water levels taken into account for hazard mapping, suggested by LAWA (2006) and the suggested technical-oriented indicators for damage assessment used within RISKCATCH

3.2 Analysis of vulnerability

The term vulnerability is used in hazard and disaster management in a large number of ways. Vulnerability is related to the consequences of a natural hazard. These consequences are generally measured in terms of damage or losses, either on a metric scale (e.g., as monetary unit), or on an ordinal scale based on social values or perceptions and evaluations. This is not necessarily a matter of ambiguity or semantic drift, but the result of different disciplinary foci. Essentially, these different uses have invisible, implied adjectives preceding them, hence structural engineering vulnerability, lifeline infrastructural vulnerability, communications system vulnerability, macro-economic vulnerability, regional economic vulnerability, commercial vulnerability (including insurance exposure), and social vulnerability (Wisner 2004). Consequently, two diverse perspectives on the concept of vulnerability exist; (1) the perspective from social science and (2) the perspective from natural science.

(1) As Cutter (1996) stated, there are no unique definitions of vulnerability in social sciences. Multiple definitions are reviewed and listed by Cutter (1996) and Weichselgartner (2001). Approaches in social sciences not only differ between several degrees of voluntariness when dealing with natural hazards, but also consider individual as well as social influences, filtered by certain conditions that determine an individual's perception of risk. Depending on various guiding elements such as probability of occurrence, extent of damage, perception, uncertainty, ubiquity, persistence, reversibility, time delay, and mobilisation potential (German Advisory Council on Global Change 1998), the degree of vulnerability may considerably change. A major difficulty is that "not only people are different, but they are changing continuously, both as individuals and as groups. This constant change within the human system (…) interacts with the physical system to make hazard, exposure, and vulnerability all quite dynamic" (Mileti 1999:119). Most problems resulting from hazard assessment are related to the difficulty of individuals in dealing with low probabilities of rare events (Kunreuther et al. 2001). Individual risk perception, passed through a communication filter, finally leads to a risk assessment as well as accompanying adaptation processes, the latter are either efforts to control hazards or to reduce vulnerability to hazards (Burton et al. 1978).

(2) From a natural science perspective, vulnerability is usually considered as a function of a given intensity of a process, and is defined as the expected degree of loss for an element at risk as a consequence of a certain event (Fell 1994; Varnes 1984). The vulnerability value ranges generally from 0 (no damage) to 1 (complete destruction). Its assessment involves in many cases the evaluation of several different parameters and factors such as building materials and techniques, state of maintenance, presence of protection structures, presence of warning systems and so on (Fell 1994; Fell and Hartford 1997). On the process side, parameters such as the process intensity have to be analysed, usually by mapping the geomorphologic disposition and previous events, and/or modelling (defined design) events.

With respect to the RISKCATCH project it has been agreed between the contributors that vulnerability will be threatened from a technical point of view, neglecting any societal implications for risk management. Vulnerability will be studied on a multi-scale level in dependence on individual process characteristics, taking loss data from previous events or data from values at risk as a proxy.

3.2.1 Large-scale analysis (Austria)

Until now, only little work has been carried out to determine vulnerability values for objects exposed to torrent processes, in particular when using an object-based approach. Vulnerability values proposed in the literature show a wide range, above all with respect to medium and high process intensities (Fuchs et al. 2007). Furthermore an application of these values might lead to an overestimation of vulnerability, as an assessment for alpine torrent events had shown. Within RISKCATCH and based on recent studies, data from the Austrian test sites were used to empirically analyse and assess the vulnerability of buildings to torrent processes, and to establish a respective vulnerability function. Since the analysis was based on process intensities and is thus independent from recurrence intervals, not only the risk resulting from design events can be calculated but also every other event with a different frequency.
The vulnerability of elements at risk was measured using an economic approach. The main criterion therefore was the damage susceptibility (vulnerability), which describes the amount of damage related to the specific damage potential of the considered element at risk, often referred to as loss severity. Following this definition, the vulnerability was derived from the quotient between the loss that occurred during the documented events, and the individual reinstatement value for each element at risk in the test sites (see Section 3.3.1). The losses due to the underlying torrent events were collected using information from the federal authorities. Since in Austria an obligatory building insurance against losses from natural hazards is not available so far, property losses are partly covered by a governmental fund[1]. Consequently, these losses were collected on an object level immediately after an event by professional judges. For this study, these data were used, adjusted to inflation and attributed to the information on every single element

[1] In Austria, natural hazards are not subject to compulsory insurance. Apart from the inclusion of losses resulting from hail, pressure due to snow load, rock fall and sliding processes in an optional storm damage insurance, no standardised product is currently available on the national insurance market. Moreover, the terms of business of this storm damage insurance explicitly exclude coverage of damage due to avalanches, floods and inundation, debris flows, earthquakes and similar extraordinary natural events (Schieferer 2006).
Furthermore, according to the constitution of the Republic of Austria, disasters resulting from natural hazards do not fall under the national jurisdiction. Thus, the responsibility for an aid to repair damage resulting from natural hazards generally rests with the federal states. As a consequence, any claim for damages is subject to a considerable insecurity, and any natural and artificial person has to take individual precautions. Thus, the society seems to be highly vulnerable to natural hazards in Austria.
However, the federal government enacted a law for financial support of the federal states in case of extraordinary losses due to natural hazards in the aftermath of the avalanche winter in 1951. The so-called ‘law related to the disaster fund’ (Katastrophenfondsgesetz) is the legal basis for the provision of national resources for

- preventive actions to construct and maintain torrent and avalanche control measures, and
- financial aids for the federal states to enable them to compensate individuals and private enterprises for losses due to natural hazards

in Austria. The budget of the disaster fund originates from a defined percentage (since 1996: 1.1 %) of the federal share on the income taxes, capital gains taxes, and corporation taxes. The prescribed maximum reserves amount to € 29 million (Republik Österreich 1996, Holub and Fuchs in press).

at risk using GIS. In a second set of calculations, this ratio obtained for every single building in the test site was attributed to the process intensities of the respective events. As a result, a vulnerability function was developed, linking process intensities to object vulnerability values (Fuchs et al. 2007, Fuchs 2008). Consequently, this vulnerability function was used as a proxy for structural resistance of buildings with respect to dynamic debris flow impacts, and thus was used for a spatially explicit assessment of debris flow risk.

3.2.2 Small-scale analysis (Germany)

Regarding the extent of flood plains in the test sites, it was necessary to use cumulated data to efficiently consider vulnerability in the risk equation. In order to meet the requirements of a small-scale analysis, an economic approach was chosen to assess vulnerability. In doing so, vulnerability was calculated on an object basis for different types of buildings using damage functions depending on the water depth. Since for the test sites no record of historical or previous flood damage was available, design values and design loss functions were applied according to suggestions made by Meyer and Mai (2004); this procedure was possible due to comparable economic settings in the test sites. Due to the large amount of buildings situated in flood-prone areas, these damage functions were not applied to individual buildings but to groups of buildings and homogenous settled areas by aggregation. The spatially representation of vulnerability turned out to be an appropriate method for a small-scale analysis.
This procedure is analogously equivalent to the small-scale approach described in the Swiss guidelines (Borter 1999) to provide an area-wide overview on susceptibility to hazard processes. Hence, vulnerability values varied between low (such as agricultural areas and individual farm estates), medium (such as dispersed settlements and small villages), and high values (city centres and industrial zones).

3.3 Analysis of values at risk

Currently, only few conceptual suggestions and operational methods are available for the comprehensive assessment of values at risk endangered by natural hazards (Wilhelm 1997; Heinimann et al. 1998). Accordingly, the evaluation of damage potential is often based on subjective estimations rather than on widely-accepted standardised approaches. Hence, results of such assessments are rarely comparable, and do not necessarily mirror the actual situation satisfyingly. With respect to integral risk management, the assessment of values at risk has to be based on a spatially explicit valuation using GIS techniques. Thus, the following procedures outlined in Borter (1999) and further developed by Keiler et al. (2006b) are recommended for an area-wide application in European mountain regions with respect to persons, infrastructure lines and buildings at risk.
Based on the modelling results of defined design events and recent events, respectively, the associated damage potential was assessed. Depending on the scale, different methods were used in Austria and Germany in order to account for different datasets available. In both countries, multi-temporal data were collected and edited for the use within a GIS environment.

3.3.1 Large-scale analysis (Austria)

The basis for this procedure was a digitised layer of the values at risk, e.g. a building shapefile originating from orthophotos and information extracted from the land register plan. The surface area of buildings provided the source for any further economic valuation. This valuation was carried out by means of average reconstruction values for different building categories, multiplied by further characteristics of these buildings such as building height and technical equipment.
The elements at risk – which were defined as those buildings within the test sites located on the fan – were analysed object-based on large scale with respect to their spatial location and extension. The type and size of the buildings was recorded from digital datasets of the communality administration and validated by remote sensing techniques as well as field studies. These data provided the basis for a monetary evaluation of the reconstruction values. These values were calculated using the volume of the

buildings and average prices per cubic metre according to the type of building, as suggested by Kranewitter (2002) and Keiler et al. (2006b, see Tab. 3-1). Following these suggestions, different price levels were applied, depending on the function of the buildings as well as on the number and kind of storeys. This information was extracted from the construction descriptions and updated by field studies. The average reconstruction value for every building resulted, using the current price level.
The number of persons at risk was derived from the number of households per building and multiplied by the average number of persons per household, e.g. by using information from the respective national statistical offices. If a considerable amount of values at risk were comprised by tourist infrastructure, the number of tourists being present in endangered buildings could be derived from the number of beds in the hotel and restaurant industry, multiplied by the respective rate of occupation (Fuchs et al. 2008a).

Table 3-1. Floor height, number of storeys, and average values per m^3 used during the set of calculation. Modified from Keiler et al. (2006:122)

Type	Floor height [m]	No of storeys	Value/m³ [€]
Detached house	2.8	3.5	350
Apartment building	2.8	4.0	385
Hotel	3.0	5.0	528
Guest house	3.0	3.5	435
Restaurant	3.0	3.0	399
Public building	3.5	3.5	406
Office building	3.5	1.0	342
Commercial building	4.0	1.0	330
Garage	4.0	1.0	212
Agricultural building	2.8	1.0	200
Car park	2.8	1.0	235
Barn	3.5	1.0	171
Storage building	6.0	1.0	105
Power substations	4.0	1.0	371

The dataset was generated (1) object-based related to the geographical location and (2) area-based with respect to the total area harmed by the design event (cf. Section 3.1.1). Thus, two different methodological concepts representing two different possibilities of data availability could be evaluated against each other. Methodological as well as spatial limits and uncertainties were quantified and critically evaluated. Issues in economical evaluation were addressed and determined within the test sites. The results of these multi-scale assessments were evaluated according to accuracy and preciseness.

3.3.2 Small-scale analysis (Germany)

Based on building types (detached buildings, apartment buildings, block of flats, etc.) the resulting values at risk were derived by an object based approach. Additionally, econometric and land use data was used to analyse the spatial distribution of values at risk. Regarding persons at risk a particular type of map was derived by using data from municipal registries and intersection with a register of buildings from the land register plan. Values at risk were derived by a two-step procedure, on an object basis and by using a spatial distribution regarding the needs of the small-scale approach applied in the German part of the project.

3.4 Compilation of risk maps

Having analysed the relevant hazard scenarios, the elements at risk exposed and the associated vulnerability, risk analysis is a method to estimate and assess the impact of a hazard to a given environmental setting. Hence, the method of risk analysis is the prerequisite of risk mapping, and is carried out applying the risk function (Equation (1)) using GIS. Thereby, the compilation of risk maps was based on intensive cooperation between all partners in order to fulfil the requirements for the experimental graphic semiology study (see Section 3.5), which resulted in a set of risk maps for every catchment that included several suggestions of design and layout. The originally dimensionless risk was converted into several visualisable forms in order to test different illustrative facilities.

Depending on the scale, risk was either obtained by applying average values per area during the sets of calculation, or by calculating in a spatially more explicit manner only for endangered objects. Since average values per area were based on empirical assumptions, the result provided a small-scale overview on the risk situation for a larger region, e.g., a valley. Additionally, risk analysis were carried out on a large scale spatially explicit, hence there was a need for precise and accurate data acquisition and analysis. The quantification resulted in quantitative risk for individual objects, and was therefore suitable for larger scales, e.g. individual torrent fans.

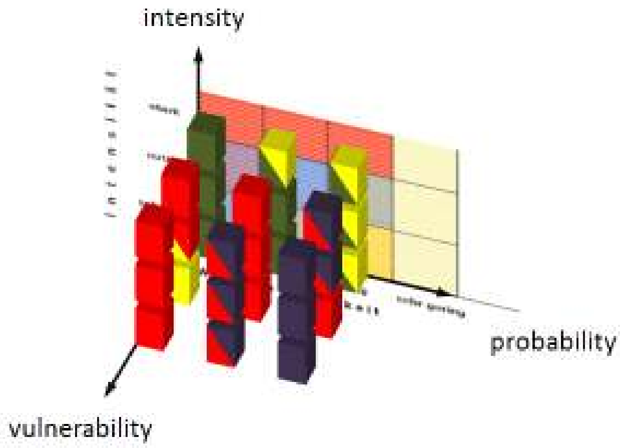

Figure 3-5. Risk cube merging intensity, probability, and vulnerability

In doing so, either the cumulative risk or the individual risk was analysed both, from a comprehensive point of view related to the studied scenario and in terms of annual risk. The analysis of cumulative risk included all elements at risk exposed to the hazard scenario, and was obtained by summing up all values achieved for every element located in the endangered area. The results were given in monetary terms or in number of persons at risk. The individual risk was based on the number of individual persons being present in endangered areas, and was obtained by dividing the cumulative risk by the number of persons.

For all catchments, hazard zones were identified and the respective maps were derived based on the Swiss guidelines (Borter 1999), the application of Equation (1) and further development and adjustment to the availability of data. Extending this approach of two-dimensional intersection between probability and intensity, the vulnerability of values at risk was invented as a third dimension. Vulnerability values varied between low (such as agricultural areas and individual farm estates), medium (such as dispersed settlements and small villages), and high values (city centres and industrial zones). Two different concepts for visualising vulnerability and risk were used, (1) an object-based approach for individual buildings and land parcels, and (2) aggregated information based on land use plans and mappings. As a result, the 3 x 3 matrix became a 3^3 risk cube with 27 risk zones (Fig. 3-5, Dorner et al. 2008). In a further step, these 27 zones were aggregated, resulting in four colours indicating different risk levels.

Taking the results from the Austrian and German catchments, 17 different but complimentary risk maps for (1) torrent processes in alpine catchments and (2) areas inundated in the Alpine foreland were compiled in order to test their perception by the method of experimental graphic semiology (for an overview on these maps, see the Appendix A-11).

3.5 Experimental graphic semiology

The representation and communication of any results from spatially-based analyses in general requires cartographic tools, i.e. maps. These maps are designed based on certain rules and common recommendations, known as graphic semiology (Bertin 1973, 1977).
The procedure of creating maps is based on a linear model from the specialist producing the map (transmitter) to the targeted reader (receiver), neglecting any specific requirements in dependence on the culture or knowledge of the receiver. Reversing this linear model by establishing the new approach of experimental graphic semiology, a cyclical model was proposed aiming at an integration of visual and cognitive perception by the receiver (Serrhini et al. 2008). This model required the quantification of properties and characteristics of visual perception. Therefore, a set of different maps was produced and a video-oculograph (Fig. 3-6) was used for recording eye movements of different user groups, including stakeholders from public authorities, experts in cartography and laypersons.

Figure 3-6. Video-oculograph

Visual strategies can be distinguished by three categories of eye movements, (1) continuous motion, (2) jerks, and (3) saccades, pursuits and fixations. From an ophthalmic point of view, the latter category is the most important when quantifying reading behaviour. Saccades are fast ocular movements with variable speed. They are triggered by fuzzy visions of an object (i.e. the appearance of a peripheral retinal stimulus) or by auditory stimuli, and are directed towards the right, the left, or vertically. Pursuits are slower ocular movements, and are triggered by the examination of a moving target (or stimulus) and therefore constitute central vision. Fixation is the condition when the gaze remains fixed during an interval ranging between 100 and 1000 milliseconds on a surface ≤ 144 mm^2. However, during the fixation of a motionless stimulus, the eye is not entirely motionless itself; micro-saccades and micro-tremors can be registered (Larmande & Larmande 1990).

3.5.1 Experimental protocol

In close collaboration between the project partners, and based on preliminary drafts that were subject to pre-test and discussion, a series of 17 risk maps was created to study visual strategies (see the Appendix A-11 and Fig. 3-7). This series contained variables such as (1) the position of the title and the legend, (2) the structure of the legend, (3) the type of background used for the depicted map content, (4) the level of complexity in discretisation, and (5) the scale. Furthermore, visual variables such as colour value and depth were modified in order to study the effect of contrast and visualisation.

Three groups of test persons were invited to the study, (1) persons specialised in risk perception and familiar with the test sites, (2) persons sensitised to cartography and/or flood risk issues, and – as a control group – (3) laypersons that were neither involved in any flood risk issues nor sensitive to map reading and interpretation (Tab. 3-2). The sample included a total of 21 people, six of which were Austrian, eight German and seven French in order to mirror the multi-national aspect of the study.

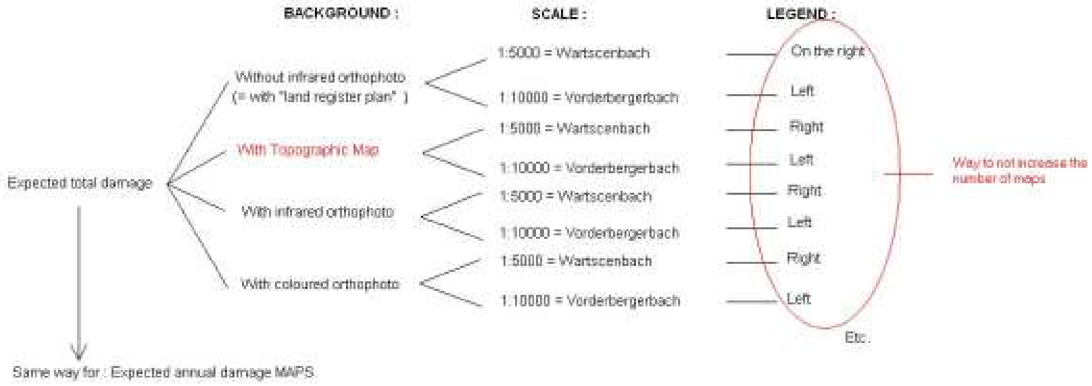

Figure 3-7. Logic diagram used to compile risk maps

Table 3-2. Test persons involved in the study on experimental graphic semiology

No.	Name	Category
	Austrian	
1	Fuchs Sven	Specialist
2	Keiler Margreth	Sensitised
3	Weber Christian	Specialist
4	Weber Elisabeth	Control group (Layperson)
5	Gruber Harald	Specialist
6	Stanzer Monika	Control group (Layperson)
	German	
7	Spachinger Karl	Specialist
8	Heindl Gariele	Control group (Layperson)
9	Ertl Maximilian	Sensitised
10	Panzirsch Michele	Control group (Layperson)
11	Dorner Wolfgang	Specialist
12	Hagemeier Maria	Sensitised
13	Merz Gabriele	Specialist
14	Schiessl Werner	Sensitised
	French	
15	Martouzet Denis	Sensitised
16	Hervé Baptist	Sensitised
17	Bois Nathalie	Control group (Layperson)
18	Larribe Sebastien	Sensitised
19	Burel Béatrice	Control group (Layperson)
20	Ducrocq Jessica	Control group (Layperson)
21	Sellami Louisa	Control group (Layperson)

To record the first moments of eye movements made by the subjects, the risk maps were exhibited for a relatively short period of time (15 seconds) to every individual test person. The analysis was carried out for

the results obtained during the entire length of the map exposure. Thereby, the focus was on (1) the determination of elements that attract the gaze by static and dynamic analyses of ocular movements, (2) the identification of the most visually attractive components of the maps to facilitate statistically those sections that mobilise the most ocular movements of saccades, pursuits and fixations, and (3) highlighting the temporal order in the visual assessing of the various elements of the maps.
To cross-check the results of the experimental graphic semiology, a cognitive survey was carried out during the set of tests, using a specifically developed questionnaire in French and German (see the Appendix). The participants were asked to evaluate (1) the level of complexity, (2) the density of information, (3) the innovative character, (4) the aesthetic value in the information presented, and (5) the applicability for decision making. Furthermore, the test persons were asked to specify their preferences concerning (1) the position of the title and the legend, (2) the structure of the legend, (3) the type of background used for the depicted map content, (4) the level of complexity in discretisation, and (5) the scale when comparing different types of maps.

3.5.2 Analysis of eye movements

Based on the experimental protocol, the test was conducted and the analysis of eye movements was carried out by a three-stage statistic, static and dynamic analysis to prepare recommendations of how risk maps should be designed. Using the eye movement sensor of the video-oculograph in combination with a high resolution colour generator for static and dynamic images, gaze direction was measured from the distance between the corneal reflex and the pupil centre. This technique provided measurements which were absolute (no drift), quantifiable, reliable in all gaze directions (horizontal, vertical and oblique), and independent from head movements.

Statistic analysis

Using descriptive statistics, the recorded eye movements were analysed with respect to (1) the average number of fixations per map, (2) the average length of fixation per map and (3) the number of saccades. Additionally, (4) the span of each saccade was assessed.

- The average number of fixations per map was related to the visual effort mobilised in searching for more or less attractive elements in a map. A high number of fixations indicated a considerable visual exploration.
- The average length of fixation per map provided information concerning the amount of time the test person needed to observe various zones of the picture. Moreover, an indication of which elements retained the readers' attention most or least was given.
- The number of saccades provided information concerning the amount of saccade-type ocular movements made when passing from one visual element to another. A large number of saccades suggested that it might be difficult for the tested subject to identify the main information presented.
- The span of each saccade described the angular distance between fixations and, consequently, the distance between the zones fixed by the tested subject. Saccades of great amplitude suggested that the visual information scattered considerably.

Static analysis

To assess the visual strategies applied by the test persons, spatial patterns in the eye movements were analysed using the method of static analysis. Thereby, video files were produced for a precise ex-post analysis of eye movements. Systematic and regular patterns in map exploration were identified according to different visual behaviour between the groups of test persons.

Dynamic analysis

Using the vision monitor of the video-oculograph, the dynamic analysis of eye movements was carried out aiming at the determination of the most attractive elements that were recognised by the test persons in individual maps. The order of succession in the visual access to information was identified and assessed, and regularities in the visual strategies were shown. Thus, the preferences for specific, visually attractive elements were deduced for each individual tested person as well as for the respective group of test persons.

3.5.3 Cognitive survey

A bi-lingual questionnaire was developed for the assistance during the analysis and evaluation of the test results from the video-oculographic device (Serrhini 2005; see the Appendix A-95) for a complete set of questions). This survey consisted of three parts, (1) the first part to be filled by each participant before the recording of eye movements, (2) the second part that was presented to the test persons step-by-step during the test, and (3) a third part to be filled in by the test persons after the recording of eye movements.
The first part of the cognitive survey was systematically handed to the test persons before the beginning of the recordings, and was related to personal information. The purpose was to identify each participant clearly as a member of one of the three stakeholder groups identified (specialist, sensitised user, and layperson).
The second part of the questionnaire was related to individual sets of maps and requested the appreciation of (1) the level of complexity, (2) the density of information contained, (3) the innovative character, (4) the aesthetic value, and (5) the potential relevance for decision making.
The third part requested the comparison between maps, the test persons had to specify their preferences concerning (1) the position of the legend and the title, (2) the level of discretisation, (3) the colour, (4) the scale, and (5) the background of the map.

4 Results (Risk Mapping)

"This chapter provides information of the scientific results of large-scale and small-scale risk mapping. It is shown how process analysis, the analysis of values at risk, and the assessment of vulnerability are merged together in order to compile cartographic information on risk. In doing so, the focus is not only on different parameters of how to express risk, but also on possible different communication purposes with respect to the presentation of these maps to different stakeholders, and the different understanding of the respective map content by multiple user groups. Additionally, underlying results related to the temporal and spatial development of risk are presented. It is shown that the general statement that risk has increased over the last decades is not necessarily true, if hazards in mountain catchments are evaluated."

The results of the compilation of risk maps are presented for the large-scale analysis undertaken in the upper parts of (torrent) catchments in Austria, and for the medium- and small-scale analysis in the related mountain forelands (Germany).

4.1 Large-scale analysis

The overall development of losses due to torrent events in Austria, and thus the resulting risk, did not show any clear temporal trend (Fig. 4-1). However, both, the number of events (green columns) and the extent of damage (orange columns) fluctuated considerable but with no functional relationship. Thereby, the number of events showed smaller ranges than the extent of damage, which had been attributed to the concentration of tangible assets in endangered areas during the last decades and to an assumed increased damage susceptibility (Oberndorfer et al. 2007, Keiler & Fuchs 2008). Similar patterns have also been reported by Fuchs et al. (2005, 2006) and Keiler et al. (2006a) with respect to mountain settlements.

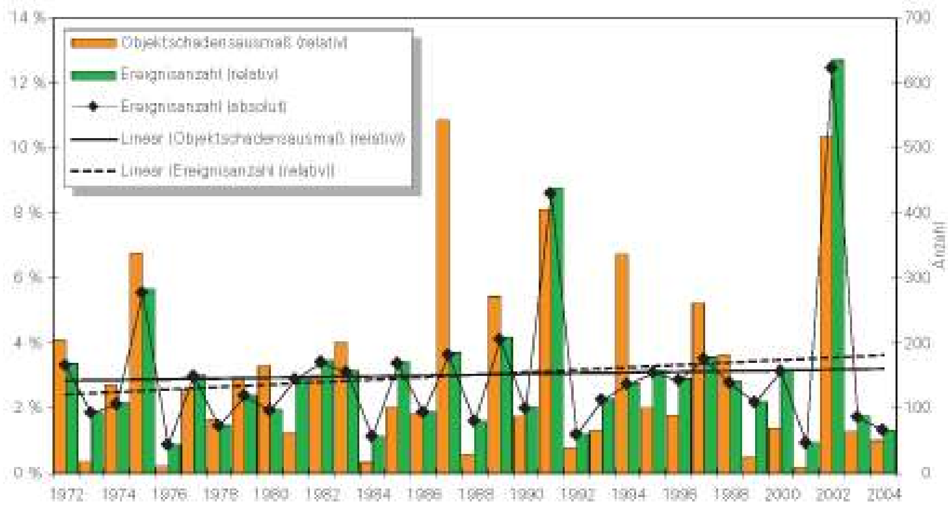

Figure 4-1. Analysis of losses resulting from torrent processes in Austria 1972-2004. Adopted from Oberndorfer et al. (2007:34)

The results of the process analysis are presented in Fig. 4-2 for the torrent fans in the Austrian test sites. These results were based not only on modelling, but also on the analysis of event documentation and geomorphologic terrain analysis. For the subsequent steps, accumulation depths and flow heights were used as proxies for process intensities.

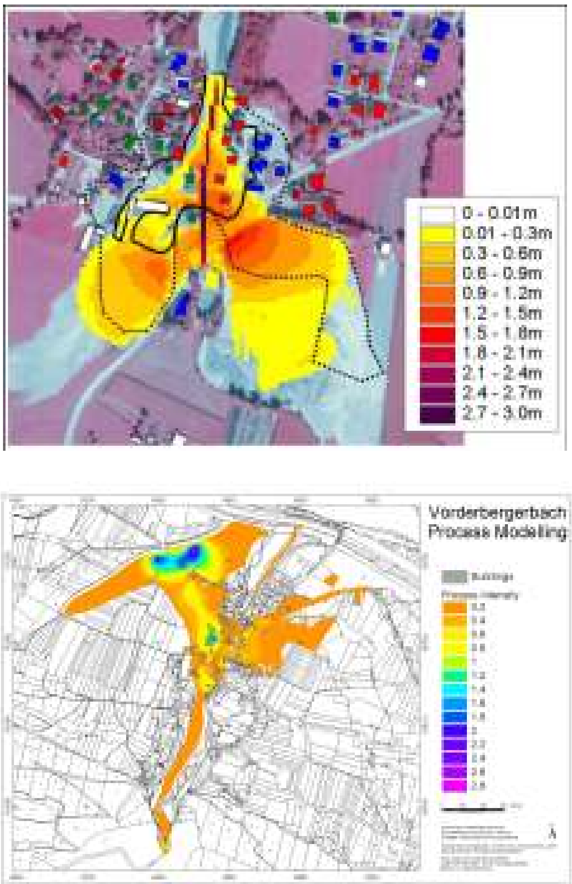

Figure 4-2. Results of process modelling by FLO-2D: Wartschenbach (top) and Vorderbergerbach (bottom)

These proxies were linked to vulnerability quantifications in order to develop a vulnerability function that can be applied for the risk calculation. The respective cure valid for the predominant type of building located in the test sites is presented in Fig. 4-3. The process intensity, plotted as the abscissa in terms of deposit height, was grouped in steps of 0.5 metres. In general, the results suggest a low vulnerability if the process intensity is low and an increased vulnerability if the process intensity is higher. In detail, the data do not suggest a linear increase in vulnerability, which is a result of the specific process characteristics. Low process intensities cause noticeably less damage than medium and high intensities.

$$f_{(x)} = \begin{cases} 0 \;\; if \;\; x < 0.\overline{3} \\ 0.12x^2 - 0.04x \;\; if \;\; 0.\overline{3} \le x \le 3.06 \\ 1 \;\; if \;\; x > 3.06 \end{cases} \qquad (2)$$

The relationship between process intensity x and vulnerability y in the Austrian test sites, supplemented by additional studies carried out in the Swiss Alps (Kimmerle 2002), was found to fit best to the data by a

second order polynomial function for all intensities 0.33 m ≤ x ≤ 3.06 m. The coefficient of determination R^2 is 0.97, which seems to be comparatively sound with respect to the amount of data available.
A process intensity of 0.33 m was found to represent a lower impact threshold since no damage to buildings occurred below this value. Taking into consideration the relatively formal procedure of applying for subsidies from the federal and national funds in Austria, this lower threshold might be an artefact since similar data from Italy had shown minor losses related to such process intensities (Dall'Amico, pers. comm.). In addition, the analysis of the data had shown that the vulnerability of buildings affected by medium debris flow intensities (1.00-1.50 m) is highly dependent on whether or not the entrained material harms the interior of the building (i.e., by an intrusion of material through openings such as doors, wells and windows). Consequently, local protection measures such as deflection walls and specially designed closure structures for at-grade openings definitely play a major role in reducing the vulnerability of buildings, particularly with respect to low and medium process intensities.

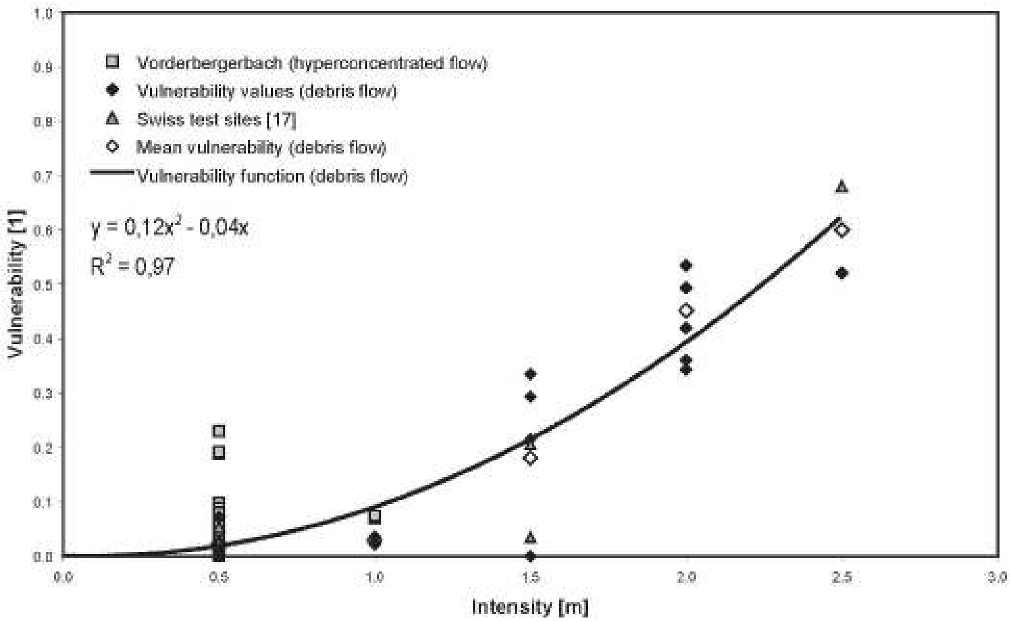

Figure 4-3. Vulnerability function for torrent processes (Fuchs 2008). Data related to debris flows is shown by solid black rhombi (mean by framed white rhombi). Data from Swiss test sites (Kimmerle 2002) is presented by grey triangles. Data originating from hyperconcentrated flows is shown by grey squares.

Table 4-1. Values at risk exposed in the Austrian test sites.

	Wartschenbach	Vorderbergerbach
Reconstruction value [M€]	7.15	14.6
Buildings [N]	33	113
Detached houses [N]	21	29
Apartment buildings [N]	2	2
Agricultural main buildings [N]	1	32
Agricultural adjoining buildings [N]		38
Adjoining buildings [N]	6	7
Commercial buildings [N]	2	
Guest houses [N]		3
Special risk buildings [N]	1	2

The elements at risk – which were defined as those buildings within the test sites located on the fan – were analysed object-based on large scale with respect to their spatial location. A shown in Tab. 4-1, the exposed values differ considerably in number and value. The overall reconstruction value at Wartschenbach test site amounted only to approximately 50 % of the value in Vorderbergerbach test site, while the number of buildings exposed was only one third. Hence, buildings located on the Wartschenbach fan were comparatively valuable, which was proven by a field study and explained by different socio-economic conditions in the test sites.

Linking process intensities, vulnerabilities and values at risk, risk maps were compiled on a large scale for the test sites (see the Appendix A-11). In doing so the focus was not only on different parameters of how to express risk, but also on the different communicative purposes with respect to the presentation of these maps to different stakeholder groups. All maps were compiled using a landscape layout in DIN-A4 format.

Map 1 (Wartschenbach) and map 2 (Vorderbergerbach) only provided the hazard and the building categories and served as an introduction during the perception study. Maps 3-6 provided information on the expected total risk with an underlying design event of 1/150 years. Maps 7-10 provided information on the expected annual risk applying a design event of 1/150 years. The sets of maps were modified according to several variables in order to test the different accessibility and readability, and thus understanding by different stakeholders.

4.2 Small-scale analysis

The temporal analysis of risk carried out on a large scale showed remarkable results related to an increase in exposed values, even if considerable efforts had been undertaken to protect these values by technical flood mitigation measures. By comparing land register maps of different time periods (1850, 1920, 1970, and 2000), and overlaying them with the inundation areas, a tenfold increase in the development area exposed to a 100-year design flood was proven, as shown in Fig. 4-4 for the test site of Lower Vils. With respect to the (rare) 1000-year design flood, the affected area in the year 2000 was 20 times larger than it had initially been in the year 1850. This increase was particularly evident if certain map segments were compared (Fig. 4-5). Considerable development took place in flood-prone areas leading to an increase of both, built-up areas and agricultural areas in former flood plains[2].

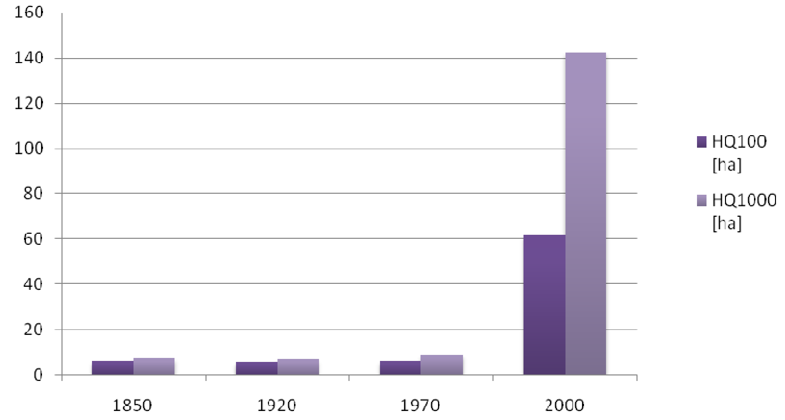

Figure 4-4. Development areas [ha] affected by flooding in the Lower Vils region 1850-2000

[2] Which lead to the fact that in the Lover Vils region, even agricultural areas such as cornfields were recently protected by constructive flood mitigation measures.

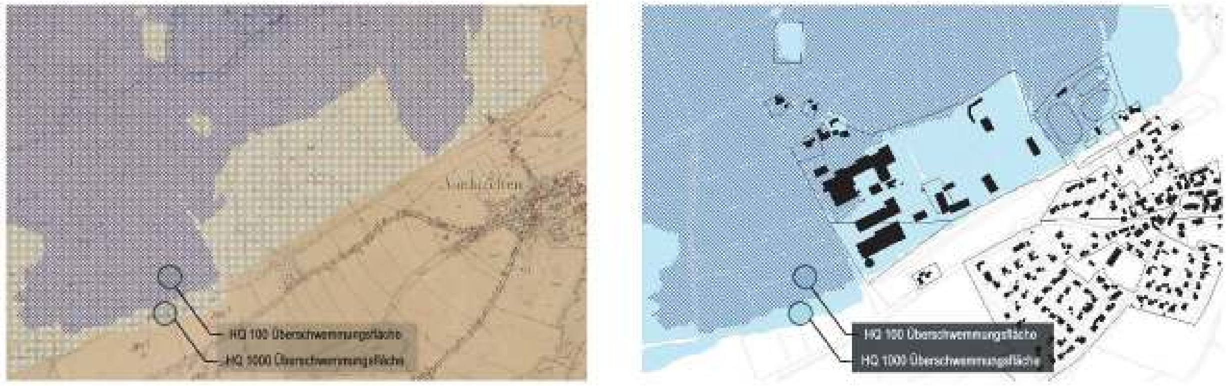

Figure 4-5. Comparison of developed areas affected by flooding in the Loser Vils region 1850 (left) and 2000 (right)

These losses of flood plains resulted in increased water levels and a reduced efficiency of levees in order to protect settled areas (Dorner et al. 2008).
Although the building activities in flood-prone areas were restricted since the late 1980s, a considerable increase took place in the outgoing 20th century. This might be a result of

(1) the effect that diked areas were not taken into account when endangered areas were identified, and as a consequence, residual risks were not communicated. Moreover, recent analyses had shown that most technical flood protection structures had been designed based on an underestimation of the design discharge (HQ_{100}) and did not provide sufficient protection against inundation; and
(2) the fact that building restrictions were not applied to already established building land, leading to an increased building activity in these areas. Therefore, the concentration of buildings in these areas mainly contributed to the increase of values at risk.

The analysis of four different planning alternatives carried out in the test site of Lower Vils had shown that non-technical flood mitigation is effective and efficient, and can play a major role in reducing losses. Alternative (1) considered as minimum variant aimed to establish technical structures and to increase the crest of the levees, alternatives (2)-(4) focused on the deconstruction of levees protecting agricultural areas in order to increase the available flood plain. Besides the costs for necessary construction or deconstruction, the economic valuation included the required purchase of agricultural land to make it available as natural detention area. The latter alternatives resulted to be more efficient not only from an economic point of view but also in a considerable decrease of water levels and therefore a remarkable relieve of pressure to structures protecting settlements.
To indicate the spatial distribution of risk, three to seven classes of risk were used based on either individual objects (Fig. 4-6) or the aggregation of values, e.g., settlement areas, industrial areas, agricultural areas, and forestry (Fig. 4-7).
Linking process intensities, vulnerabilities and values at risk, small-scale risk maps were compiled for the test sites (see the Appendix A-14). In doing so the focus was not only on different parameters of how to express risk, but also on the different communicative purposes with respect to the presentation of these maps to different stakeholder groups. All maps were compiled using a landscape layout in DIN-A1 format.
Map 11 and map 12 (Rott) provided information on risk based on aggregated building categories. Maps 13-17 provided information on the persons at risk. The sets of maps were modified according to several variables in order to test the different accessibility and readability, and thus understanding by different stakeholders.
Considering that scale and consequently level of detail varied due to different size of the test sites, the concept of visualising risk was remarkable successful using spatial signatures already at scales ≤ 1:10,000. This requires the recalculation of values at risk for individual objects in order to adapt the values to larger areas.

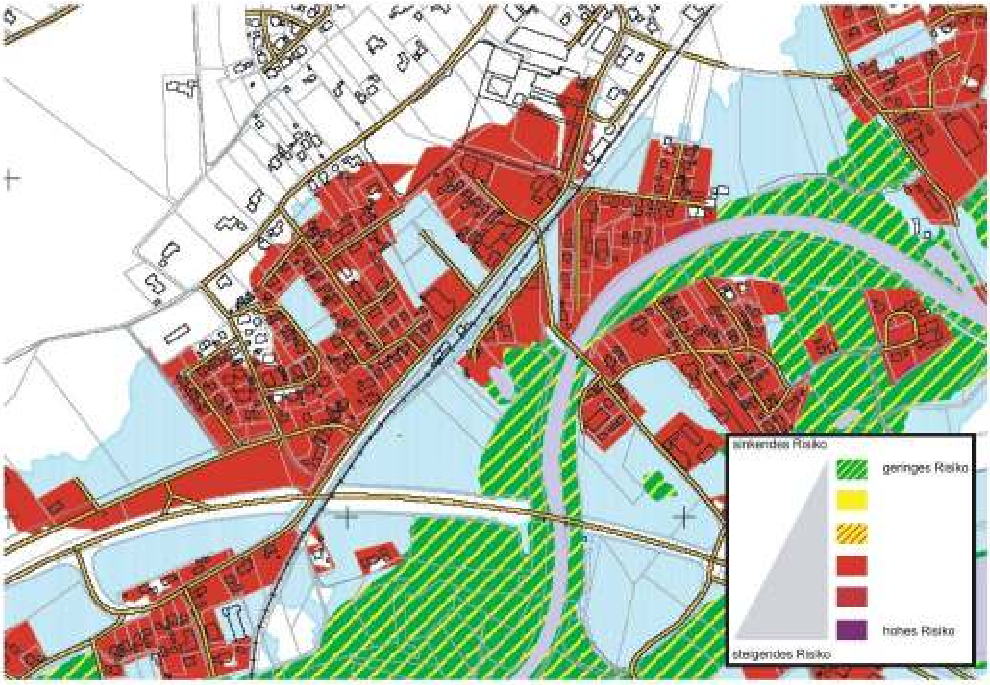

Figure 4-6. Risk map indicating economic risk per object

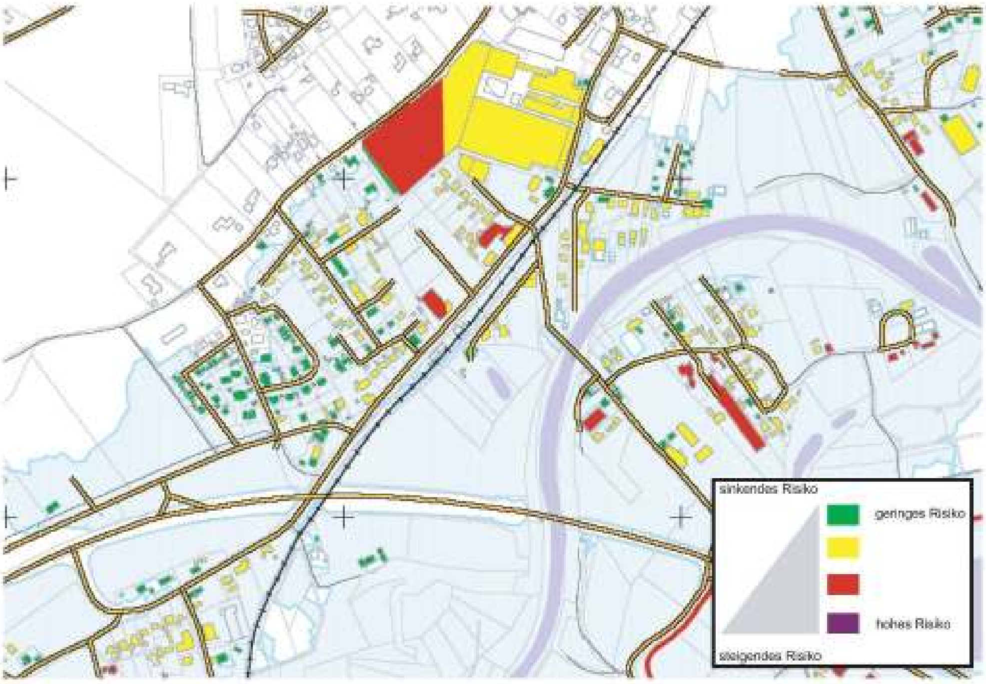

Figure 4-7. Risk map indicating economic risk per area

The associated generalisation raised the question whether or not vulnerability has to be considered during the sets of calculation, since the necessary re-classification of data resulted in a certain loss of information. Hence, an additional valuation of risk was carried out based on land-use types, the underlying values are shown in Tab. 4-2. This procedure principally equals a suggestion made by Borter (1999) for semi-quantitative small-scale analyses, but was extended by quantifiable data.

Table 4-2. Recalculation of values at risk for a spatial analysis

Category	Values at risk [€/m^2]	Fraction of object related to total area [-]	Spatial distribution of values at risk [€/m^2]
Farmland	< 1	1.0	< 1
Farm estate	20-70	0.1	2-7
Residential building	200-400	0.2	40-80
Commercial building (Trade and Services)	400-1000	0.5	200-500
Industrial building (Production)	> 800	0.5	> 400

4.3 Overall recommendations

The analysis of natural hazard risk is embedded in the circle of integral risk management, including a risk assessment from the point of view of social sciences and economics, and strategies to cope with (adverse) effects of hazards. The underlying objective for risk management is the planning and implementation of protective measures in an economically efficient and societal agreeable manner. Thus, risk assessment includes both, risk analysis and risk valuation within a defined system at the intersection between different disciplines. For this reason, the scales of valuation (temporal, spatial, level of detail) have to be well defined for a sustainable risk minimisation.

To be able to compare different types of hazards and their related risks, and to design and implement adequate risk reduction measures, a consistent and systematic approach has to be established. While a hazard analysis focuses on natural processes such as torrent processes and inundation, the method of risk analysis additionally includes the qualitative or quantitative valuation of elements exposed to these hazards, i.e. their individual values and the associated vulnerability. Originating from technical risk analyses (Schneider 1980; Fritzsche 1986), the concept of risk with respect to natural hazards is defined as a quantifying function of the probability of occurrence of a process and the related extent of damage, the latter specified by the damage potential and the vulnerability, see equation (1).

Hence, according to Chapter 2, specifications for the probability of the defined scenario (p_{Si}), the value at risk affected by this scenario (A_{Oj}), the vulnerability of object j in dependence on scenario i ($v_{Oj,\,Si}$), and the probability of exposure of object j to scenario i ($p_{Oj,\,Si}$) are required for the ex-ante quantification of risk ($R_{i,\,j}$). The procedure of hazard assessment is methodologically reliable in determining the hazard potential and the related probability of occurrence (p_{Si}) by studying, modelling, and assessing individual processes and defined design events. Until now, little attention has been given to the damage potential (A_{Oj}) affected by hazard processes, even if theoretic concepts and guidelines exist in some European countries.

As shown in Table 4-3, risk analysis includes (1) hazard analysis, (2) vulnerability analysis, and (3) the analysis of values at risk. All three steps of risk analysis should be carried out within a GIS-environment for a spatially explicit calculation.

After defining the scale and system boundary for the analysis, all necessary steps for the risk analysis will be conducted. The hazard analysis includes an event and impact analysis and results in a specific process scenario, e.g. the extent of a 150-year design event. Identifying elements at risk harmed by the defined scenario, a vulnerability analysis and an analysis of values at risk will be carried out. A vulnerability analysis includes the assessment of resistance, resilience and coping capacity; with respect to flood hazards in European mountain regions, and from an engineering point of view, only the analysis of structural resistance is regularly carried out. The analysis of values at risk includes number and value of tangible assets, and an analysis of number and categories of people being present in endangered areas. A facultative analysis of intangibles can be undertaken, while the valuation procedure of intangibles is neither always satisfyingly nor definitely possible. All steps of the risk assessment have to be undertaken by a well-defined objective procedure to guarantee for transparent and reproducible results.

Table 4-3. Elements to be considered within the framework of risk analysis. Adopted from Fuchs et al. (2008b)

Definition of scale (e.g., time, space,…) and system boundaries		
Hazard analysis	**Vulnerability analysis**	**Analysis of values at risk**
Analysis of terrain and environment	Analysis of direct and indirect consequences	Analysis of number and categories of persons
Definition of scenarios/design events	Analysis of (structural) resistance	Analysis of number and value of tangible assets
Modelling and simulation	Analysis of resilience and coping capacity	Analysis of intangibles (monetarily?)

Socio-economic development in European mountain environments and downstream riparian regions is reflected by an increasing usage of areas affected by flooding processes for settlement purpose and economic activities (Fuchs & Holub 2007). Consequently, considerable economic losses resulted in recent years (e.g., Linnerooth-Bayer & Amendola 2003; Mitchell 2003 for flood hazards and Oberndorfer et al. 2007 for torrent processes).

In order to minimise these losses, technical and non-technical mitigation measures have been implemented within the framework of integral risk management (e.g., Kienholz et al. 2004). This framework combines constructive measures to mitigate the process magnitude and frequency with supplementing organisational and passive measures in order to reduce values at risk exposed. Passive measures include temporary organisational measures, such as evacuation in case of an event, and permanent measures, above all the implementation of land-use regulations in areas prone to hazards. To implement land-use regulations, a common procedure applied in most European countries is hazard and risk mapping. Hence, an intersection of hazard-prone areas with values at risk exposed is required. On the European level, such maps are mandatory with respect to flood hazards area-wide until 2013 (Commission of the European Communities 2007). By these maps, areas endangered by processes and showing considerable accumulation and concentration of values at risk are depicted.

Risk mapping can be carried out on different scales depending on the purpose. In order to gather information over larger areas, small-scale analysis (1:2,500-1:5,000) is carried out on an object basis. Hence, detailed information on the number and value of elements at risk is needed, and concise information on the type of building and material used for construction is collected in order to mirror the individual susceptibility and to calculate the associated vulnerability. The requirements for the process modelling include detailed information on process intensities for specific locations, however, the model results need to be carefully validated with recent events that occurred in the same test site. With respect to the required preliminary flood risk maps (Commission of the European Communities 2007), large-scale analyses of risk can be carried out on a scale of 1:10,000-1:25,000. By conducting larger scale analyses, average values – often based on a spatial approach – have to be assigned to the elements at risk, and average vulnerability values have to be used in order to calculate the expected degree of loss. The requirements for process modelling include generalised information on process intensities, and these intensities should mirror the generally expected magnitudes of the design events.

Having analysed the relevant hazard scenarios, the elements at risk exposed and the associated vulnerability, risk maps were compiled. Depending on the scale, risk was either obtained by calculating spatially explicit values for individual objects, or by applying average values per area during the sets of calculation. Since average values per area were based on empirical assumptions, the result provided a small-scale overview on the risk situation for a larger region, e.g., a valley bottom. Additionally, risk analysis were carried out on a large scale and the calculation resulted in quantitative risk for individual objects, and was therefore suitable for larger scales, e.g. individual torrent fans. The initially dimensionless risk figures were converted into a number of visualisable forms in order to test different illustrative facilities

and to obtain a set of maps for every catchment featuring several suggestions of design and layout. In doing so, either the cumulative risk or the individual risk was analysed both, from a comprehensive point of view related to the studied scenario and in terms of annual risk. Large-scale maps were based on object-specific risk, and provided information on either exposed building categories, exposed total damage or expected annual damage. Small-scale maps were based on (1) an object-based approach for individual buildings and land plots, or (2) aggregated information based on land use plans and mappings. These maps provided information on monetary loss or on the number of persons at risk. A complete set of maps is shown in the Appendix A-11.
The following minimum requirements should be met when risk maps have to be compiled:

- Process analysis
    - Assessment of historical events, including available cadastres, chronicles, and communication with people concerned
    - Process modelling by appropriate software tools for defined (targeted) design events
    - Evaluation of existing hazard maps
    - Validation of the results
- Analysis of values at risk
    - Spatially explicit analysis of number and values of exposed buildings, this step can either be carried out object-based (large-scale) or by applying average values (small-scale)
    - Subsequent analysis of people at risk, e.g. by using statistical data related to the number of persons per building
    - Individual analysis of elements with high-risk potential (hospitals, schools,…)
- Analysis of vulnerability for identified values at risk with respect to the process scenarios selected
- Intersection of process scenarios with values at risk and related vulnerabilities in order to calculate the cumulative risk for the defined scenario. Dividing the values by the annuality of the design event results in the expected annual risk

Risk analyses are per definition static approaches and result in certain values for specific locations and specified periods in time. However, risk can temporally change as a result of changes of individual risk parameters, i.e.:

- the probability of defined scenarios (p_{Si}),
- the values at risk affected by these scenarios (A_{Oj}),
- the vulnerability of objects in dependence on the defined scenarios ($v_{Oj, Si}$), and
- the probability of exposure of objects to the defined scenarios ($p_{Oj, Si}$).

Hazards and their temporal occurrence and distribution, as the basis for the assessment of the probability of a scenario and the probability of exposure of objects, seem to be a variable factor at least with respect to observed and predicted changes of the natural environment. Moreover, the following items not specifically being addressed during RISKCATCH have to be taken into account when process scenarios are defined:

- Possible improved understanding of hazards and underlying triggering factors and better data basis for the analysis and the prediction of design events, respectively.
- Land use changes or structural changes within the river system resulting in hydrological and hydrodynamic changes of design event parameters.
- Changes of regional climatic conditions and the above-mentioned global climate change, e.g. resulting in altered precipitation patterns and precipitation intensities.

Values at risk affected by hazardous processes change temporally; hence the identification of possible areas at risk and areas to be developed in the future should include some information with respect to these changes. With respect to land use, risk may be variable as a consequence of one of the following actions:

- Increase of the number of elements at risk in the hazard prone area, e.g. as a consequence of urban development and related concentration processes,
- increase of individual elements at risk as a consequence of building extension and outbuilding, and
- increase of the value of individual elements at risk, e.g. due to renovation works and increasing value of furniture or machinery in the object

The evaluation of historical data (cf. Fig. 4-4) shows that the development of settlements towards the river and in the flood plain was a major reason for the development of risk during recent decades, a phenomenon that has been simultaneously reported by Fuchs et al. (2005) and Keiler et al. (2005, 2006a) with respect to mountain hazards. Due to economic development in European mountain regions and associated forelands, it has to be assumed that values at risk per object also increased significantly over the past 50 years. Hence, risk analyses should take into consideration such developments; if carried out comparative the associated increase in risk can be quantified.

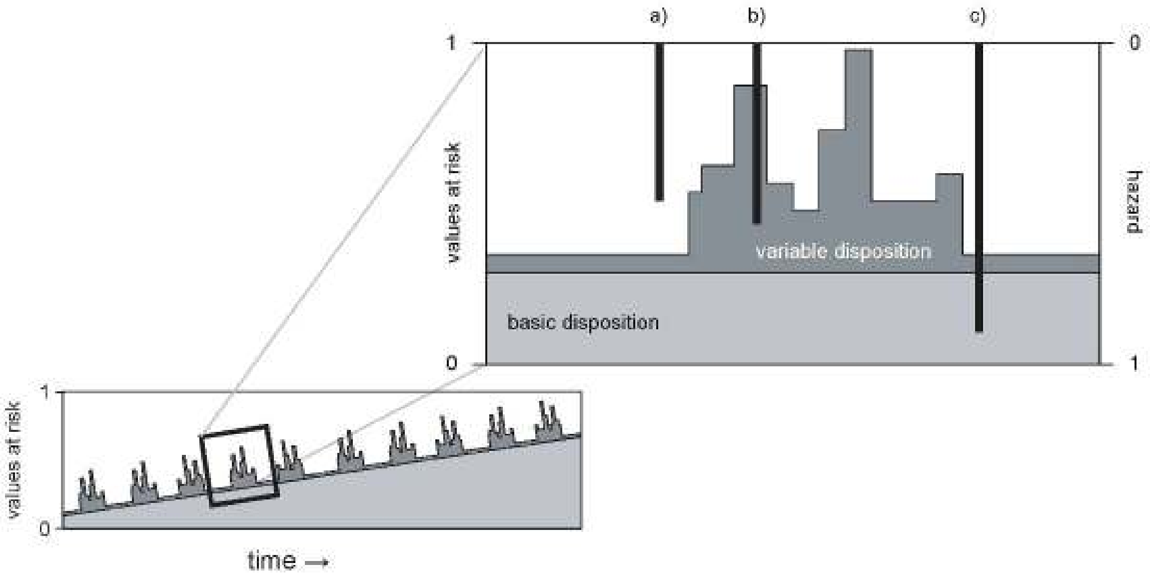

Figure 4-8. Schematic description of the concept of basic (long-term) and variable (short-term) damage potential and the relation to triggering events. Adopted from Fuchs and Keiler (2007:275)

The development of values at risk due to socioeconomic transformation in the European Alps and related forelands varies remarkably on different temporal levels. Long-term changes and short-term fluctuations have to be considered when evaluating risk resulting from natural hazards. Long-term changes in values at risk could be considered as basic disposition (Fig. 4-8). To reduce the risk resulting from this basic disposition, permanent constructive mitigation measures could be constructed and land-use regulations as a form of non-constructive mitigation strategies should be enforced. As a consequence, the basic risk could be reduced due to a spatial reduction of the process area. However, extraordinary losses could be estimated if rare events with severe effects occur, since the delimitation of the respective process areas is based on defined design events. This problem emerged during the flood hazards in Germany and Austria 2002 and 2005.
Short-term fluctuations in damage potential supplement this continuing development of damage potential within a specific range. Thus, they have to be considered as variable disposition (Fig. 4-8). To mitigate those fluctuations, temporal measures could be applied, such as evacuations or temporary road closures.
Furthermore, since the socioeconomic development differs within different European regions, studies on the long-term behaviour of values at risk contribute to the ongoing discussion of passive and active developing regions and suburbanization. However, if a potentially dangerous natural event will occur, it

depends on the actual amount of values at risk (basic and variable disposition) within the process area whether or not damage will be triggered.
To conclude, risk analyses concerning natural hazards should be carried out with respect to a dynamic change of input parameters. Information on the temporal variability of values at risk both from a long-term as well as from a short-term point of view provide in combination with process knowledge is the basis for dynamic risk visualisation. Such information may help to recognize high risk situations more easily and enables a situation-oriented and risk-based decision-making. This is essential for efficient disaster risk reduction and contributes to the concept of resilience as part of proactive adaptation. Thus, future research is needed to quantify the impact of modifications in process behaviour and damage potential exposed on (1) the result of risk analyses, (2) the assessment of risk in the cycle of integrated risk management, (3) the adjustment of coping strategies, and (4) the perception of risk by all parties involved, including policy makers.

5 Results (Experimental Graphic Semiology)

"This chapter provides an overview on the scientific results obtained when applying the innovative approach of experimental graphic semiology to risk maps. It is shown that the visual accessibility of cartographic information is highly dependent on minimising information where possible and highlighting necessary information. In general, the focus of visual perception is on textual and coloured information, and areas with clear contrast. More specific, eye movements are attracted by the main elements of the map, the legend and the figure part. Thereby, approximately two third of the observation time is devoted to less than one fourth of the map surface."

The results emerging from the experimental graphic semiology are presented from a statistical point of view, and by means of the static and dynamic analysis. The summary and evaluation of the parallel conducted cognitive survey supplemented these analyses.

5.1 Statistic analysis

The average number of fixations per map provided information concerning the extent of visual exploration; however, the 17 maps did not induce the same visual impact. Maps that included more graphic information, e.g., an infrared or coloured orthophoto representing the overall setting of the situation depicted, resulted in significantly more fixations (and thus were intensively visual explored) than those maps that contained only a black and white land register plan for background information instead (Fig. 5-1). Hence, the visual accessibility of maps is highly dependent on minimising information where possible and highlighting only necessary information since the eye visually fixes the most outstanding elements successively. If graphic information was delivered less dense, a considerable lower visual impact was noticed.

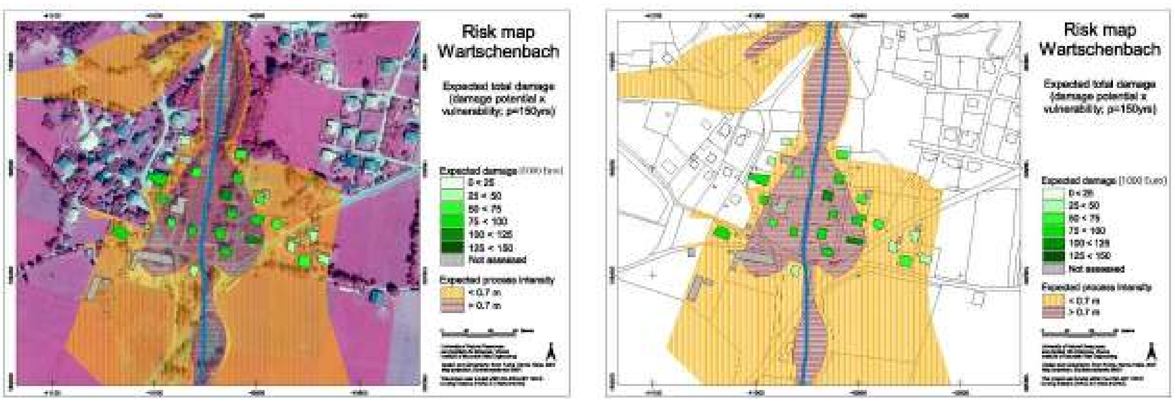

Figure 5-1. Example from the set of risk maps for the Austrian test site "Wartschenbach", produced in order to study differences in visual perception (maps 5 and 3). In the background left: IR orthophoto, right: land register plan.

Considering the limited period of 15 seconds that was chosen for presenting each individual map to the test persons, maps that caused more number of fixations per map resulted in shorter duration of fixations per map, and vice versa (Tab. 5-1).
However, the average number of fixations per map is not only dependent on the map content, but also on (1) the effect of habituation, in particular the control group of laypersons, that gradually get accustomed to map reading, (2) the effect of tiredness, since the recording process spanned a period of 25 minutes per person, and (3) the repetitiveness character of certain maps with only marginal differences in depiction and thus visual distinction.
Those risk maps that followed general rules of design with respect to natural hazards, i.e., red and yellow hazard zones and only sketchy depiction of the overall setting, resulted in a considerable number of fixations within the group of specialists. On the other hand, a strongly coloured map background seemed to induce a noticeable attractiveness to the group of laypersons; the visual exploration was stimulated in particular for those maps that were based on infrared and coloured orthophotos. The group of people sensitised for map production or flood risk showed rather variable visual behaviour.

Table 5-1. Average number of fixations, average duration of fixations, and average number of saccades per map.

Map no.	Ø number of fixations [N]	Ø duration of fixations [ms]	Ø number of saccades [N]
1	35	368	34.2
2	37	340	35.1
3	37	344	35.1
4	36	338	34.0
5	41	309	39.0
6	36	332	33.7
7	36	349	34.4
8	33	368	31.2
9	37	342	35.4
10	36	363	34.2
11	35	360	32.8
12	35	362	32.3
13	33	376	31.2
14	34	359	31.8
15	34	351	31.7
16	33	385	30.5
17	32	381	29.3

As a result of the statistic analysis, specialists in risk mapping do not scatter their attention over the map (less fixations per map) but do more thoroughly access the map content (more time for each fixation), while laypersons spend most of the time in a random access of the map content with no particular focus except from a certain interest in coloured information. A correlation between the number of fixations (attractive zones visually fixed) and the number of saccades (ocular movements that enable the passage from one zone of the picture to another) was observable (Tab. 5-1).

5.2 Static analysis

The static analysis was used to identify systematic and regular spatial patterns in map exploration. First, based on the analysis of video recordings, certain repetitive elements were identified that attracted the gaze of the entire sample of test persons. Second, certain specific elements of the maps could particularly be assigned to individual groups of test persons.

5.2.1 *Static analysis for the entire sample*

In general, the focus of visual perception was on textual and coloured information, and areas with clear contrast; 90 % of the fixations were concentrated in these areas. These areas contained three different elements (1) the title, (2) the legend, and (3) the central element of cartographic information. Hence, the focus in static analysis was on whether or not fixations upon these elements were undertaken, and if regular patterns could be discovered in dependence on the graphic semiology used.
There was a clear tendency that the gaze of all test persons followed along those information that was arranged in a vertical or diagonal order, e.g. along the river that was depicted on some of the maps (Fig. 5-2).

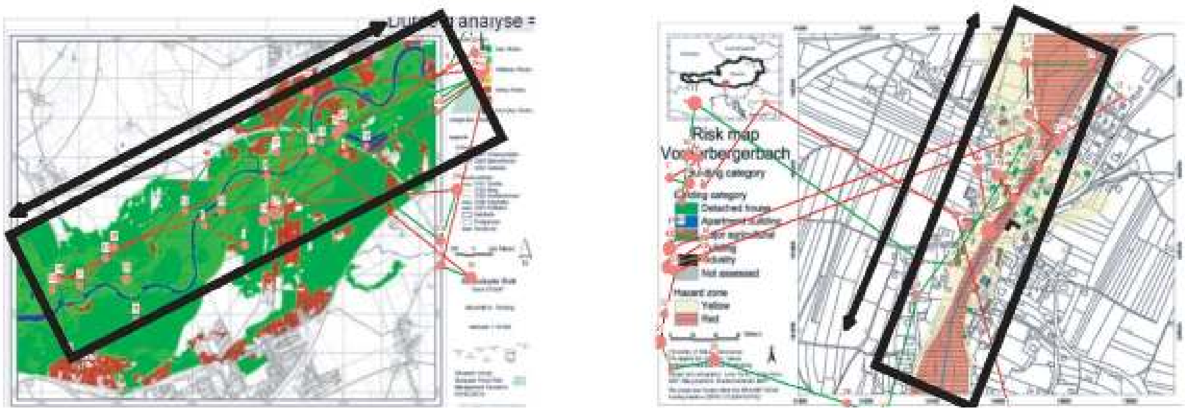

Figure 5-2. Ocular movements distributed according to a diagonal axis following the coloured axis (left: map 11, right: map 2).

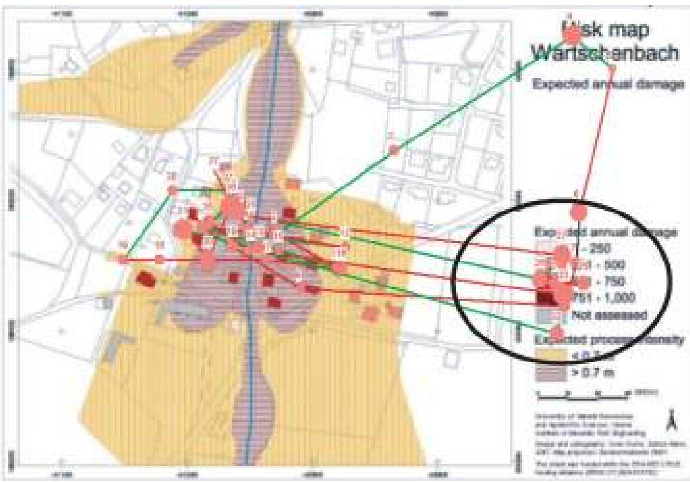

Figure 5-3. Ocular movements distributed over the most coloured elements of the legend (map 7).

The map title provided the first major information concerning the displayed content. If the title was located at the upper part of the legend section located on the top of the map, the whole group of test persons looked at it during their first ten fixations. If the tile was situated at the bottom (as usual for many engineering maps due to their specific folding), this pattern was not as clearly observable, in particular if the title was additionally written inverse in bright colours with a dark coloured box. Therefore, the title seems to fulfil its informative function best when placed above the legend at the top of the map, and emphasised by good contrast (preferably black coloured text on a bright coloured background). This was also confirmed by the cognitive survey that accompanied the study.

The map legend is fundamental information for the understanding of the map content and enables the comprehension of the graphic symbolic system used. However, if the space between legend and map title was considerable large, relatively ample saccades were created that did not alternate with fixations. The test persons devoted between three and seven seconds out of 15 to the reading of the legend, which equals to approximately 20-50 % of the total exposure time. Placed either on the right or on the left of the map, the legend attracted the eye; and vertical or quasi-vertical saccades clearly represented the process of vertical reading. However, the most coloured elements of the legend were the areas of major concentration of fixations (Fig. 5-3). This tendency had an explicitly strong appearance if the legend was highly complex and contained a large amount of different information.

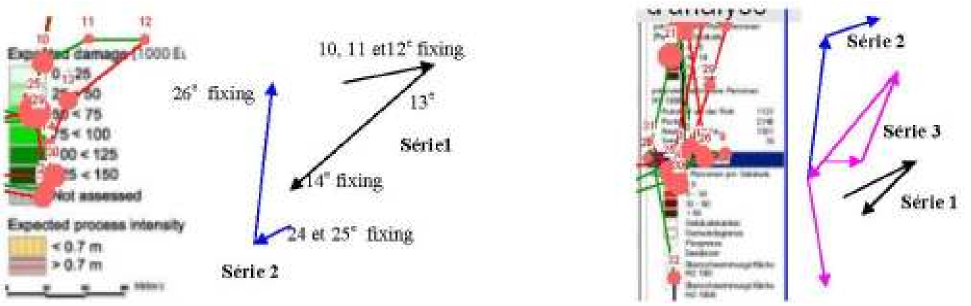

Figure 5-4. Two and three sets of ocular movements are necessary in order to interpret detailed and complex legends.

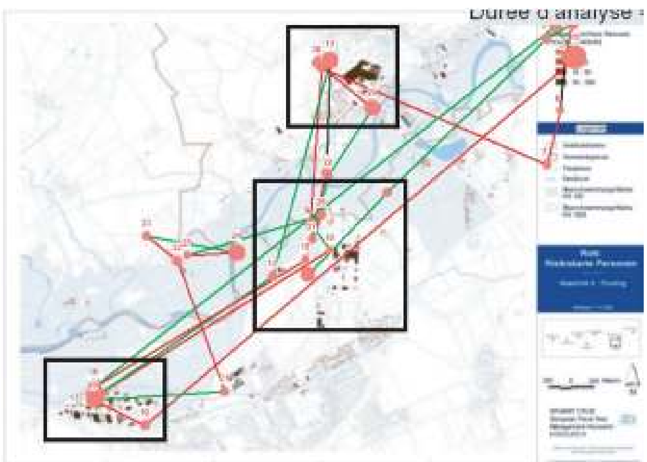

Figure 5-5. Coloured elements carrying almost all information depicted, therefore most of the fixations are located in these areas of the map (map 15).

A simple legend, containing up to five classes and two sets of information resulted in one set of ocular movements, while the visual strategy necessary for a detailed and complex legend generated two or even three sets of ocular movements (Serrhini et al. 2008; Fig. 5-4). As a result, the more accessible a legend is the more effective the visual transmission of information will be.

The central element of every map is the cartographic information depicted. This element in general drew the most attention and the test persons spent 65-80 % of the exposure time of 15 seconds for analysing information. In doing so, the ocular movements were concentrated systematically on the most coloured areas, which represented the 'colour effect' (Serrhini et al. 2008; Fig. 5-5). In addition, the more a specific information was visually distinguishable – namely through the contrast created by the overlapping of various colours used and the map background – the more fixations focused on this information.

Conversely, the less specific information appeared in contrast to the map background the more fixations seemed to be dispersed. It is therefore preferable that the most significant information to be delivered, such as the degree of hazard, should – from a visual point of view – have a stronger contrast than secondary information, such as the map background.

5.2.2 Static analysis for specific groups

Even if each individual test person developed an own visual strategy depending on the individual cultural background, the visual habits and the knowledge of cartography, major specificities were traceable for the specific groups tested.

Specialists in flood risk mapping in general devoted only few fixations in number and time to understand the legend, in particular if the described content was equal to specific regulations on hazard mapping known by the specialists (Serrhini 2006). Moreover, a considerable effort was undertaken to visually explore the maps thoroughly; the gaze often covered practically the whole surface of the map.

Sensitised users appeared to be quite heterogeneous in map reading; however, their visual strategy included a very methodological and synthetic behaviour. Approximately the whole exposure time was spent to compare the information depicted in the map with the information provided in the legend. This enabled them to understand the general structure and essential information depicted, as shown in Figure 5-6.

Laypersons developed two types of visual behaviour, (1) devoting a large amount of relatively long fixations to discover the legend and only little time to understand the central element of the map, or (2) multiplying short fixations and saccades in order to apprehend as much graphic information as possible.

Hence, the visual effort undertaken by laypersons was manifested by (1) a strong focus on the legend, and (2) an intense visual exploitation, as indicated by the multiplied number of saccades and fixations. However, the phenomenon of habituation to the projected information was progressively detectable, and a relative homogenisation from the first type of visual behaviour to the second one could be observed. In doing so, an increasing amount of time was spent to identify information contained in the figure part of the map.

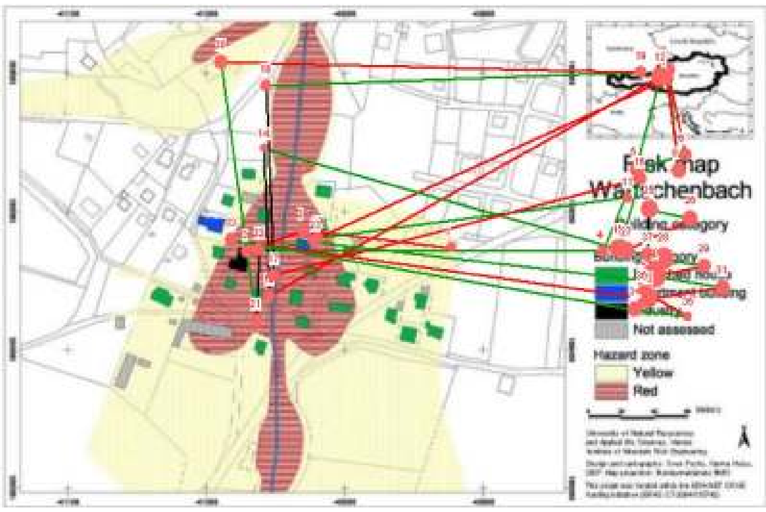

Figure 5-6. Methodical and synthetic reading of maps by sensitised users (map 1).

5.3 Dynamic analysis

The dynamic analysis was based on the assessment of eye movements for all 21 test persons on individual sectors of the maps. It could be shown that the gazes were drawn to the main elements of the map, the legend and the figure part.

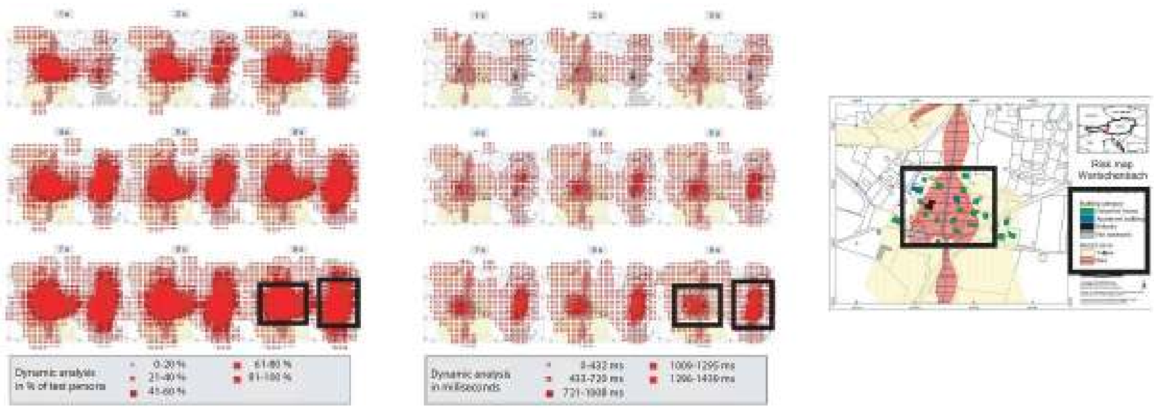

Figure 5-7. Dynamic analysis in percent of test persons (left), and in milliseconds (middle), compiled for the whole sample of test persons. For comparison, the underlying map 1 is shown (right).

As shown in Figure 5-7 for a high-contrast map with an accessible legend, 80-90 % of the test persons looked at the central elements of the map and the written information once the map was exposed to them. However, the central elements only included approximately 10 % of the map surface, and the legend 15 %. By the end of the ninth second, the ocular movements remained between 1,295 and 1,439 milliseconds on the most observed areas of the central elements and the legend. 36 % of all fixations with a total length of 4,690 milliseconds were devoted to the central elements, and 30 % of all fixations with a total length of 3,199 milliseconds were given to the legend. Hence, both areas retained 66 % of the total number of fixations, and 78 % of the total length of fixations.

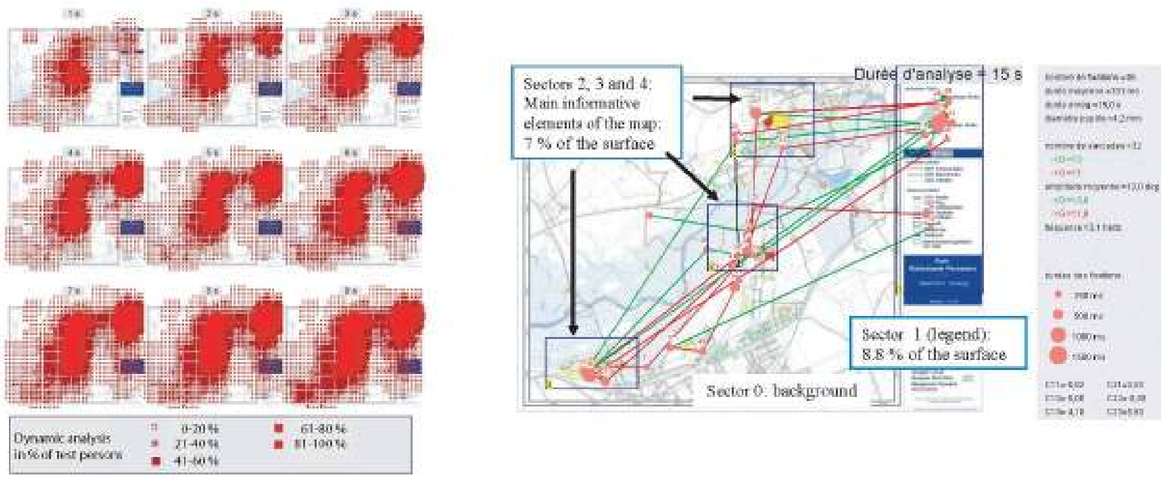

Figure 5-8. Dynamic analysis of map 14 for the number of fixations and the total length of fixations

As illustrated in Figure 5-8 by the dynamical analysis of map 14, various centres of strong visual contrast resulting from a considerable spread of cartographic information lead to a less accessible delivering of information. Covering 7 % of the map surface, the main informative elements only retained 24 % of fixations with a total length of 1,925 milliseconds (corresponding to 18 % of the exposure time), while the legend (9 % of the surface) attracted 30 % of the fixations with a total length of 4,429 milliseconds (corresponding to 40 % of the exposure time). Hence, both areas retained 55 % of the total number of fixations, and 57 % of the total length of fixations.

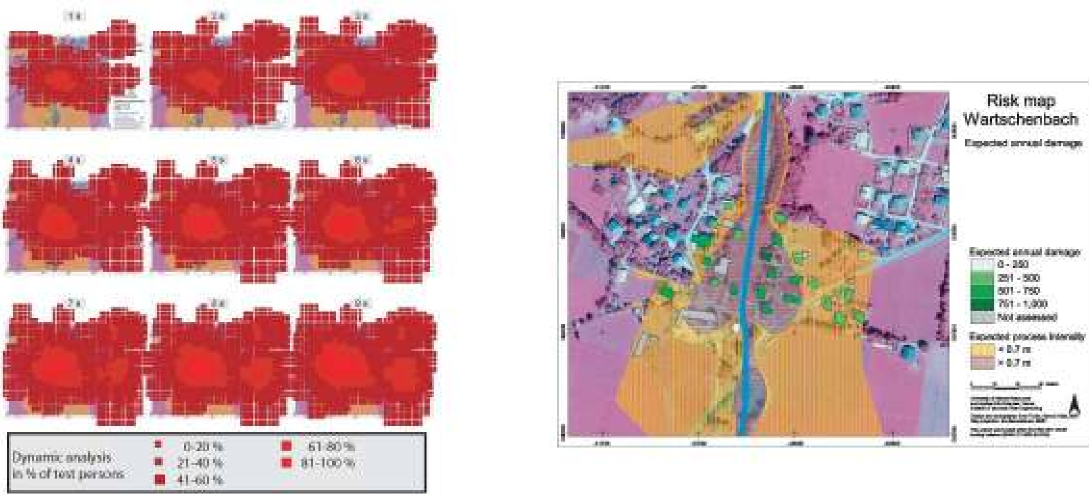

Figure 5-9. Dynamic analysis of map 9 for the relative number of fixations

Conversely, for a low-contrast map it was shown by the dynamic analysis that the location and focus of the gaze scattered considerably (Figure 5-9); the underlying map 9 had an infrared orthophoto as setting. By the end of the ninth second, the map was almost entirely covered by the gaze due to little visual contrast between the main elements and the background. During statistical analysis, this was proven by a large number of short fixations.
Moreover, the sectoral analysis (Serrhini 2000) for the whole sample had shown that approximately two third of the observation time is devoted to less than one fourth of the map surface. While maps with dark background and only little visual contrast between the various elements depicted were entirely covered by the ocular movement of the test persons, maps with a clear distinction between central element and background showed less disperse fixations.

5.4 Cognitive survey

The cognitive survey accompanying the experimental graphic semiology aimed at the support of the analysis, and the results were found to fit in the overall results from the analysis of video-oculography. A summary of the replies to the cognitive survey is presented in Table 5-2. The various questions addressed (1) the level of complexity of the maps, (2) the density of information contained, (3) the innovative character, (4) the aesthetic value, and (5) the potential relevance and suitability for decision-making.
Related to the reading of information and the comprehension, the maps that were considered as most complex by all test persons were maps 5 and 9, with a total score of 82. A considerable amount of test persons specified that the background contrasts insufficiently with the main elements of the maps, a fact that was already stated in Sections 5.1. and 5.2. The group of sensitised users expressed some difficulties in the reading and comprehension of map 11, and the group of laypersons (control group expressed these difficulties for map 12. In contrast, all test persons had a direct access to maps 1-4 considering reading and comprehension.

Regarding the density of information, each group of test persons expressed different opinions. The specialists expressed the greatest density for maps 13-17, above all because of the complexity in the legend containing up to 11 types of information. Sensitised users indicated maps 5 and 9 as being dense in information, and the control group of laypersons regarded map 11 as being overcrowded with information. In contrast, maps 1-4 were considered as being least dense in information content.
Although being judged among the most complex by the specialists, maps 13-17 were regarded as innovating by this group of test persons and by the group of laypersons. On the other hand, maps 5 and 9 turned out to be most innovative for the group of sensitised users. Maps 1-4 were considered as having least innovative character, above all because of the least density in information.

Table 5-2. Summary of the cognitive survey

Maps	Category	Complexity	Density of information	Innovative character	Aesthetics	Decisional interest
Maps 1-4	**total**	**50**	**66**	**45**	**65**	**78**
	specialist	1,8	3,7	2,0	3,2	4,5
	sensitised users	2,1	3,0	2,3	3,3	3,7
	control group	3,0	2,9	2,1	2,9	3,1
Maps 5 and 9	**total**	**82**	**73**	57	**47**	**57**
	specialist	4,2	3,0	2,3	2,2	2,7
	sensitised users	3,6	3,7	3,0	2,1	3,1
	control group	4,0	3,6	2,8	2,4	2,4
Maps 6 and 10	**total**	58	66	59	**70**	**73**
	specialist	2,5	3,7	3,3	3,7	4,0
	sensitised users	2,6	3,1	2,9	3,8	3,9
	control group	3,1	2,8	2,8	2,9	2,8
Map 11	**total**	73	**76**	60	55	68
	specialist	3,0	3,6	2,8	3,0	4,3
	sensitised users	4,0	3,6	2,7	2,4	2,6
	control group	3,4	3,8	3,0	2,5	3,0
Map 12	**total**	**74**	71	**62**	65	64
	specialist	3,3	3,5	3,3	3,7	4,0
	sensitised users	3,3	3,6	2,9	2,9	2,6
	control group	3,9	3,1	2,9	2,8	2,8
Maps 13-17	**total**	72	68	**62**	60	67
	specialist	3,8	3,8	3,2	3,2	3,3
	sensitised users	3,6	3,3	2,4	2,3	2,9
	control group	3,0	3,1	3,3	3,1	3,4

Considering the aesthetic character of the different maps, the group of specialists judged maps 6, 10 and 12 as being most attractive, while the group of sensitised users judged maps 6 and 10. For the laypersons, maps 13-17 were preferred because of the inherent simplicity. In contrast, maps 5 and 9 – those with an infrared orthophoto background – were considered as being the least aesthetic by the whole group of test persons.

Maps 1-4 and maps 6 and 10 appeared to the specialists and the sensitised users as most interesting in terms of potential decision-making, while the group of laypersons preferred maps 13-17. Thus, each category of stakeholders does not necessarily bear the same expectation on cartographic communication, presumably because of different necessities. However, the simpler the character of the map, and the better the contrast of principal information, the higher is the potential to serve as a decision-making tool.

With respect to the open questions in part 3 of the survey, approximately 75 % of the test persons preferred the legend on the right side of the map, and 70 % preferred the title being in the upper part, on top of the legend. Almost 90 % would like to have a simplified legend with five classes, if risk is depicted the range of colour should be in red hues. Approximately 50 % of the test persons would like to have a land register as background, while around 45 % preferred the aerial orthophoto.

6 Discussion of Results

Risk management for natural hazards is based on risk assessment techniques, including methods to determine the hazard potential and procedures to analyse and evaluate the damage potential exposed. For these management issues, risk maps provide the basis (1) for any planning and implementation of mitigation measures by public authorities as well as for the prioritisation of these measures, and (2) for any activities concerning regional development, land-use and construction engineering. Thus, the overall aim of risk mapping includes (1) the delineation of areas endangered by defined risk thresholds, (2) the assessment of exposure levels in such areas, and (3) the communication of risk to various stakeholders, e.g. politicians, residents and other people concerned. Therefore, the impact of information has to be assessed in order to provide these issues appropriately.

Using the method of experimental graphic semiology had shown that the structure of maps influences the visual strategy of the readers; therefore, map perception is iconographic. The more accessible visual information is, the more effective it will be in terms of visual transmission of information. Moreover, particular reading behaviour of specialists, sensitised people and laypersons led to the conclusion that perception is anthropic. Hence, risk maps should be compiled according to these different needs, in particular bearing in mind that approximately 65 % of the observation time of subjects is devoted to less than 25 % of the map surface.

To summarise, the spatial and dynamic analysis highlighted certain aspects that were identified as being important for an efficient design of risk maps, and will contribute to professional risk communication:

- Coloured zones and written information concentrated approximately 90 % of the fixations.
- The concentration of information in the legend needs to be visible (contrast and colour used) and accessible (limited number of information), to attract the eye and deliver information.
- The spatial localisation of information considerably influences the perception by the reader.

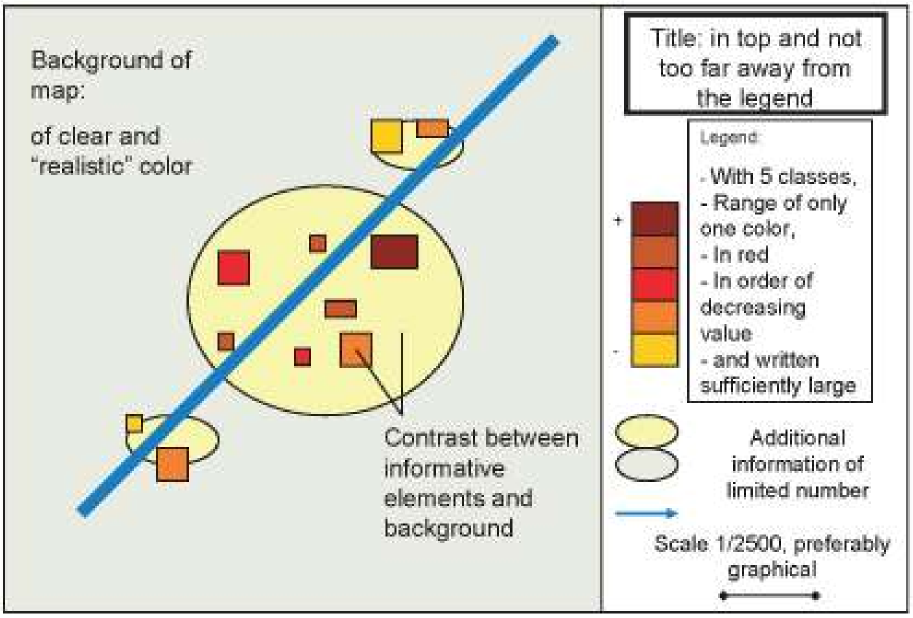

Figure 6-1. Suggestions for the compilation of risk maps in order to allow for efficient and target-oriented risk communication (Fuchs et al. 2008a; Serrhini et al. 2008).

Even if the study is based on some restrictions and constraints, above all the limited number of 21 participating test persons, a number of general conclusions originating from visual strategies resulted (Fig. 6-1). Specific elements of semiology for a cartographic representation of risk include

- a map background in bright colour to increase the contrast to informative elements, and to avoid an overload of information;
- a sufficiently large legend, preferably on the right side of the central element of the map, with a limited number of information (five classes of discretisation) comprised from one range in colour only and arranged in decreasing values;
- a sufficiently large scale that the elements of the map are recognisable sufficiently rapid.

A risk map compiled according to these conclusions would result in a visual strategy that is composed from three clear sets of ocular movements. Starting from the centre, the eye moves to the title of the map, following a vertical axis downwards the legend section and returning back to the central element of the map. If there is sufficient time, the additional peripheral elements of the figurative part are explored subsequently.
In application of these findings and recommendations, a new set of maps has been generated. The comparison with the original set clearly indicates the improvements (Figs. 6-2 and 6-3). Taking map 12 as an example, the contrast in the original map did not allow the visual determination of different flood events. These were visualised in the revised version based on the results of experimental graphic semiology. Furthermore, the legend composed from six colours with additional ten further information categories turned out to be too complex. Consequently, this information was reduced to only four colours and four additional items (Fig. 6-2). Taking map 15 as an example, it was again the contrast that did not allow for the visual determination of flood events. Furthermore, the choice of colours was found not to organise the risk information in an appropriate order, and the contrast and information density was to weak. Based on the outcomes of the study, the contrast was enhanced in order to visualise the different design events, and the information density was re-organised into hierarchy which allowed an enhanced accessibility to information (Fig. 6-3).
However, due to budget constraints, the results of this pilot study are not yet fully representative. They can only provide first hints for further research, with respect to a larger group of test persons as well as with respect to further refinements of the method. In particular concerning the European Flood Risk Directive, but also with respect to the overall aim of building hazard-resilient communities, future studies might include the applicability of risk maps within flood risk management plans. This is of particular relevance since different methods and guidelines exist in European countries in order to deal with hazard and risk, based on different national legislation. Hence, there is no commonly accepted guideline or template of how risk maps have to be compiled according to scale, design, content, etc. Moreover, due to different administrative organisation (e.g., centralised vs. federal) and multiple technical responsibilities on national scales (e.g., Torrent and Avalanche Control Service vs. Hydraulic Engineering), the compilation of necessary information remains often un-coordinated and even mono-disciplinarily organised between multiple stakeholders. Apart from these constraints it is still not sufficiently discussed which target scale to be used for the compilation of risk information (generalised using aggregated data vs. specific using object-based data). Therefore it might be necessary to compile different risk maps according to different scales, but also to deliver diversified risk information to different target groups and stakeholders.
Nevertheless, the study has proven that a stakeholder-oriented compilation and design of risk maps is of considerable importance in order to deliver information target-oriented. Therefore it is necessary to identify precisely the specific needs of different target groups and stakeholders.
This had additionally been confirmed by the third RISKCATCH workshop, held in Deggendorf, 28-30 April, 2008. The participants from regional land-planning authorities and national or federal emergency management and disaster relief authorities clearly stated the need for such differentiation. Moreover, it was affirmed that by such approaches the inclusion of local and site-specific knowledge will be enhanced since the method of experimental graphic semiology using eye tracking implicitly does allow for such a consideration.
To conclude, developing the method of experimental graphic semiology and applying it to risk maps resulted in considerable insights of target-oriented delivery of information and risk communication. Major findings led to recommendations that will allow for an efficient and adapted map design.

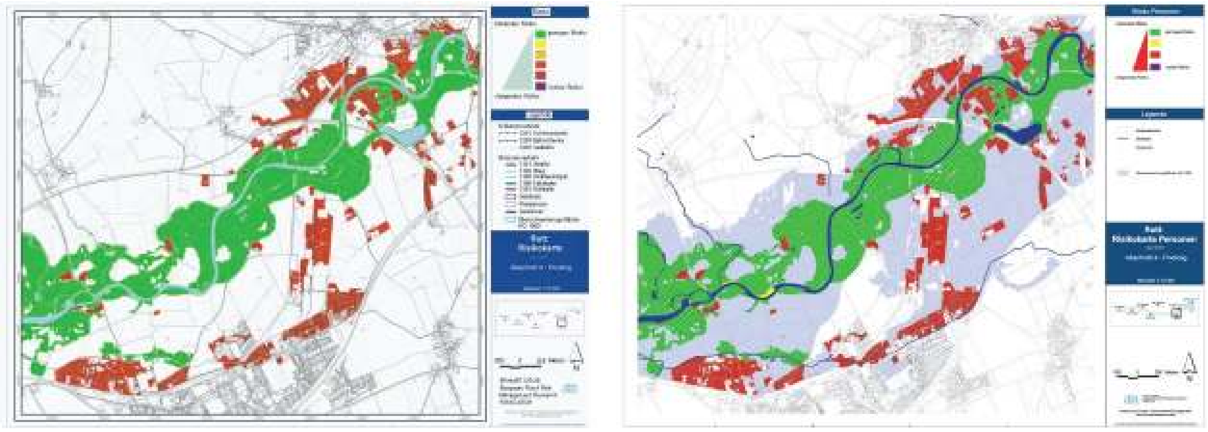

Figure 6-2. Map 12: Original risk map (left) and improved version according to the results of RISKCATCH (right)

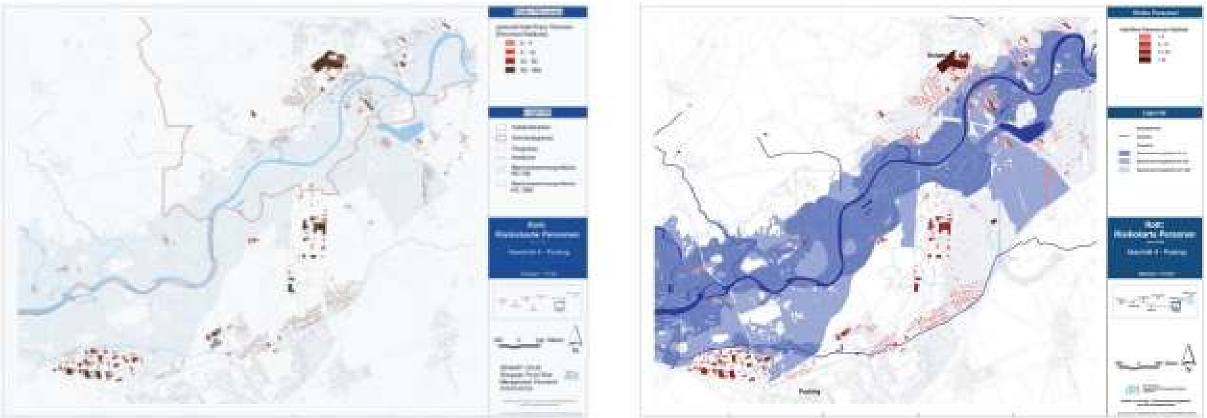

Figure 6-3. Map 15: Original risk map (left) and improved version according to the results of RISKCATCH (right)

7 Implications for Stakeholders

Risk mapping is a common procedure when dealing with natural hazards, even if the methods of map compilation differ. However, only little information is available so far concerning the impact of such maps on relevant stakeholders, since the traditional approach of graphic semiology does not allow for feedback mechanisms originating from different perception patterns. Reversing this traditional approach, different sets of small-scale as well as large-scale risk maps were presented to test persons in order to (1) study reading behaviour as well as understanding and (2) deduce the most attractive components that are essential for target-oriented risk communication. As a result, a suggestion for a map template was made that fulfils the requirement to serve as efficient communication tool for specialists and practitioners in hazard and risk mapping as well as for laypersons.

Stakeholders as affiliates of public administration on a regional, national, or EU-wide level need appropriate risk communication tools in order to provide best possible service public. Above all, risk communication aims at objective information on risks in order to strengthen the respective coping capabilities. Risk communication includes all processes of understanding between multiple stakeholder groups, aiming at the identification, assessment and management of risks. Decision makers, people concerned, scientists and specialists as well as all other actors involved are equally participating in risk communication as receiver and transmitter. Hence, communicating risks is the key or a successful and sustainable risk management. With respect to natural hazards, risk communication is a fundamental component of the risk analysis paradigm. Not only is risk communication necessary among experts of various disciplines in order to assess the risks, but also is an essential tool for bi-directional sharing of information, values, and preferences between experts, decision-makers, stakeholders and the public with respect to risk governance. Moreover, with a view to avoiding and reducing the adverse impacts of floods in the areas concerned it is appropriate to provide for flood risk management plans. Flood risk management plans should take into account the particular characteristics of the areas they cover and provide for tailored solutions according to the needs and priorities of those areas, and focus on prevention, protection, and preparedness (Commission of the European Communities 2007). In order to have available an effective and target-oriented tool for information and communication, as well as a valuable basis for priority setting and further technical, financial and political decisions regarding flood risk management, it is necessary to provide for the establishing of flood hazard maps and flood risk maps showing the potential adverse consequences associated with different scenarios. Furthermore, a successful risk communication program should also focus on the risk management strategies. Special attention deserves the impact of risk maps on risk perceptions. Social science research on risk demonstrates that basing risk communication solely on a scientific risk characterisation falls short of the mark. The current social perception and potential for emotional and social risk amplification, as well as their dynamics, must also be considered (see Pidgeon et al. 2003). The results from RISKCATCH contribute to this discussion by delivering quantitative information on the perception of risk by different target groups.

Within RISKCATCH, a major focus was put at the communication of risk, since until now only little information has been available on the impact of hazard and risk maps to different stakeholders, in particular those that are not specialists, i.e. residents and laypeople affected by flooding. By closing this gap, the quantifying method of experimental graphic semiology was developed to reverse the traditional way of delivering information, and to include a feedback loop in order to increase the accessibility of various stakeholders to risk information.

It had clearly been shown that if risk maps will be designed according to certain guidelines, the information could be delivered in a visually efficient manner. Specific elements of semiology that have to be taken into account when designing risk maps include the contrast, the level of discretisation and the colour range and hue. Consequently, if risk maps are adjusted to these findings, risk communication will be enhanced, and awareness-building of the public will be increased (Fig. 7-1). With respect to flooding and torrent processes, the increase in both, individual preparedness and public participation, starts with the notion of risk. Therefore, access to information is inevitable, which is usually understood as obligation of people concerned (Step 1). If the editing of information is possible, e.g. by the method of experimental graphic semiology, a pro-active access to information results, and decisions become transparent and reproducible (Step 2). As a consequence, information on risk can be addressed target-oriented and therefore understandable by multiple stakeholders. If this is actively done by the respective authorities through appropriate dissemination strategies, the involvement of the public will be further increased (Step 3). If issues related to risk are dealt with internal (Step 4), by a temporal societal dialogue (Step 5) or even by a permanent advisory board (Step 6) it becomes apparent that information should be delivered accessible and understandable in order to rise public awareness.

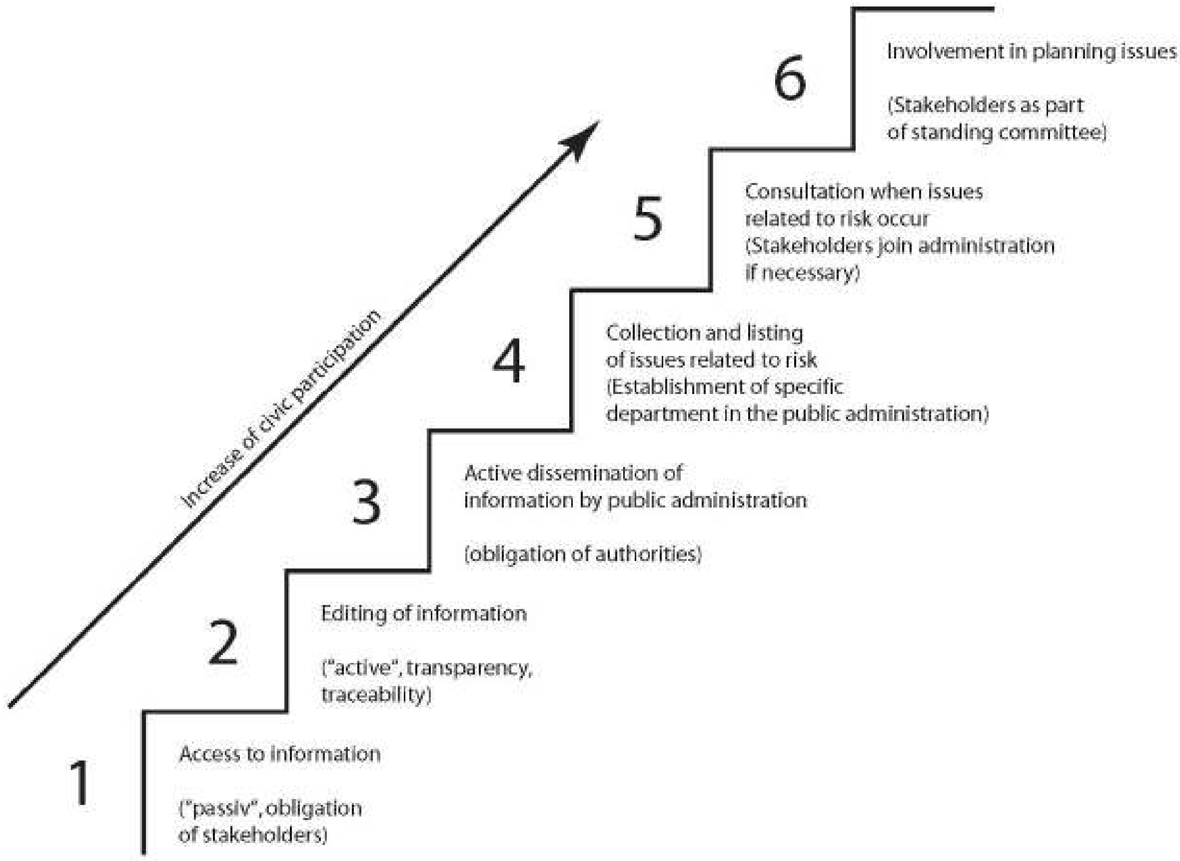

Figure 7-1. Staircase of risk communication. Modified from Fuchs (2004) after a sketch in Wiedemann & Clauberg (2003).

Within RISKCATCH it has been shown that the structure of risk maps influences the reader's visual strategy, the more accessible information is, the more effective it will be in terms of transmitting information, and the higher the level of understanding. Since perception is anthropic, risk maps should be compiled according to different needs of stakeholders involved, i.e. people concerned and laypersons. As a result, information is delivered accordingly, risks will be communicated efficiently, and thus capacity building will be increased and risk awareness will be strengthened. Extending these results by additional future studies may lead to a more conscious attitude towards flood risks by giving priority to preparedness through perception.

8 Recommendations for future Work

Non-technical mitigation concepts, above all land-use planning, aim at reducing losses resulting from flooding by establishing building regulations and bans in order to keep endangered areas free of values at risk. One major tool to achieve these regulations are risk maps, which were not only implemented according to national regulations in many countries; the compilation of such maps has also been demanded on the European level, e.g. by the European Flood Risk Directive. Risk maps contain multiple information on different levels, and are key elements with respect to non-technical hazard mitigation strategies. These maps serve as an information basis for multiple stakeholders from official authorities. In addition, they could be used as a tool to strengthen natural hazard awareness of the public concerned, thus they form a risk communication tool.

As stated in Section 6, some open questions should be discussed in the near future with respect to flood risk management plans to be compiled according to the European Water Framework Directive and the European Flood Risk Directive.

With respect to the overall aim of building hazard-resilient communities, future studies might include the applicability of risk maps within flood risk management plans. This is of particular relevance since different methods and guidelines exist in European countries in order to deal with hazard and risk, based on different national legislation. Hence, there is no commonly accepted guideline or template of how risk maps have to be compiled according to scale, design, content, etc. The basic common understanding to compile such information includes the intersection between different design events on the process side, and data on values at risk exposed. Moreover, due to different administrative organisation (e.g., centralised vs. federal or regional) and multiple technical responsibilities on national scales (e.g., Torrent and Avalanche Control Service vs. Hydraulic Engineering), the compilation of necessary information seems often to be diversely organised between multiple stakeholders and authorities. Apart from these constraints it is still not sufficiently discussed which target scale to be used for the compilation of risk information (generalised using aggregated data vs. specific using object-based data), which is also a result of the different processes to be considered. Therefore it might be necessary to compile different risk maps according to different scales, but also to deliver diversified risk information to different target groups and stakeholders. The discussion of how such issues might be solved should be strengthened, a purposeful example of good practice is given by the “Atlas on the risk of flooding and potential damage due to extreme floods of the Rhine”, compiled under the umbrella of the International Commission of the Protection of the Rhine (ICPR 2001).

Since risk maps are of a certain relevance order to deal in a pro-active and from an ex-ante perspective with flooding hazards, the applicability in the framework of flood risk management plans should be discussed. If information on flood risk will be delivered to the public concerned in an accessible manner, it might serve as an additional tool in order to communicate disaster preparedness. A possible way to target this aim could be the inclusion of certain additional map features, such as evacuation paths, escape routes and the localisation of shelters. Moreover, additional information could also include technical instructions for rescue services in case of emergency aid, such as the trafficability of driveways besides dikes and levees in terms of carrying capacity of dirt tracks, or crossing widths at points of constriction. Such issues already have been intensively discussed and claimed during the third RISKCATCH workshop by stakeholders from federal emergency and disaster relief agencies. If this information is included in current strategic emergency planning, intervention maps will result, indicating (1) the hazard-prone areas and the concentration of values at risk including critical infrastructure and population distribution, (2) possible escape routes, and (3) key positions of the technical mitigation measures to take particular care of, such as weak dike sections or levees with below-average protection heights that may develop to bottlenecks in case of an event.

Apart from these conceptual issues, the overall practical question of data handling still remains unsolved. There is a considerable gap between the requirements for integrated data management in order to deliver information needed for an area-wide spatially explicit risk mapping, and (1) the available modelling and geoinformation infrastructure, as well as (2) the general policies of responsible authorities in making available their data sources. Only if these problems will be approached in the near future, an IT-based compilation of information on risk will be feasible, and the assessment of risk will be possible with an economically efficient allocation of resources. This would additionally allow an automatic map generation and the ability for cross-media publishing of data in the web as well as in printed format.

Furthermore, risk is highly variable over time (e.g., Fuchs et al. 2005; Keiler et al. 2006a). Hence, information necessary for the assessment of risk has to be regularly updated, i.e. information related to values at risk such as land register plans, development plans and data related to population density. Moreover, global change processes might result in alternations of the process characteristics, manifested by e.g. altered statistical time series used for modelling individual hazard processes. Due to the time lack between scientific verifiable changes in such process characteristics and the implementation in operational hazard analysis, considerable efforts will have to be undertaken in order to provide the necessary data to allow for a real-time implementation.

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Appendix

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Terms and Definitions

Term	*Definition*
Risk	Expected losses (e.g., of lives, persons injured, property damaged and economic activity disrupted) due to a particular hazard scenario for a given area and a reference period. Based on mathematical calculations, risk is a product of hazard, vulnerability, and values at risk.
Values at risk	With respect to RISKCATCH, values at risk were defined in terms of expected economic losses, i.e., buildings exposed to hazard.
Vulnerability	Sensitivity of a system's attribute(s) of concern to a hazard (in temporal reference), i.e., the degree of loss (from 0 % to 100 %) resulting from a potentially damaging phenomenon.
Hazard	A threatening event, i.e. the probability of occurrence of a potentially damaging phenomenon within for a given area and reference period.
Flood	Significant rise of water level in a stream, including a variable amount of suspended load of small grain size being eroded, transported, and deposited.
Torrent event	Significant rise of water level in a torrent, including a variable amount of gravel of different grain size being eroded, transported, and deposited.
Large-scale	Large-scale analysis is defined as the detailed assessment of a particular location by using mapping scales of 1:2,500-1:5,000; object-based data is needed for risk evaluation.
Small-scale	Small-scale analysis is defined as the assessment of a larger region by using mapping scales of 1:10,000-1:25,000; average values for object categories is needed for risk evaluation and the assessment is generally based on average values per area.
Experimental Graphic Semiology	So far, the procedure of risk mapping is based on a linear model from the specialist producing the map (transmitter) to the targeted reader (receiver), known as graphic semiology. Graphic semiology is based on certain rules and recommendations neglecting any specific requirements in dependence on the culture or knowledge of the receiver. Reversing this linear model by establishing the new approach of Experimental Graphic Semiology, a cyclical model was proposed aiming at an integration of visual and cognitive perception by the receiver. This model required the quantification of properties and characteristics of visual perception and visual strategy, and thus an analysis of map reading behaviour by the method of eye tracking.
Visual strategy	Ocular movements developed for reading information. Visual strategies can be distinguished by three categories of eye movements, (1) saccades, (2) pursuits, and (3) fixations.
Saccades	Saccades are fast ocular movements with variable speed. They are triggered by fuzzy visions of an object (i.e. the appearance of a peripheral retinal stimulus) or by auditory stimuli, and are directed towards the right, the left, or vertically.
Pursuits	Pursuits are slower ocular movements, and are triggered by the examination of a moving target (or stimulus) and therefore constitute central vision.
Fixations	Fixation is the condition when the gaze remains fixed during an interval ranging between 100 and 1000 milliseconds on a surface ≤ 144 mm^2. However, during the fixation of a motionless stimulus, the eye is not entirely motionless itself; micro-saccades and micro-tremors can be registered.

Glossary of abbreviations and acronyms

Term		Definition
%	◄	Per cent
€	◄	Euro
ø	◄	Average
GIS	◄	Geographic Information System
Fig.	◄	Figure
Tab.	◄	Table
m	◄	Metres
mm	◄	Millimetres
ms	◄	Milliseconds

Project Summary

Joint project title	**Development of flood risk in mountain catchments and related perception (RISKCATCH)**
CRUE Project No.:	I-2
Project partner #1 (Co-ordinator):	Dr Sven Fuchs
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Project website:	http://www.riskcatch.info
Objectives	Risk mapping is a common procedure when dealing with natural hazards, even if the methods of map compilation differ. However, only little information is available so far concerning the impact of such maps on relevant stakeholders, since the traditional approach of graphic semiology does not allow for feedback mechanisms originating from different perception patterns. Reversing this traditional approach, different sets of small-scale as well as large-scale risk maps were presented to test persons in order to (1) study reading behaviour as well as understanding and (2) deduce the most attractive components that are essential for target-oriented risk communication. As a result, a suggestion for a map template was made that fulfils the requirement to serve as efficient communication tool for specialists and practitioners in hazard and risk mapping as well as for laypersons.
Background	The underlying concept applied in this work is relied on the theory of risk, which with respect to natural hazards and from an engineering point of view is defined as a quantifying function of the probability of occurrence of a process and the related extent of damage, the latter specified by the damage potential and the vulnerability. During the last decades, lots of work has been carried out in order to study and assess the hazard potential. Only recently, quantitative methods for the evaluation of values at risk and vulnerability have been developed. By applying these methods to different areas, and thus merging the information using GIS, hazard and risk maps might be compiled. However, only little information is available so far according to the possible impact of these maps, which seems surprising since they provide an essential base with respect to non-technical flood mitigation. A particular need has been deduced for quantifying information related to the perception of risk information by different end-users, apart from specialists familiar with hazard issues primarily people concerned and laypersons.
Research	Individual steps necessary for the compilation of risk maps were carried out, including process modelling, determination of values at risk exposed, and the assessment of vulnerability. A set of different but complimentary risk maps was compiled, showing risk to torrent process and flooding by multiple indicators. In order to assess the accessibility of risk information, the innovative method of experimental graphic semiology was developed, reversing the traditional linear approach of information delivery by establishing a feedback loop between receiver and transmitter. In doing so, eye movements of a group of test persons were recorded, and analysed statistically, statically, and dynamically.
Findings	It had been shown that the structure of maps influences the visual strategies of the readers. Textual elements were considerably attractive to the gaze. The central elements of the map have to contrast the background and should be designed in bright and dark colours, respectively. The position of various elements in a map, i.e. the title, the legend, and the central figurative element, is of particular importance for the visual comprehension; therefore, map perception is iconographic. The more accessible visual information is the more effective it will be in terms of visual transmission of information. Moreover, particular reading behaviour of stakeholder groups led to the conclusion that perception is anthropic. Hence, risk maps should be compiled according to these different needs.

Implications (Outcome) ◄	By identifying preferences concerning graphic representation and arrangement, general conclusions were drawn aiming at the development of an optimum risk map to allow for efficient and target-oriented communication of flood risk. With respect to the European Flood Risk Directive, the results will be a useful tool in order to (1) primarily assess flood risk, (2) establish hazard and risk maps, and (3) compile adopted flood risk management plans. In particular with respect to the latter, the results of RISKCATCH will particularly support the management of the consequences of flooding in order to raise flood awareness, and to create resilient communities.
Publications related to the project ◄	1. Fuchs, S.; Spachinger, K.; Dorner, W.; Rochman, J. & K. Serrhini (in prep.): Efficient risk communication through experimental graphic semiology, Risk Analysis 2. Dorner, W.; Spachinger, K.; Serrhini, K.; Rochman, J. & S. Fuchs (in prep.): Visualising hydrological risks, Hydrology and Earth System Sciences 3. Serrhini, K.; Fuchs, S.; Dorner, W.; K. Spachinger; Rochman, J. & A. Bignard (in prep.): Sémiologie Graphique Expérimentale: Vers un outil efficace de communication sur le risque d'inondation, Revue Internationale de Géomatique 4. Fuchs, S.; Dorner, W.; Spachinger, K.; Rochman, J. & K. Serrhini (submitted): Flood risk map perception through experimental graphic semiology, Proc. Floodrisk2008 – Oxford (30 September - 2 October 2008), Leiden: Balkema 5. Dorner, W.; Spachinger, K.; Fuchs, S. & K. Serrhini (in press): Integration von Computermodellen im Hochwasserrisikomanagement. In: Strobl, J.; Blaschke, T. & G. Griesebner (eds.): Angewandte Geoinformatik 2008. Beiträge zum 20. AGIT-Symposium Salzburg (02.-04. Juli). Heidelberg: Wichmann 6. Fuchs, S. (2008): Vulnerability to torrent processes. WIT Transactions on Information and Communication Technologies 39, p. 289-298 7. Fuchs, S., Serrhini, K.; Dorner, W. & K. Spachinger (2008): Development of land use, related vulnerability and the interpretation of risk maps by different user groups. In: Mikoš, M. & J. Hübl (eds.): Interpraevent 2008 – Extended Abstracts. Klagenfurt: International Research Society Interpraevent, p. 112-113 8. Serrhini, K.; Fuchs, S.; Spachinger, K. & W. Dorner (2008): Evaluation of risk perception using experimental graphic semiology. Geophysical Research Abstracts 10, # 06549 9. Serrhini, K.; Rochman, J.; Fuchs, S.; Dorner, W. & K. Spachinger (2008): Sémiologie graphique expérimentale et cartographie du risque d'inondation. In: Pinet, F & A. Miralles (eds.): Actes de l'Atelier «Systèmes d'Information et de Décision pour l'Environnement». Proc. XXVIème Congrès INFORSID – Fontainebleau (27 - 30 May). Clermont Ferrand and Montpellier: Cemagref, p. 31-40 10. Spachinger, K.; Dorner, W.; Fuchs, S.; Serrhini, K. & R. Metzka (2008): Flood risk and flood hazard maps – visualization of hydrological risks. Proc. XXIVth Conference of the Danubian Countries on the Hydrological Forecasting and Hydrological Bases of Water Management – Bled (02 - 04 June), CD-ROM 11. Fuchs, S.; Heiss, K. & J. Hübl (2007): Towards an empirical vulnerability function for use in debris flow risk assessment. Natural Hazards and Earth System Sciences 7 (5), p. 495-506 12. Fuchs, S.; Dorner, W. & K. Serrhini (2007): Development of flood risk in mountain catchments and related perception. Geophysical Research Abstracts 9, # 01631 13. Spachinger, K.; Dorner, W. & R. Metzka (2007). Development of flood hazards in alpine space and related forelands. *University of Deggendorf Techpaper* 09/2007, 14 pp.

Dissemination

Risk communication is a fundamental component of the risk analysis paradigm. Not only is risk communication necessary among experts of various disciplines in order to assess the risks, but also is an essential tool for bi-directional sharing of information, values, and preferences between experts, decision-makers, stakeholders and the public (see Renn 1992, Gee & Sterling 2002). Dissemination, communication and education as well internal knowledge management need to be regarded as a major issue of the RISKCATCH project. Communicating and disseminating state-of-the-art research to society in a target-group specific manner is an efficient attempt to bridge the constantly widening gap between research community and the general public. In addition to involving stakeholders and experts, strategies (e.g. environmental education approaches) for externally disseminating information can be further developed for various target-groups and different scales.
The results of the project were presented to the scientific community as well as to practitioners at international workshops and conferences. Furthermore, the dissemination of results took place (or is in preparation, respectively) via papers in international, peer-reviewed journals as well as in (national) journals and book chapters common to the practitioners to stimulate exchange and discussion (see Tab. A-1).

Table A-1. Presentations and publications resulting from RISKCATCH

	[N]
Presentation	**11**
- Oral	6
- Poster	5
Publication	**18**
- Journal	4
- Journal ISI	3
- Book Chapter	1
- Conference Proceedings	3
- Research Abstract	3
- Reports	4

Internal RISKCATCH Workshops

1. Kick-off workshop, Vienna, Austria (30 - 31 January 2007) – Definition of minutes
2. Mid-term workshop, Tours, France (18 - 19 October 2007) – Discussion of results and preparation of study on experimental graphic semiology
3. Final workshop, Deggendorf, Germany (28 - 30 April 2008) – Discussion of results and further needs. The final workshop was open to invited stakeholders from practice and public administration, presentation of results and discussion.

Presentations at conferences and workshops

1. Flood risk map perception through experimental graphic semiology, FloodRisk 2008 (Oxford, 30. September - 02. October 2008), (**Fuchs**, Dorner, Serrhini; oral)
2. Improving the perception of risk maps by experimental graphic semiology, European Commision Working Group Flood, Thematic Workshop Flood Mapping (Dublin, 17.-19. September 2008), (**Fuchs**; oral)
3. AGIT 2008 (Salzburg, Austria, 02 - 04 July 2008): "Integration von Computermodellen im Hochwasserrisikomanagement", (**Dorner**, Spachinger, Fuchs, Serrhini; oral).

4. Interpraevent 2008 (Dornbirn, Austria, 26 - 30 May 2008): “Development of land use, related vulnerability and the interpretation of risk maps by different user groups“ (**Fuchs**, Serrhini, Dorner, Spachinger; poster).
5. XXIVth Conference of the Danubian Coutries (Bled, Slovenia, 02 - 04 June 2008): “Flood risk and flood hazard maps – Visualisation of hydrological risks“ (Spachinger, **Dorner**, Fuchs, Serrhini, Metzka; oral).
6. XXVIe Congrès INFORSID (Fontainebleau, France, 27 - 30 May, 2008): “Sémiologie graphique expérimentale et cartographie du risque d’inondation“ (**Serrhini**, Rochman, Fuchs, Dorner, Spachinger; oral)
7. EGU 2008 (Vienna, Austria, 14 - 18 April 2008): “Evaluation of risk perception using experimental graphic semiology“ (Serrhini, **Fuchs**, Spachinger, Dorner; oral)
8. 10th International River Symposium and Environmental Flows Conference (Brisbane, Australia, 31 August – 09 September 2007) “Development of land use and flood risk - analysis, assessment, measures” (**Dorner**, Spachinger, Metzka, Fuchs, Serrhini; poster)
9. EGU 2007 (Vienna, 16 - 20 April 2007) „Development of flood risk in mountain catchments and related perception“ (**Fuchs**, Dorner, Serrhini; poster)
10. EGU 2007 (Vienna, 16 - 20 April 2007) „Economic aspects of flood protection enhancements“ (Spachinger, **Dorner**, Metzka; oral)
11. EGU 2007 (Vienna, 16 - 20 April 2007) „Application of the vulnerability concept to torrent events in Austria“ (**Fuchs**, Oberndorfer, Heiss; poster)

Publications

1. Fuchs, S.; Dorner, W. & K. Serrhini (in prep.): The challenge of communicating flood risk. Environmental Hazards
2. Dorner, W.; Spachinger, K.; Serrhini, K.; Rochman, J. & S. Fuchs (in prep.): Visualising hydrological risks, Hydrology and Earth System Sciences
3. Serrhini, K.; Fuchs, S.; Dorner, W.; K. Spachinger; Rochman, J. & A. Bignard (in prep.): Sémiologie Graphique Expérimentale: Vers un outil efficace de communication sur le risque d’inondation, Revue Internationale de Géomatique
4. Fuchs, S.; Spachinger, K.; Dorner, W.; Rochman, J. & K. Serrhini (in press): Efficient risk communication through experimental graphic semiology, Risk Analysis
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14. Spachinger, K.; Dorner, W. & R. Metzka (2007). Development of flood hazards in alpine space and related forelands. *University of Deggendorf Techpaper* 09/2007, 14 pp.

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1. Fuchs, S., Dorner, W. & Serrhini, K. (2008): Development of flood risk in mountain catchments and related perception. Document synthèse. Summary document prepared for the Ministère de l'Energie, de l'Ecologie, du Développement durable et de l'Aménagement du territoire, France (30 June 2008), 10 pp.
2. Spachinger, K., Dorner, W., Fuchs, S., Serrhini, K. (2008): Development of flood risk in mountain catchments and related perception. Final report prepared for the Ministry of Education and Research, Germany
3. Fuchs, S.; Dorner, W. & K. Serrhini (2007): Development of flood risk in mountain catchments and related perception. Report prepared for the mid-term seminar, ERA-Net CRUE funding initiative (17 October 2007, Lyon), 6 pp.
4. Serrhini, K. & S. Fuchs (2007): Development of flood risk in mountain catchments and related perception. Mid-term report prepared for the Ministère de l'Ecologie, du Développement et de l'Aménagement Durables, France (29 May 2007), 12 pp.

Public relation

1. Donau-Anzeiger 28 November 2007

Hochwasserrisiken als Schwerpunkt

Forschungsgruppe Wasser und Umwelt der Fachhochschule kooperiert mit Frankreich

Deggendorf. (da) Bereits im Jahr 2006 hat die Europäische Union eine einheitliche Hochwasserrichtlinie eingeführt. Diese ist die Grundlage für unterschiedliche Hochwasserkarten, die die Behörden, Anlieger und Interessenten über ein bestehendes oder zukünftiges Hochwasserrisiko informieren.

Prototypen solcher Karten liegen in verschiedenen Formaten bereits vor. Allerdings müssen nicht nur die Experten, sondern vor allem auch die Betroffenen über ein Hochwasserrisiko unterrichtet werden. Daher ist es notwendig, Karten für die einzelnen Nutzergruppen anzufertigen. Während Experten mit einer Vielzahl unterschiedlicher Karten tagtäglich konfrontiert werden, ist für Laien die Darstellung oftmals zu komplex. Ebenso beanspruchen Entscheidungsträger möglichst umfassende und damit vielfältige Informationen in den Karten zu finden.

Die Forschungsgruppe Wasser und Umwelt der Hochschule Deggendorf nahm sich innerhalb des Projekts RISKCATCH (www.riskcatch.info), das vom Bundesministerium für Bildung und Forschung gefördert wurde, dieser Aufgabe an und kooperiert derzeit gleichzeitig mit Partnern aus Österreich und Frankreich.

Verschiedene Wahrnehmung

Mit Hilfe einer speziellen Apparatur des Krankenhauses von Tours/Frankreich wurde analysiert, wie verschiedene Personen solche Risikokarten auf unterschiedliche Art und Weise wahrnehmen. Diese individuellen Wahrnehmungen wurden anhand der Pupillenbewegung verfolgt. Ein Fragebogen zu den einzelnen Karten gab zusätzlichen Aufschluss über die weiteren Vor- und Nachteile. 20 Testpersonen aus Bayern, Österreich und Frankreich, darunter Bürgermeister Werner Schießl aus Eggenfelden und Regionalmanager Wolfgang Dorner aus Deggendorf, leisteten dabei durch ihre Teilnahme einen entscheidenden Beitrag zum Resultat des Projekts. In den nächsten Monaten werden die Testreihen ausgewertet und dann den öffentlichen Organisationen, wie Landesamt oder Staatsministerium, präsentiert.

2. Deggendorfer Zeitung 29 November 2007

Hochwasserrisiken als Forschungsschwerpunkt

Karten für Laien zu komplex

Deggendorf. Mit Hilfe von Grundlagenforschung, bei der sogar die Pupillenbewegungen der Nutzer untersucht werden, arbeiten Experten der FH derzeit an besseren Hochwasserkarten.

Bereits im Jahr 2000 hat die Europäische Union eine einheitliche Hochwasserrichtlinie eingeführt. Diese ist die Grundlage für unterschiedliche Hochwasserkarten, die die Behörden, Anlieger und Interessenten über ein bestehendes oder zukünftiges Hochwasserrisiko informieren sollen. Prototypen solcher Karten liegen bereits in verschiedenen Formaten vor. Allerdings müssen nicht nur die Experten, sondern vor allem auch die Betroffenen, über ein Hochwasserrisiko unterrichtet werden. Daher ist es notwendig, Karten für die einzelnen Nutzergruppen anzufertigen.

Während Experten mit einer Vielzahl unterschiedlicher Karten tagtäglich konfrontiert werden, ist für Laien die Darstellung oftmals zu komplex. Ebenso beanspruchen Entscheidungsträger möglichst umfassende und damit vielfältige Informationen in den Karten zu finden. Die Forschungsgruppe Wasser und Umwelt der Hochschule Deggendorf nahm sich innerhalb des Projekts Riskcatch (www.riskcatch.info), das vom Bundesministerium für Bildung und Forschung gefördert wurde, dieser Aufgabe an und kooperiert derzeit gleichzeitig mit Partnern aus Österreich und Frankreich. Mit Hilfe einer speziellen Apparatur des Krankenhauses von Tours/Frankreich wurde analysiert, wie verschiedene Personen solche Risikokarten auf unterschiedliche Art und Weise wahrnahmen. Diese individuellen Wahrnehmungen wurden anhand der Pupillenbewegung verfolgt. Ein Fragebogen zu den einzelnen Karten gab zusätzlichen Aufschluss über die weiteren Vor- und Nachteile. 20 Testpersonen aus Bayern, Österreich und Frankreich, darunter Bürgermeister Werner Schießl aus Eggenfelden und Regionalmanager Wolfgang Dorner aus Deggendorf, leisteten dabei durch ihre Teilnahme einen entscheidenden Beitrag zum Resultat des Projekts. In den nächsten Monaten werden die Testreihen ausgewertet und dann den öffentlichen Organisationen wie Landesamt oder Staatsministerium präsentiert. – dz

Website

www.riskcatch.info

List of maps

Maps produced by the Austrian partner (large-scale) and by the German partner (small-scale) were distinguished in two different categories, and further sub-classified in separate sets.

Austrian maps

Set 1. Building category

Map no.	Variables tested			
	Test site	**Background**	**Scale**	**Caption/Legend**
1	Wartschenbach	Land register	1:2500	Right
2	Vorderbergerbach	Land register	1:5000	Left

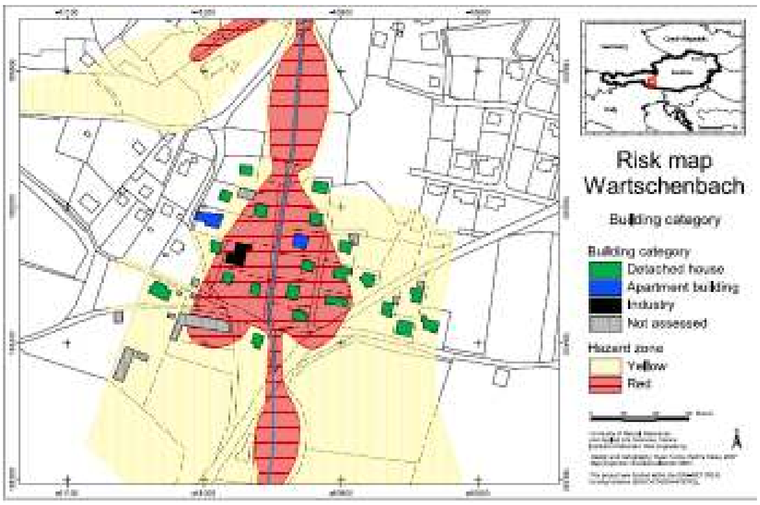
Common elements:

Title in top

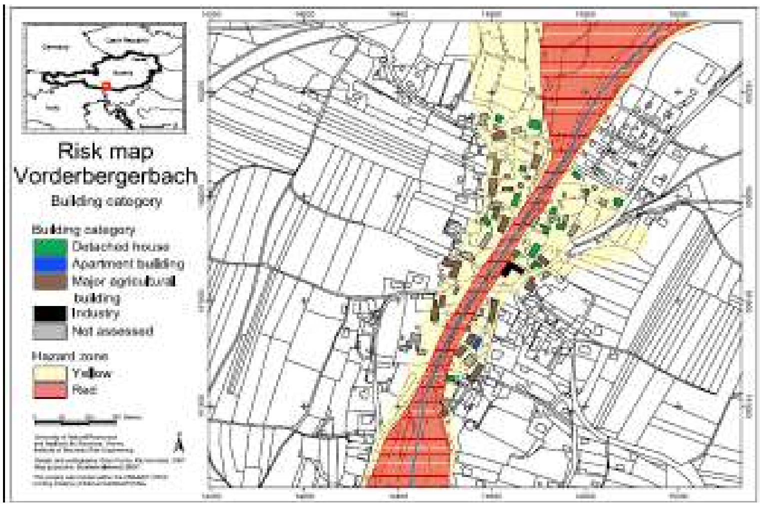
Discretisation (the same for these two maps)

Composition of the legend

Map no. 1



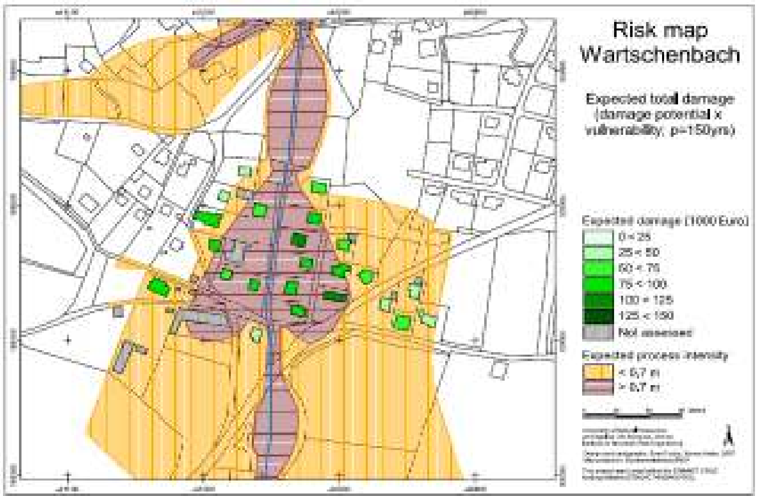
Map no. 2



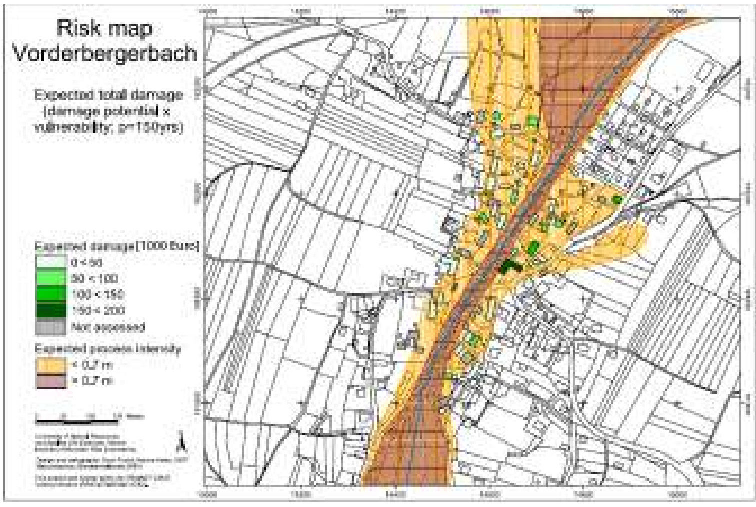
Set 2. Total damage

Map no.	Variables tested					
	Test site	**Background**	**Scale**	**Caption/Legend**	**Classes**	**Colour**
3	Wartschenbach	Land register	1:2500	right	7	green
4	Vorderbergerbach	Land register	1:5000	left	5	green
5	Wartschenbach	Orthophoto (IR)	1:2500	right	7	green
6	Vorderbergerbach	Orthophoto (colour)	1:5000	left	5	red

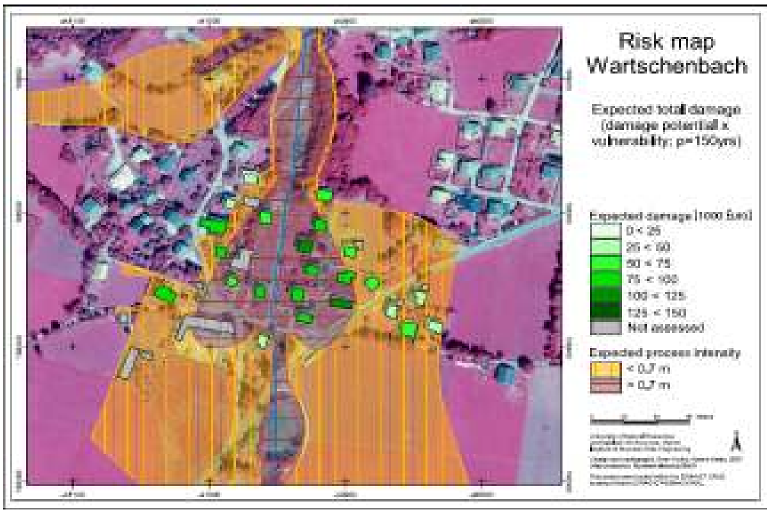
Map no. 3



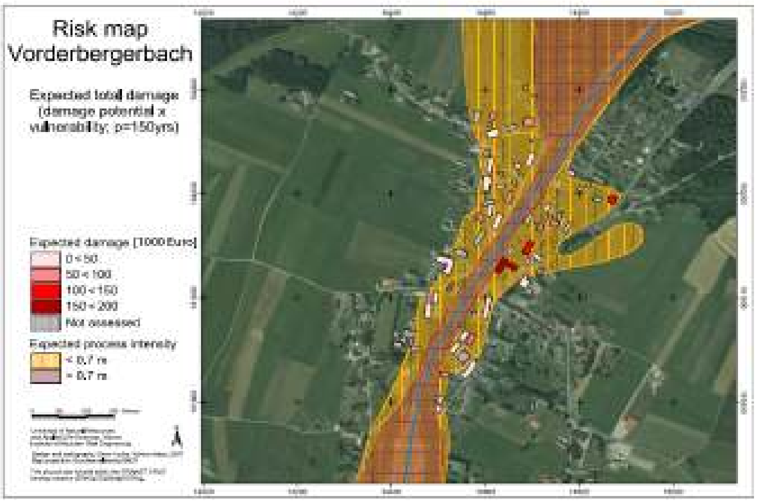
Map no. 4



Map no. 5



Map no. 6



Set 3. Annual damage

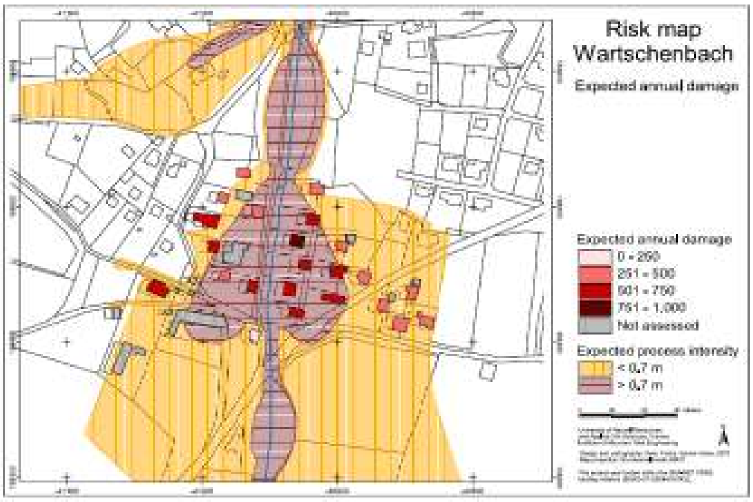
Map no.	Variables tested					
	Test site	**Background**	**Scale**	**Caption/Legend**	**Classes**	**Colour**
7	Wartschenbach	Land register	1:2500	right	5	red
8	Vorderbergerbach	Land register	1:5000	left	7	green
9	Wartschenbach	Orthophoto (IR)	1:2500	right	5	green
10	Vorderbergerbach	Orthophoto (colour)	1:5000	left	7	green

Common elements:

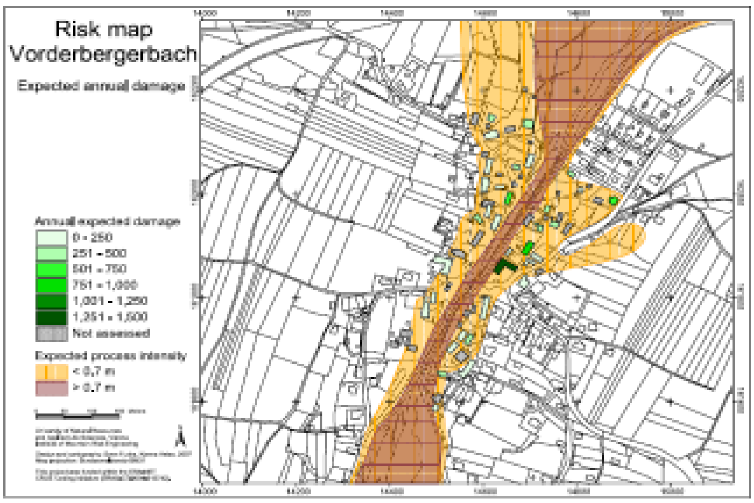
Title in top

Composition of the legend

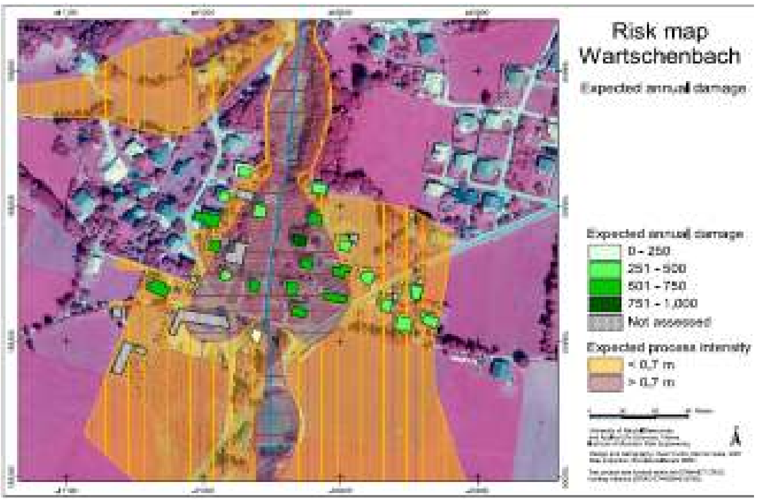
Map no. 7



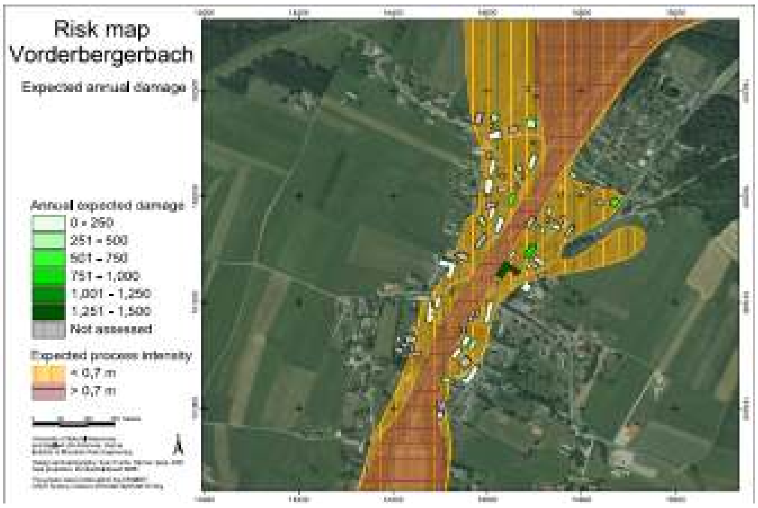
Map no. 8



Map no. 9



Map no. 10



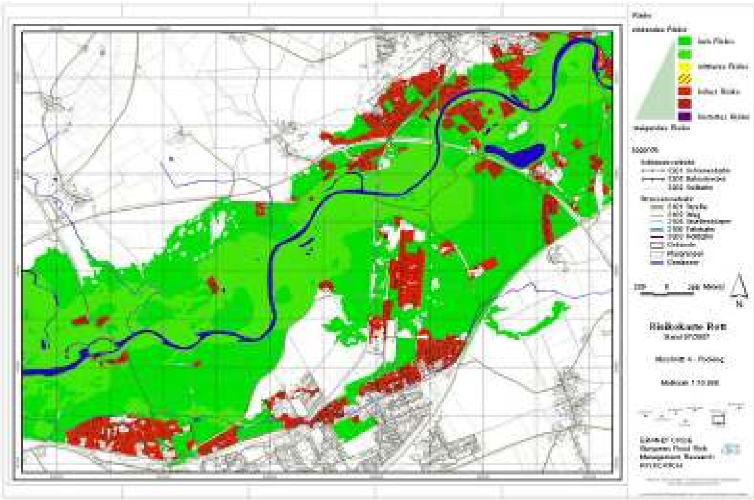
German maps

Set 1. Areas affected by flood risk

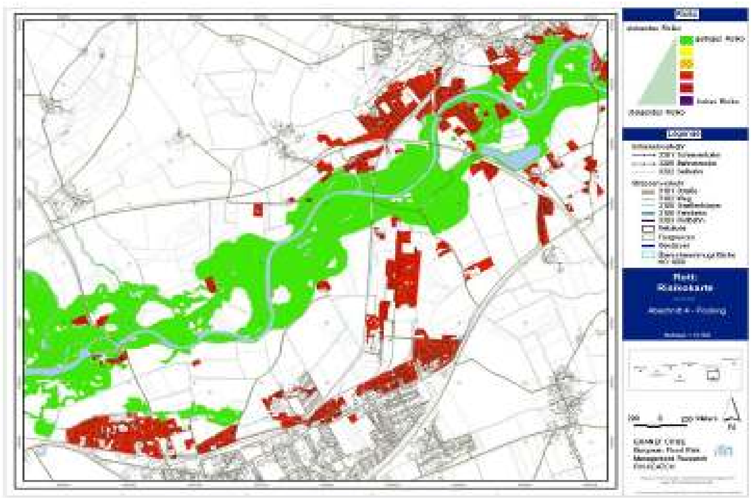
Map no.	Variables tested				
	Test site	**Title**	**Classes**	**Value**	**Legend: Level of detail**
11	Rott	bottom	7	several colours	11 types of information
12	Rott	bottom	6	several colours	11 types of information

Common elements:
- Legend placed on the right margin
- Similar map background
- Scale 1:10,000

Map no. 11



Map no. 12



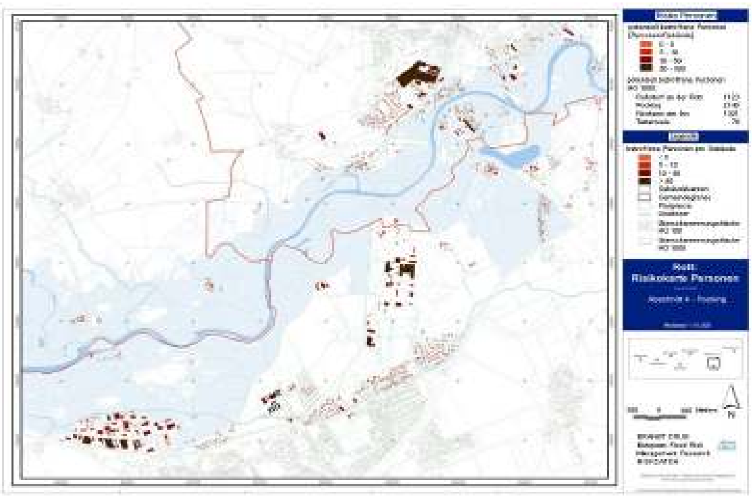
Set 2. Persons affected by flood risk

Map no.	Variables tested					
	Test site	**Title**	**Classes**	**Value**	**Legend: Complexity**	**Information: Precision**
13	Rott	bottom	4	range of one colour	11 types of information	1 information
14	Rott	bottom	4	several colours	11 types of information	2 types of information
15	Rott	bottom	4	range of one colour	6 types of information	1 information
16	Rott	bottom	5	range of one colour	5 types of information	2 types of information
17	Rott	top	6	range of one colour	5 types of information	2 types of information

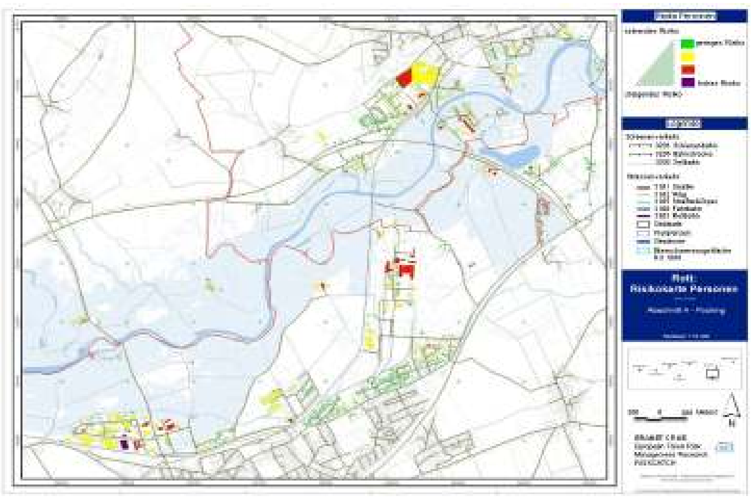
Common elements:

Legend placed on the right margin
Similar map background
Scale 1:10,000

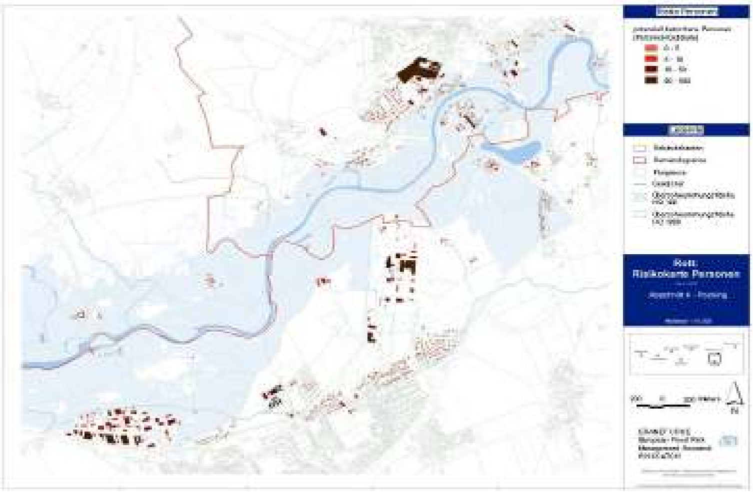
Map no. 13



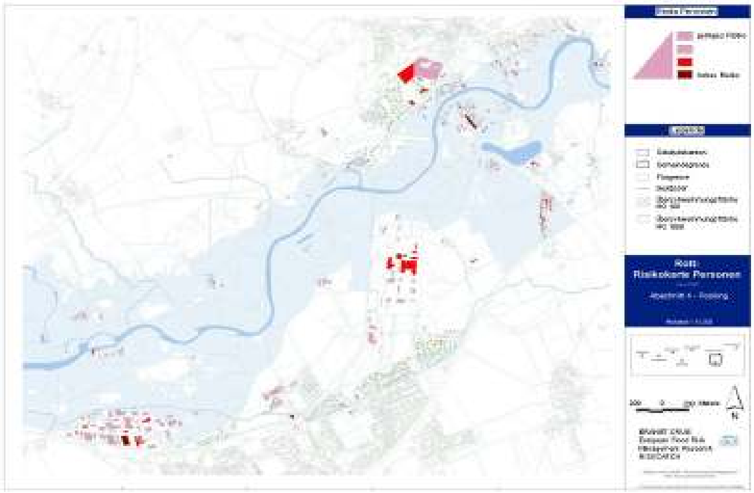
Map no. 14



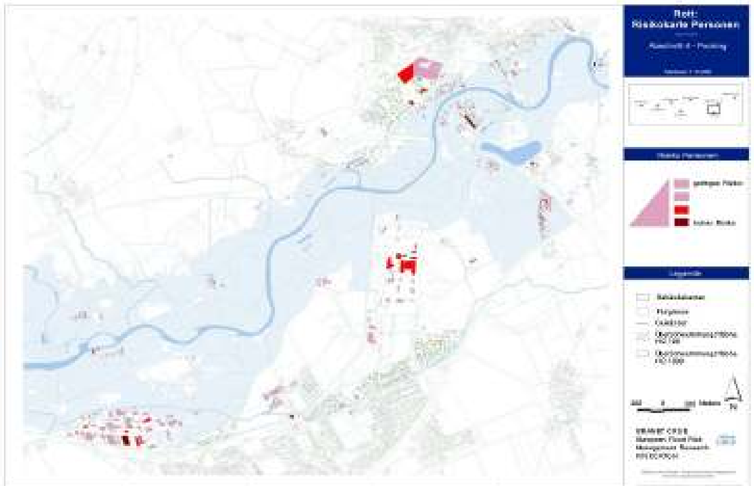
Map no. 15



Map no. 16



Map no. 17



Ocular movement recordings data per map

Map 1: Risk map Wartschenbach Building category	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	26	532	25	5.2
KEILER	40	286	37	9.8
WEBER C	31	430	30	5.6
WEBER E	38	327	36	6.1
GRUBER	33	409	32	5.6
STANZER	37	349	36	8.7
SPACHINGER	30	442	29	9.1
HEINDL	29	456	28	6.1
ERTL	34	388	33	7.0
PANZIRSCH	39	317	38	8.5
DORNER	38	346	37	6.0
HAGEMEIER	35	390	34	4.9
MERZ	34	389	33	7.1
SCHIESSL	37	356	36	9.1
MARTOUZET	37	335	35	7.4
BAPTISTE	38	340	37	9.8
BOIS	48	261	47	9.3
LARRIBE	32	402	31	5.5
BUREL	31	416	29	4.8
DUCROCQ	41	314	40	7.6
SELLAMI	37	339	35	5.8
AVERAGE	**35**	**368**	**34.2**	**7.1**

Map 2: Risk map Vorderbergerbach Building category	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	36	375	35	6.8
KEILER	36	270	33	9.1
WEBER C	38	346	37	6.0
WEBER E	33	401	32	5.6
GRUBER	37	355	36	6.3
STANZER	41	309	40	7.5
SPACHINGER	38	337	37	8.4
HEINDL	30	423	29	7.1
ERTL	33	410	32	5.2
PANZIRSCH	41	313	40	8.1
DORNER	36	374	35	5.0
HAGEMEIER	33	399	32	7.7
MERZ	43	306	42	5.7
SCHIESSL	35	369	34	11.0
MARTOUZET	42	299	41	7.1
BAPTISTE	37	354	36	8.5
BOIS	43	299	42	7.4
LARRIBE	27	310	21	6.7
BUREL	32	302	26	6.7
DUCROCQ	40	312	38	8.8
SELLAMI	42	286	40	7.1
AVERAGE	**37**	**340**	**35.1**	**7.2**

Map 3: Risk map Wartschenbach Expected total damage	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	36	369	35	6.3
KEILER	43	277	42	7.3
WEBER C	38	345	37	6.7
WEBER E	34	329	30	6.2
GRUBER	40	301	39	7.3
STANZER	37	325	35	7.9
SPACHINGER	36	363	35	6.6
HEINDL	33	409	32	6.9
ERTL	36	363	35	5.1
PANZIRSCH	32	312	26	7.2
DORNER	30	445	29	4.4
HAGEMEIER	33	411	32	4.6
MERZ	42	311	41	6.7
SCHIESSL	43	288	41	7.7
MARTOUZET	40	284	38	7.0
BAPTISTE	35	383	34	6.6
BOIS	46	274	45	7.4
LARRIBE	36	335	34	6.3
BUREL	28	490	27	4.8
DUCROCQ	39	332	38	7.8
SELLAMI	39	270	32	7.3
AVERAGE	**37**	**344**	**35.1**	**6.6**

Map 4 : Risk map Wartschenbach Building category	**Fixations [N]**	**Average duration of Fixation [ms]**	**Saccades [N]**	**Median Amplitude [deg]**
FUCHS	33	408	32	6.8
KEILER	37	325	34	8.3
WEBER C	30	452	29	5.9
WEBER E	46	246	44	6.8
GRUBER	42	308	41	6.6
STANZER	37	324	35	8.8
SPACHINGER	34	374	33	9.8
HEINDL	38	346	37	6.5
ERTL	38	341	37	6.5
PANZIRSCH	29	291	20	8.0
DORNER	32	420	31	8.3
HAGEMEIER	40	309	39	8.2
MERZ	34	394	33	6.7
SCHIESSL	39	318	37	8.9
MARTOUZET	39	315	38	9.4
BAPTISTE	35	363	34	9.3
BOIS	37	348	36	7.2
LARRIBE	32	263	23	9.0
BUREL	40	285	36	6.5
DUCROCQ	38	336	37	7.5
SELLAMI	32	330	29	6.3
AVERAGE	**36**	**338**	**34.0**	**7.7**

Map 5: Risk map Vorderbergerbach Expected total damage	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	35	369	33	6.8
KEILER	36	351	35	6.8
WEBER C	40	333	39	6.4
WEBER E	43	295	42	6.0
GRUBER	38	352	37	4.6
STANZER	36	316	32	7.9
SPACHINGER	39	323	38	6.1
HEINDL	37	355	36	6.3
ERTL	38	339	37	7.4
PANZIRSCH	36	288	31	6.1
DORNER	46	276	45	5.8
HAGEMEIER	50	255	49	5.7
MERZ	48	268	47	6.6
SCHIESSL	44	280	43	9.4
MARTOUZET	42	292	41	8.3
BAPTISTE	38	346	37	7.1
BOIS	48	257	47	8.1
LARRIBE	35	325	30	5.6
BUREL	41	292	40	6.5
DUCROCQ	44	286	43	8.5
SELLAMI	40	300	36	6.1
AVERAGE	**41**	**309**	**39.0**	**6.8**

Map 6: Risk map Vorderbergerbach Expected total damage	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	37	288	32	6.9
KEILER	37	325	35	7.7
WEBER C	35	371	34	7.4
WEBER E	37	288	32	6.9
GRUBER	37	358	36	6.8
STANZER	39	319	38	9.5
SPACHINGER	33	396	32	7.6
HEINDL	37	355	36	7.1
ERTL	35	340	32	5.3
PANZIRSCH	34	293	28	8.5
DORNER	37	353	36	5.1
HAGEMEIER	38	338	36	6.5
MERZ	31	418	30	5.9
SCHIESSL	37	320	36	11.0
MARTOUZET	40	305	39	6.8
BAPTISTE	32	418	31	7.2
BOIS	37	337	36	6.5
LARRIBE	17	294	10	4.4
BUREL	37	284	32	7.8
DUCROCQ	43	299	42	6.1
SELLAMI	46	271	45	7.0
AVERAGE	**36**	**332**	**33.7**	**7.0**

Map 7: Risk map Wartschenbach Expected annual damage	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	37	363	36	5.9
KEILER	34	348	32	6.8
WEBER C	33	409	32	4.1
WEBER E	36	346	35	8.5
GRUBER	35	375	31	7.1
STANZER	36	368	35	6.4
SPACHINGER	36	364	35	6.4
HEINDL	35	336	33	5.8
ERTL	33	377	31	6.4
PANZIRSCH	28	311	21	9.5
DORNER	36	396	35	5.4
HAGEMEIER	42	301	41	6.7
MERZ	36	361	35	6.8
SCHIESSL	41	314	40	8.8
MARTOUZET	42	299	41	8.0
BAPTISTE	36	364	35	8.1
BOIS	40	316	39	8.0
LARRIBE	38	329	37	5.3
BUREL	33	370	31	5.1
DUCROCQ	40	329	39	6.2
SELLAMI	31	350	28	6.6
AVERAGE	**36**	**349**	**34.4**	**6.8**

Map 8: Risk map Vorderbergerbach Expected annual damage	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	23	385	22	7.1
KEILER	37	337	36	6.7
WEBER C	28	496	27	5.7
WEBER E	27	320	25	7.4
GRUBER	23	587	22	4.7
STANZER	39	329	38	6.5
SPACHINGER	29	381	25	8.3
HEINDL	32	411	31	6.2
ERTL	28	471	26	6.5
PANZIRSCH	27	369	20	10.0
DORNER	36	372	35	5.8
HAGEMEIER	40	276	36	5.1
MERZ	35	381	34	6.3
SCHIESSL	41	301	40	7.3
MARTOUZET	38	325	36	6.8
BAPTISTE	40	319	39	8.8
BOIS	42	303	41	7.9
LARRIBE	29	386	25	5.5
BUREL	34	294	27	8.0
DUCROCQ	38	332	37	9.3
AVERAGE	**33**	**368**	**31.2**	**7.0**

Map 9: Risk map Wartschenbach Expected annual damage	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	40	318	38	5.4
KEILER	21	350	20	7.2
WEBER C	28	489	27	4.5
WEBER E	35	373	33	4.4
GRUBER	37	358	36	6.2
STANZER	37	330	35	7.2
SPACHINGER	34	390	33	5.7
HEINDL	40	324	39	7.2
ERTL	29	448	27	6.2
PANZIRSCH	36	311	32	6.6
DORNER	36	369	35	4.6
HAGEMEIER	44	295	43	5.4
MERZ	42	311	41	7.0
SCHIESSL	42	303	41	5.6
MARTOUZET	41	311	40	7.0
BAPTISTE	45	288	44	6.7
BOIS	47	264	46	7.6
LARRIBE	29	427	27	7.1
BUREL	31	375	27	7.0
DUCROCQ	41	307	40	6.3
SELLAMI	44	249	40	4.7
AVERAGE	**37**	**342**	**35.4**	**6.2**

Map 10: Risk map Vorderbergerbach Expected annual damage	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	36	363	35	5.7
KEILER	37	334	36	7.0
WEBER C	28	491	27	3.8
WEBER E	33	347	30	6.5
GRUBER	33	406	32	6.5
STANZER	47	261	46	8.8
SPACHINGER	32	392	31	8.1
HEINDL	31	427	30	5.1
ERTL	24	453	22	7.6
PANZIRSCH	39	291	36	8.9
DORNER	34	401	33	4.9
HAGEMEIER	42	308	41	8.5
MERZ	39	324	38	11.0
SCHIESSL	37	352	36	6.7
MARTOUZET	35	360	34	7.5
BAPTISTE	31	424	30	7.8
BOIS	45	270	44	7.2
LARRIBE	31	398	29	7.1
BUREL	35	356	33	7.2
DUCROCQ	41	310	40	6.9
SELLAMI	36	347	35	6.6
AVERAGE	**36**	**363**	**34.2**	**7.1**

Map 11: Risikokarte Rott	**Fixations [N]**	**Average duration of Fixation [ms]**	**Saccades [N]**	**Median Amplitude [deg]**
FUCHS	40	285	37	7.8
KEILER	33	343	28	7.3
WEBER C	35	392	34	4.7
WEBER E	41	308	40	7.3
GRUBER	30	443	29	6.9
STANZER	28	336	25	9.2
SPACHINGER	32	414	31	6.6
HEINDL	35	347	32	5.5
ERTL	33	379	32	7.9
PANZIRSCH	30	417	29	9.3
DORNER	37	359	36	5.6
HAGEMEIER	32	401	30	8.7
MERZ	39	332	38	6.8
SCHIESSL	36	362	35	9.4
MARTOUZET	32	406	31	6.0
BAPTISTE	36	366	35	7.8
BOIS	36	359	35	8.7
LARRIBE	35	353	33	6.4
BUREL	32	361	26	4.8
DUCROCQ	39	309	36	4.1
SELLAMI	40	295	37	5.8
AVERAGE	**35**	**360**	**32.8**	**7.0**

Map 12: Risikokarte Rott	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	44	266	42	6.9
KEILER	35	353	33	8.4
WEBER C	35	365	33	5.4
WEBER E	40	322	39	6.5
GRUBER	42	303	41	6.5
STANZER	36	320	33	7.2
SPACHINGER	37	349	36	7.4
HEINDL	34	399	33	5.5
ERTL	38	320	35	6.1
PANZIRSCH	35	316	30	5.9
DORNER	40	325	39	7.7
HAGEMEIER	36	355	35	6.1
MERZ	36	362	35	5.6
SCHIESSL	30	449	29	9.0
MARTOUZET	31	284	25	9.6
BAPTISTE	30	447	29	7.0
BOIS	37	344	36	8.4
LARRIBE	26	383	21	6.0
BUREL	24	409	17	6.8
DUCROCQ	24	575	23	4.5
SELLAMI	35	346	34	8.0
AVERAGE	**35**	**362**	**32.3**	**6.9**

Map 13: Risikokarte Rott Persons	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	35	379	34	5.8
KEILER	31	426	30	5.8
WEBER C	39	344	38	5.7
WEBER E	38	341	37	6.2
GRUBER	29	465	28	4.4
STANZER	39	305	35	7.6
SPACHINGER	40	324	39	6.4
HEINDL	38	336	37	6.8
ERTL	31	378	29	7.4
PANZIRSCH	38	272	33	7.9
DORNER	37	366	36	4.4
HAGEMEIER	33	393	32	6.0
MERZ	35	376	34	7.3
SCHIESSL	38	342	37	7.0
MARTOUZET	22	419	18	7.7
BAPTISTE	33	417	32	5.5
BOIS	37	353	36	7.3
LARRIBE	33	329	29	6.8
BUREL	22	309	14	7.1
DUCROCQ	22	627	21	5.9
SELLAMI	30	386	26	8.4
AVERAGE	**33**	**376**	**31.2**	**6.5**

Map 14: Risikokarte Rott Persons	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	36	301	32	12.0
KEILER	38	326	37	8.3
WEBER C	34	399	33	6.3
WEBER E	39	324	38	7.0
GRUBER	35	376	34	6.9
STANZER	28	417	25	8.0
SPACHINGER	27	504	26	9.6
HEINDL	41	310	40	5.9
ERTL	31	335	25	6.7
PANZIRSCH	36	281	32	8.0
DORNER	45	280	43	7.5
HAGEMEIER	32	411	31	7.6
MERZ	36	355	34	6.9
SCHIESSL	46	275	45	7.1
MARTOUZET	24	327	19	5.6
BAPTISTE	31	436	30	6.9
BOIS	35	375	34	7.8
LARRIBE	32	314	28	8.9
BUREL	23	443	17	6.0
DUCROCQ	37	353	36	8.6
SELLAMI	31	392	29	7.8
AVERAGE	**34**	**359**	**31.8**	**7.6**

Map 15: Risikokarte Rott Persons	**Fixations [N]**	**Average duration of Fixation [ms]**	**Saccades [N]**	**Median Amplitude [deg]**
FUCHS	30	362	25	8.2
KEILER	31	397	28	9.1
WEBER C	36	373	35	6.2
WEBER E	36	280	34	8.0
GRUBER	30	439	29	5.2
STANZER	41	299	40	8.8
SPACHINGER	31	326	25	9.5
HEINDL	37	321	34	11.0
ERTL	29	307	24	7.1
PANZIRSCH	40	280	37	8.0
DORNER	33	394	32	7.4
HAGEMEIER	40	302	38	6.3
MERZ	31	447	30	5.5
SCHIESSL	37	341	35	7.0
MARTOUZET	42	299	41	8.4
BAPTISTE	37	354	36	9.7
BOIS	40	322	39	8.2
LARRIBE	30	442	29	4.4
BUREL	21	334	8	3.9
DUCROCQ	36	363	35	8.3
SELLAMI	33	399	32	7.2
AVERAGE	**34**	**351**	**31.7**	**7.5**

Map 16: Risikokarte Rott Persons	Fixations [N]	Average duration of Fixation [ms]	Saccades [N]	Median Amplitude [deg]
FUCHS	30	416	28	9.5
KEILER	36	344	34	7.8
WEBER C	30	463	29	5.1
WEBER E	44	285	43	7.0
GRUBER	33	409	32	7.0
STANZER	30	448	29	6.4
SPACHINGER	36	338	33	6.7
HEINDL	25	526	24	9.8
ERTL	30	382	26	8.6
PANZIRSCH	29	350	24	6.9
DORNER	42	261	40	9.4
HAGEMEIER	28	477	26	9.2
MERZ	27	343	24	8.6
SCHIESSL	35	370	34	7.4
MARTOUZET	37	352	36	8.5
BAPTISTE	25	533	24	7.9
BOIS	35	367	34	8.6
LARRIBE	32	375	30	7.5
BUREL	22	371	16	10.0
DUCROCQ	40	322	39	9.2
SELLAMI	37	342	36	8.2
AVERAGE	**33**	**385**	**30.5**	**8.1**

Map 17: Risikokarte Rott Persons	**Fixations [N]**	**Average duration of Fixation [ms]**	**Saccades [N]**	**Median Amplitude [deg]**
FUCHS	32	366	28	7.6
KEILER	40	309	39	9.6
WEBER C	31	443	30	4.9
WEBER E	36	339	33	5.9
GRUBER	28	486	27	6.8
STANZER	34	356	31	7.4
SPACHINGER	34	384	33	6.6
HEINDL	36	328	32	10.0
ERTL	23	339	18	7.7
PANZIRSCH	39	284	37	8.3
DORNER	29	466	28	7.9
HAGEMEIER	29	305	23	9.4
MERZ	32	399	30	7.3
SCHIESSL	35	371	34	9.2
MARTOUZET	29	412	27	6.8
BAPTISTE	29	471	28	6.3
BOIS	37	345	36	9.7
LARRIBE	30	429	28	7.2
BUREL	19	452	9	7.2
DUCROCQ	38	348	37	6.9
SELLAMI	32	364	28	6.7
AVERAGE	**32**	**381**	**29.3**	**7.6**

Ocular movement recordings data per map and group

Average number of fixations per map and per group [N]

Maps	Specialist	Sensitised users	Control group (Laypersons)	Average per map
Map 1	32.9	36	38	35
Map 2	38	35	38	37
Map 3	37	38	36	37
Map 4	34.17	37	37	36
Map 5	41	40	41	41
Map 6	35	34	39	36
Map 7	35.5	38	35	36
Map 8	29	36	34	33
Map 9	36.17	36	39	37
Map 10	33.67	34	38	36
Map 11	36	34	37	35
Map 12	39	32	33	35
Map 13	35.83	32	33	33
Map 14	35.5	33	34	34
Map 15	31.83	35	36	34
Map 16	33	32	33	33
Map 17	31	31	34	32

Average duration of fixations per map and per group [ms]

Maps	Specialist	Sensitised users	Control group (Laypersons)	Average per map
Map 1	425	356.71	347.38	368
Map 2	349	344.43	330.63	340
Map 3	356	334.43	342.63	344
Map 4	393	319.14	313.25	338
Map 5	320	312.57	290.57	309
Map 6	364	334.29	305.75	332
Map 7	378	333.14	340.75	349
Map 8	434	345	329.29	368
Map 9	373	349.31	316.63	342
Map 10	396	375.57	326.13	363
Map 11	371	372.86	341.5	360
Map 12	328	370.14	378.88	362
Map 13	376	386.29	366.13	376
Map 14	369	346.29	361.88	359
Map 15	390	348.86	324.75	351
Map 16	372	404.71	376.38	385
Map 17	424	376.57	352	381

Average number of saccades per map and per group [N]

Maps	Specialist	Sensitised users	Control group (Laypersons)	Average per map
Map 1	31.00	34.71	36.00	34.2
Map 2	37.00	33.25	35.88	35.1
Map 3	36.00	36.57	33.13	35.1
Map 4	33.17	34.57	34.25	34.0
Map 5	39.83	38.86	40.13	39.0
Map 6	33.33	31,29	36.13	33.7
Map 7	34.00	33.75	32.63	34,4
Map 8	27.50	34.00	31.63	31.2
Map 9	35.00	34.57	36.50	35.4
Map 10	32.67	32.57	36.75	34.2
Map 11	34.17	32.00	32.50	32.8
Map 12	37.67	29.57	30.63	32.3
Map 13	34.83	29.57	29.88	31.2
Map 14	33.67	30.71	31.38	31.8
Map 15	29.33	33.00	32.38	31.7
Map 16	31.00	30.00	30.63	30.5
Map 17	29.33	28.14	30.38	29.3

Average amplitude of saccades per map and per group [deg]

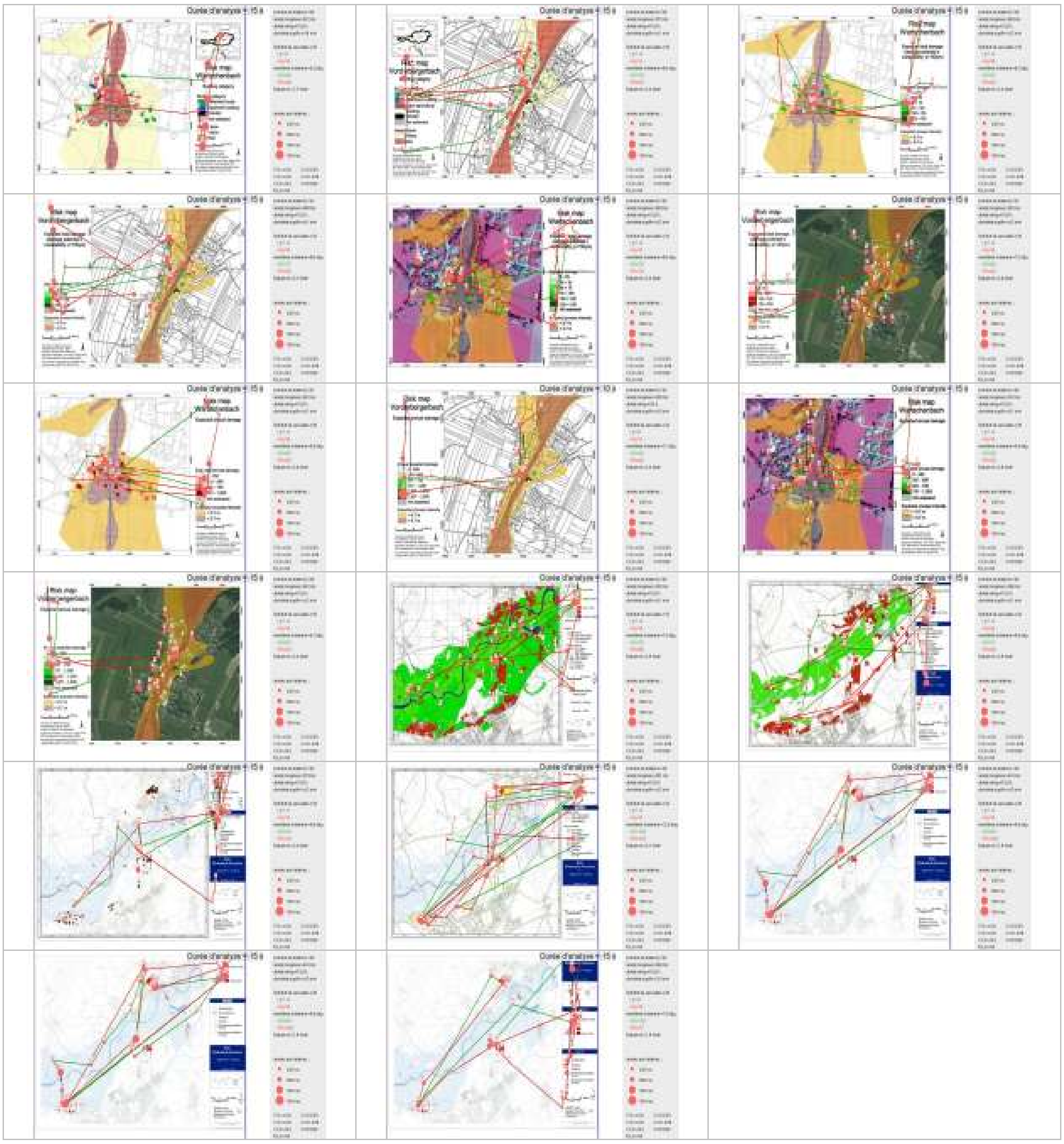
Maps	Specialist	Sensitised users	Control group (Laypersons)	Average per map
Map 1	6,43	7,64	7,1125	7,1
Map 2	6,56	7,73	7,26	7,2
Map 3	6,55	6,37	7,04	6,6
Map 4	7,35	8,39	7,2	7,7
Map 5	7	7,19	6,94	6,8
Map 6	6,62	7,07	7,43	7,0
Map 7	5,95	7,16	7,01	6,8
Map 8	6,32	6,67	7,93	7,0
Map 9	5,57	6,46	6,38	6,2
Map 10	6,67	7,46	7,15	7,1
Map 11	6,4	7,64	6,84	7,0
Map 12	6,58	7,46	6,6	6,9
Map 13	5,67	6,6	7,15	6,5
Map 14	8,2	7,3	7,39	7,6
Map 15	7	7,62	7,93	7,5
Map 16	7,72	8,13	8,26	8,1
Map 17	6,85	8,03	7,91	7,6

Average amplitude of saccades to the left and to the right per map and group [deg]

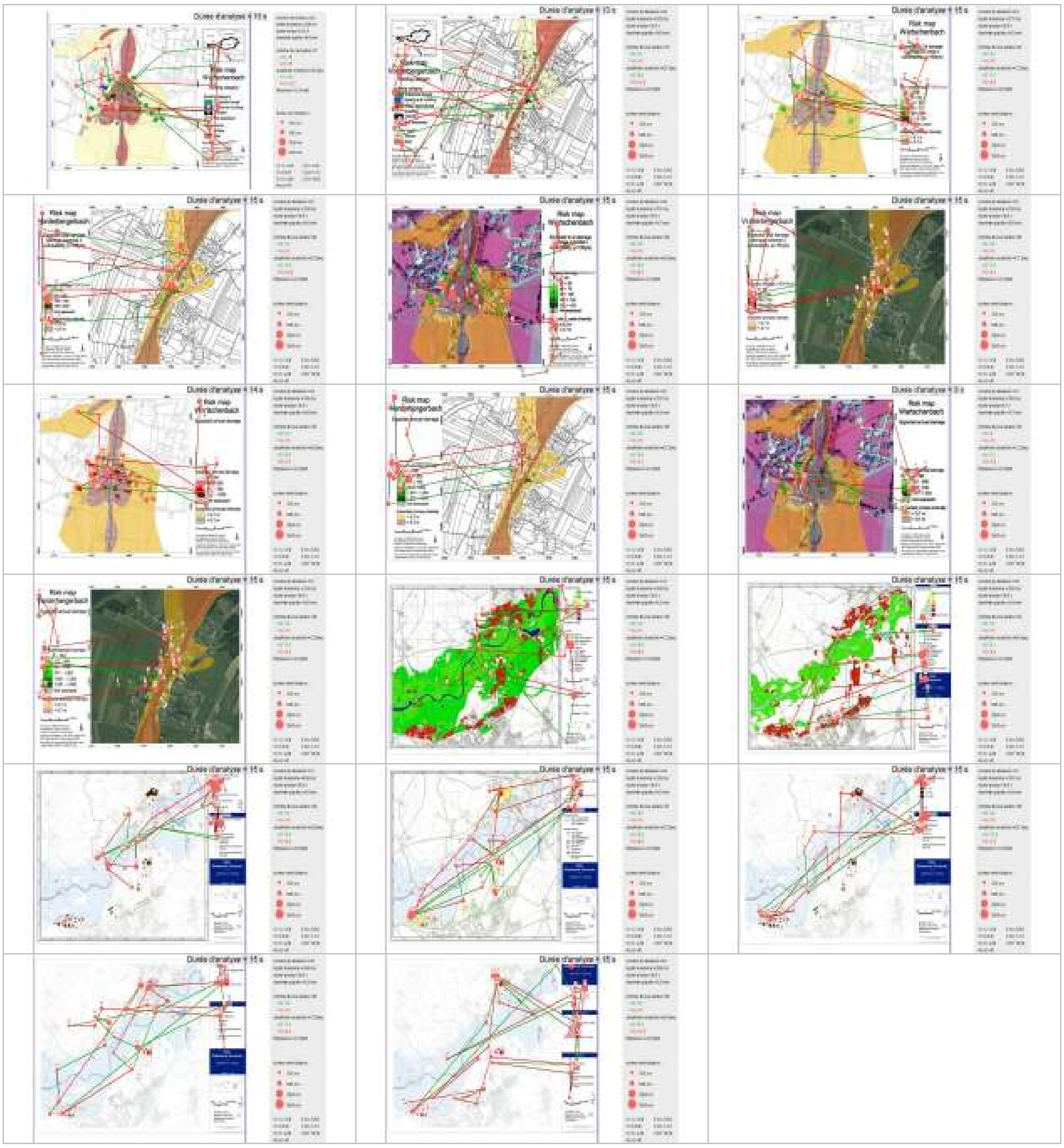
Maps	Amplitude of saccades to the right			Amplitude of saccades to the left			Average saccade amplitude	
	Specialist	Sensitised users	Control group	Specialist	Sensitised users	Control group	R	L
Map 1	7.8	8.1	7.2	6.2	8.1	7.6	7.7	7.4
Map 2	6.5	7.6	7.4	7.4	9.5	8.3	7.2	8.4
Map 3	6.5	6.4	7.1	6.5	6.8	7.5	6.7	7.0
Map 4	8.0	7.9	7.8	8.5	9.9	8.3	7.6	8.9
Map 5	6.3	7.2	6.7	6.2	7.8	7.7	6.7	7.3
Map 6	6.5	6.5	7.4	7.3	8.3	8.3	6.8	8.0
Map 7	6.3	7.3	7.5	5.9	7.6	7.3	7.1	7.0
Map 8	6.8	6.3	8.1	6.7	7.8	9.0	7.1	8.0
Map 9	5.8	6.5	6.7	6.0	7.1	6.8	6.4	6.7
Map 10	6.8	6.7	7.3	7.0	9.2	7.5	7.0	7.9
Map 11	6.8	8.6	6.8	7.4	7.9	7.6	7.3	7.6
Map 12	7.2	7.9	7.2	6.8	8.6	6.5	7.4	7.3
Map 13	6.2	7.0	7.8	5.6	7.1	7.2	7.0	6.7
Map 14	8.3	7.2	8.4	8.5	8.0	7.5	8.0	7.9
Map 15	8.0	7.7	8.1	6.9	8.1	8.3	7.9	7.8
Map 16	7.7	8.4	8.4	9.1	8.5	9.6	8.2	9.1
Map 17	8.7	7.8	7.8	7.2	9.8	8.3	8.1	8.5

Results of static analyses

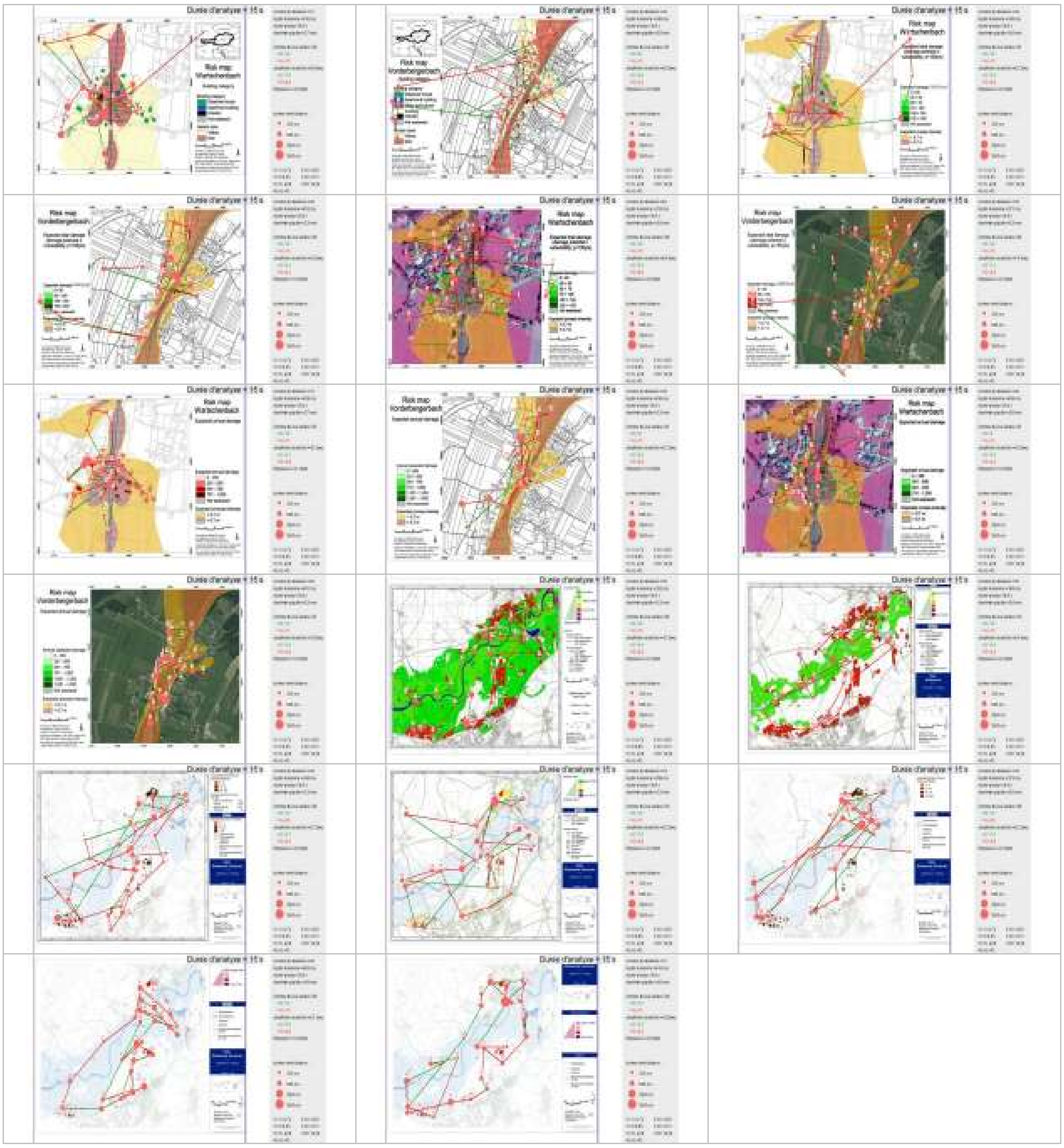
FUCHS Sven



KEILER Margreth



WEBER Christian



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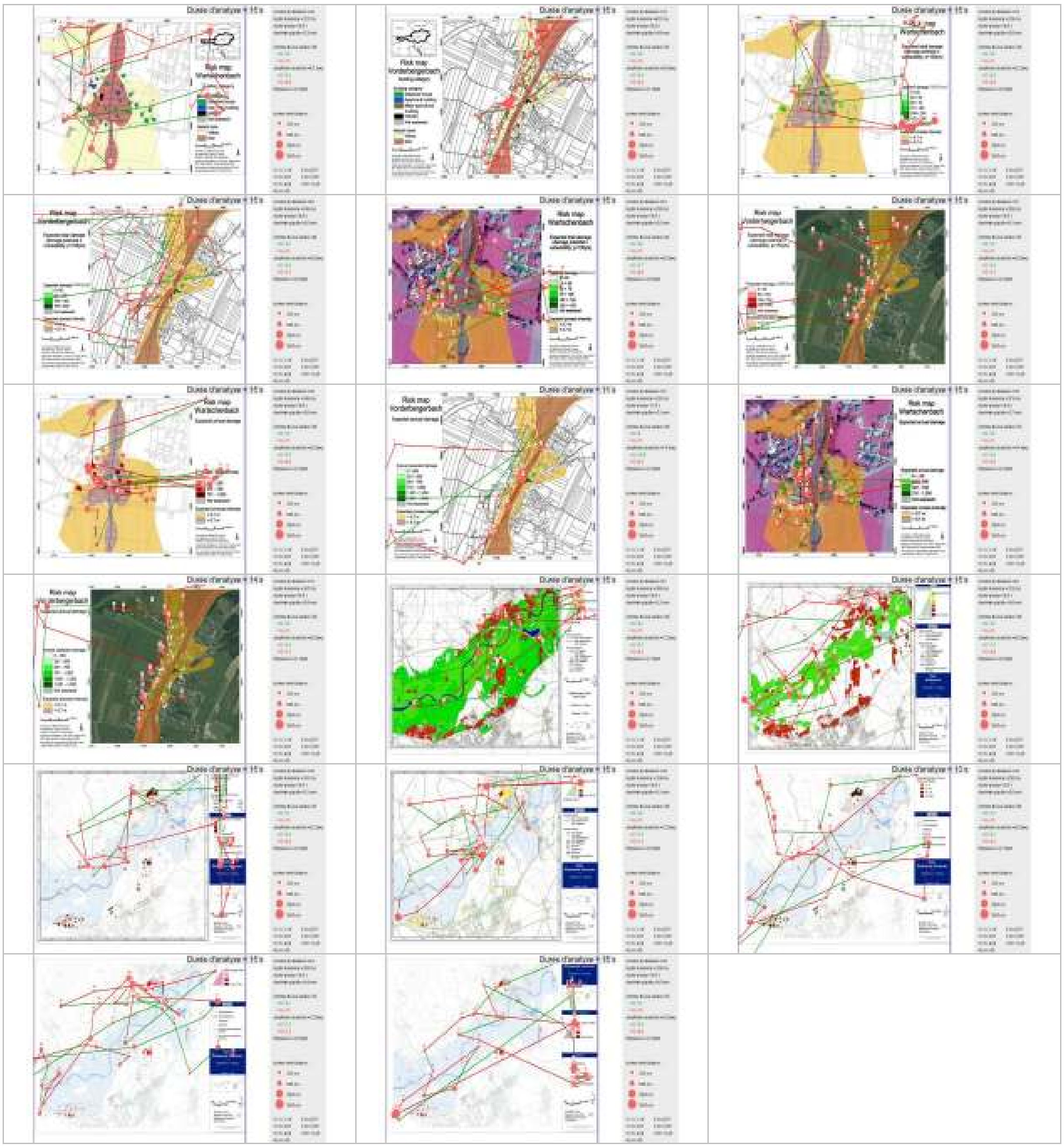
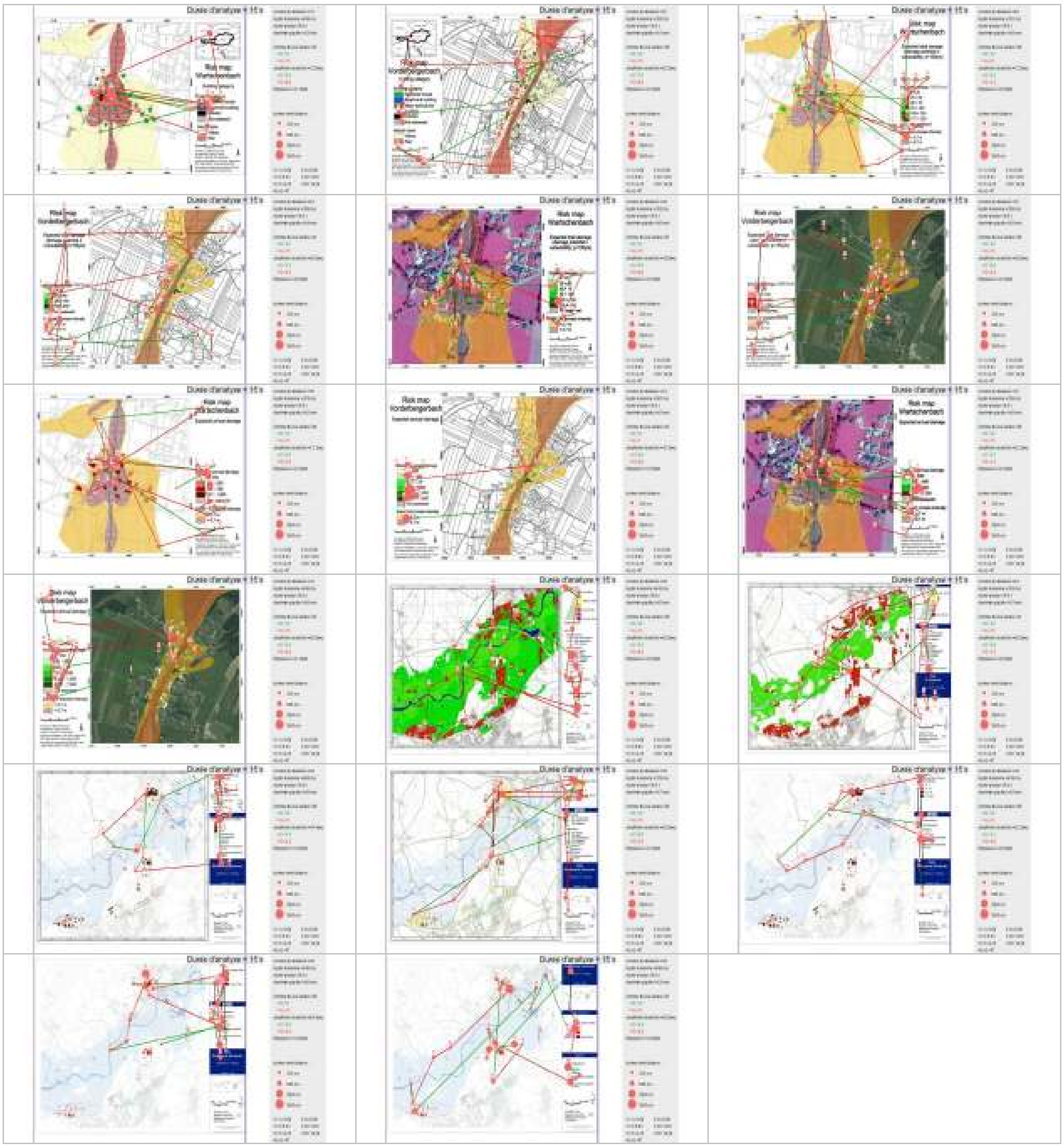
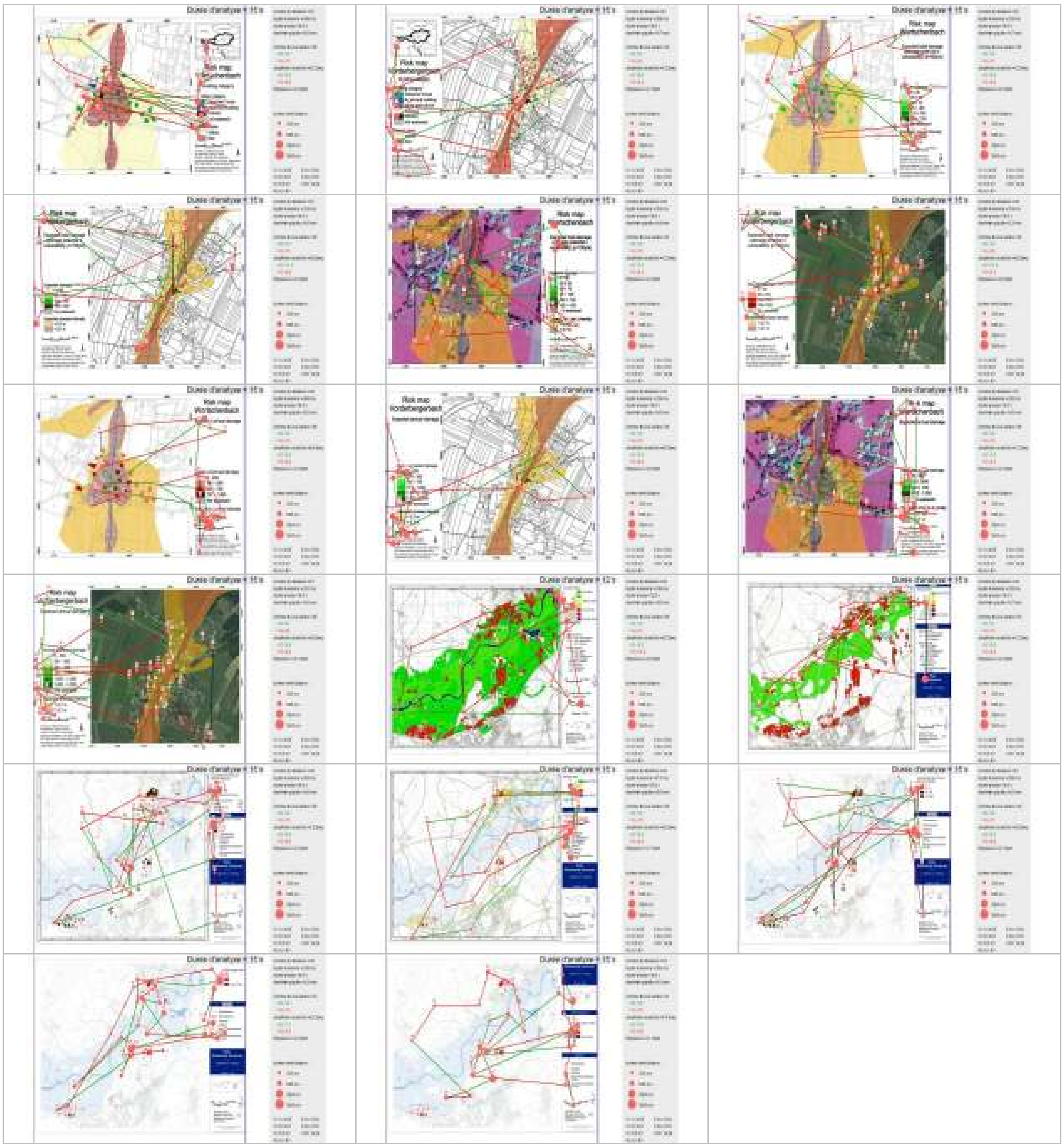


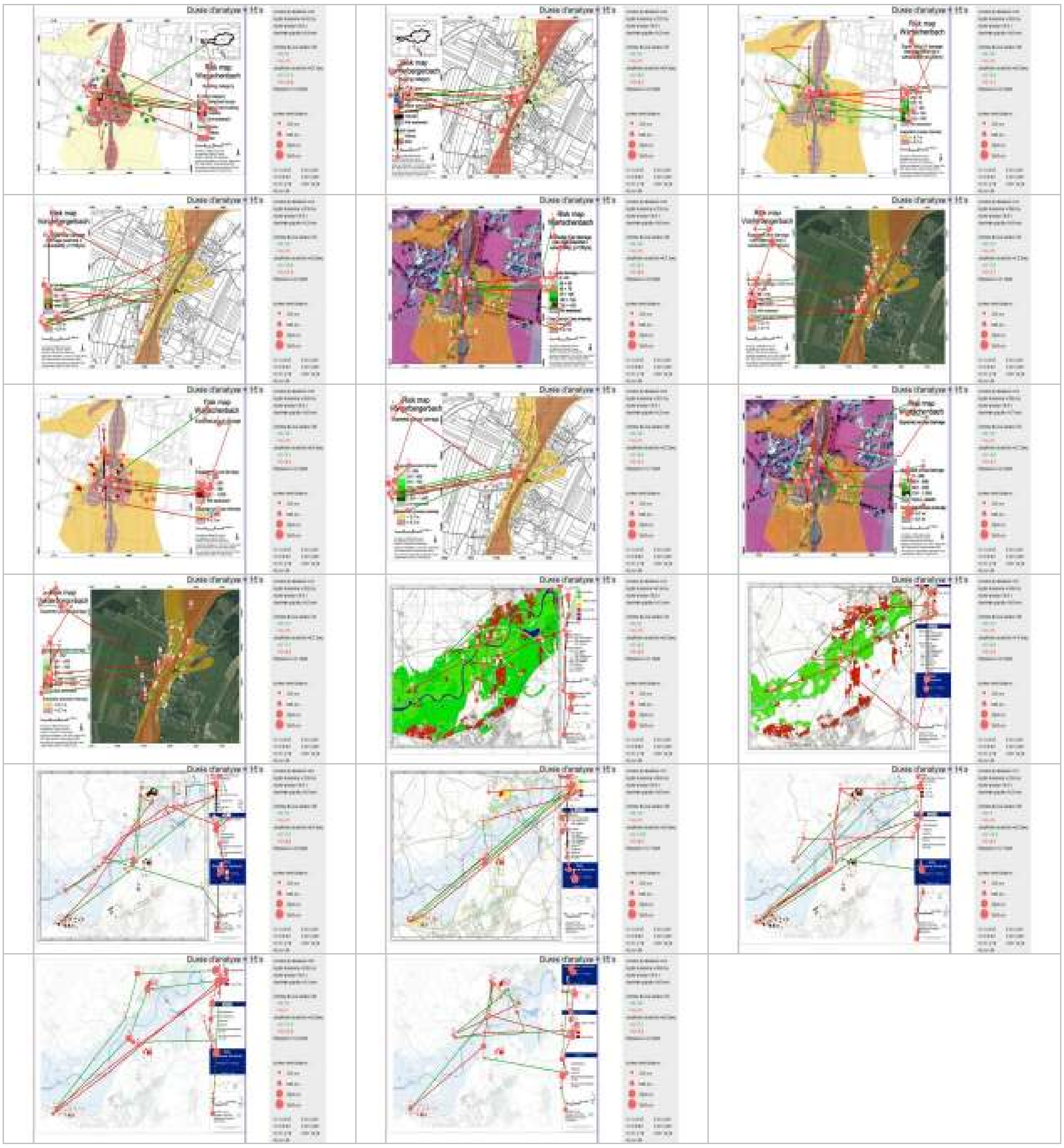
GRUBER Harald



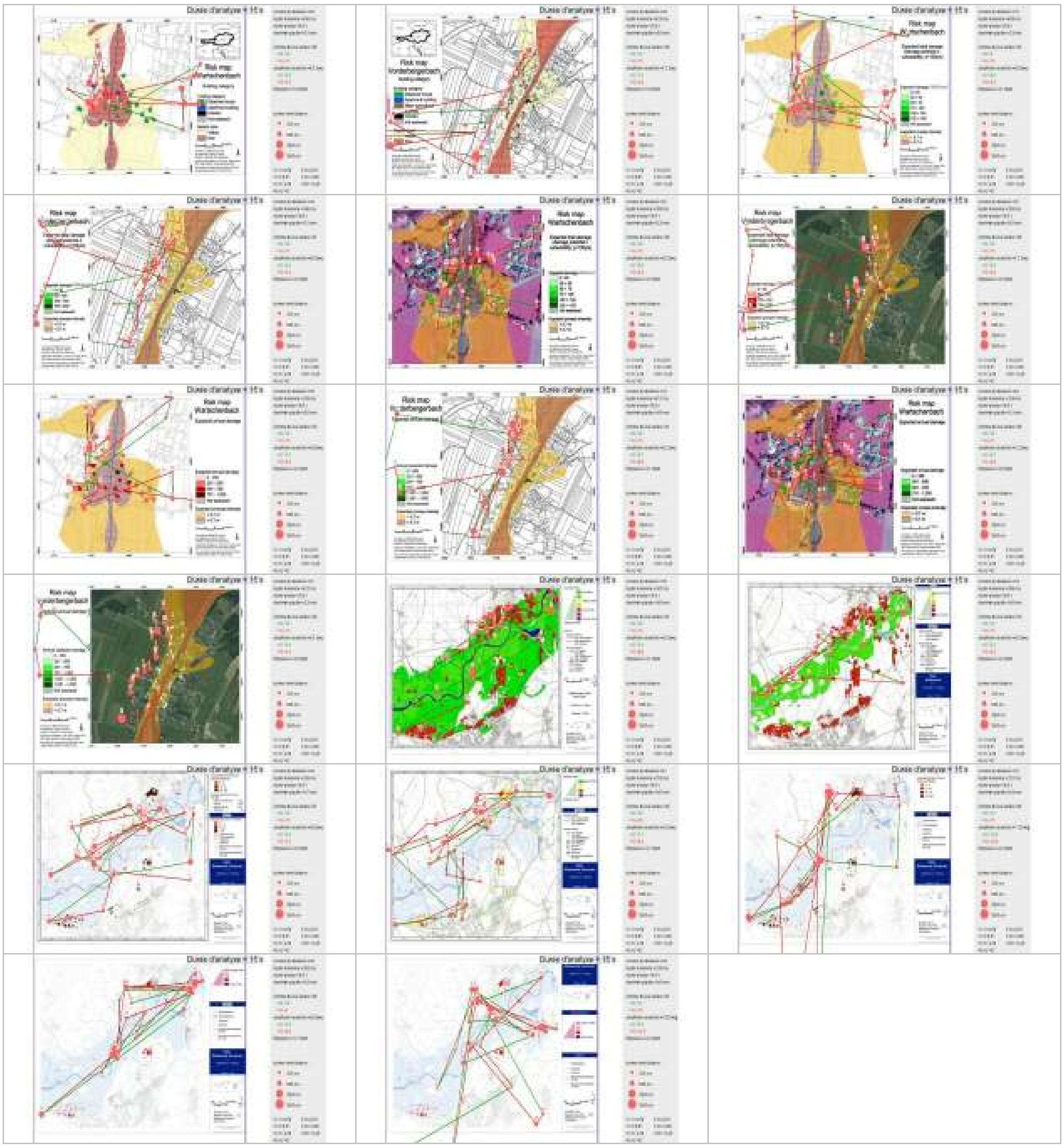
STANZER Monika



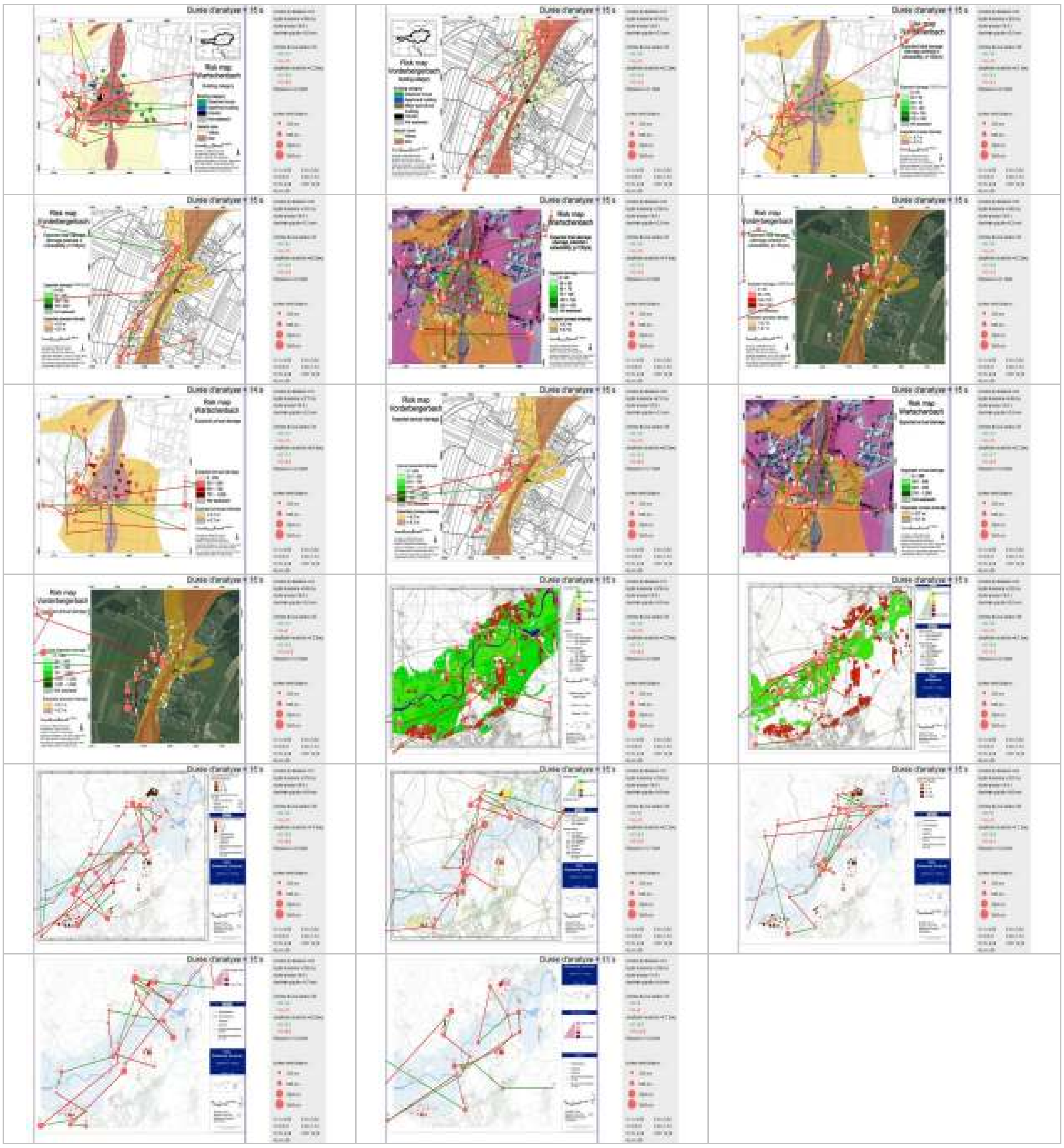
SPACHINGER Karl



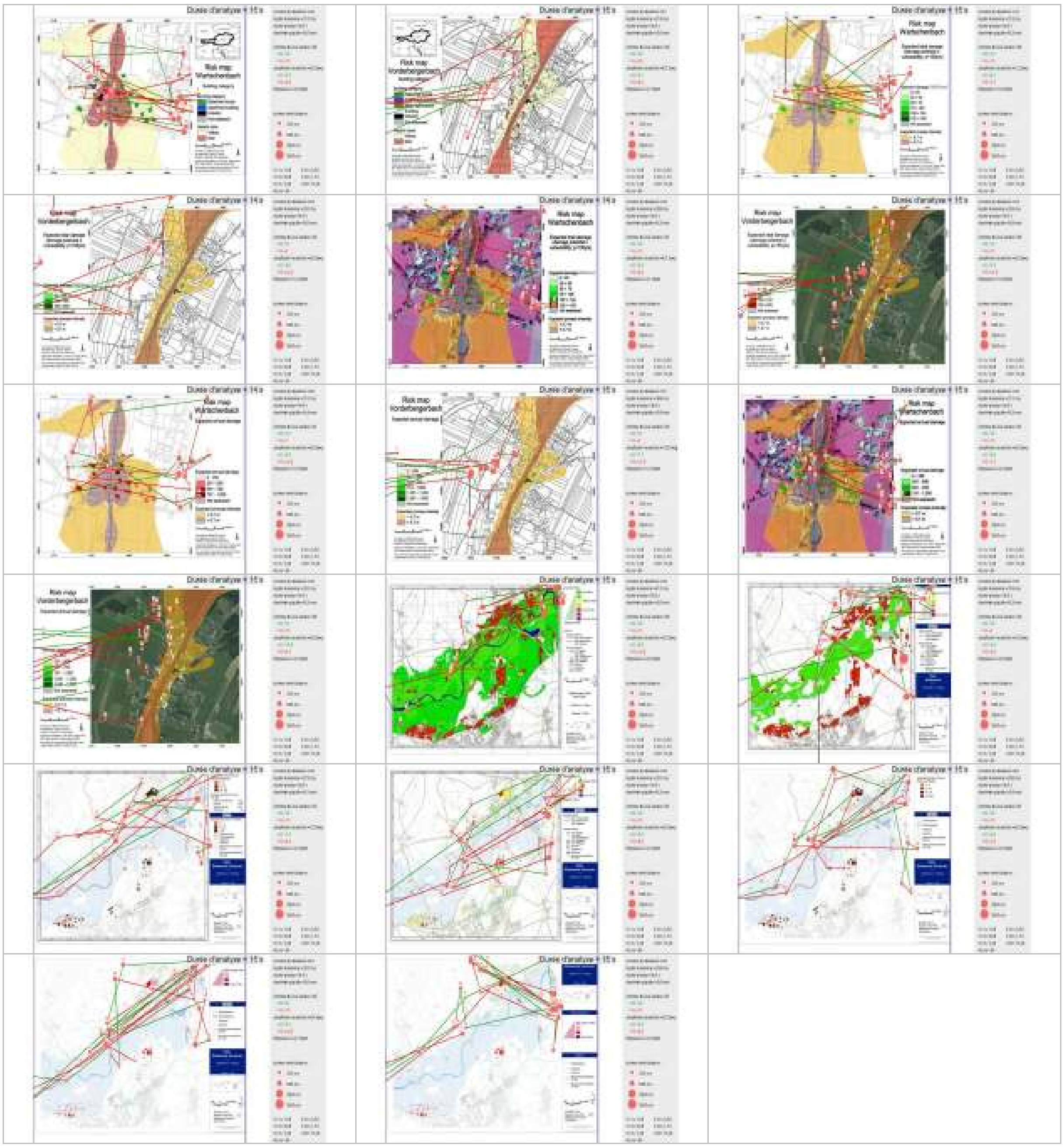
HEINDL Gabriele



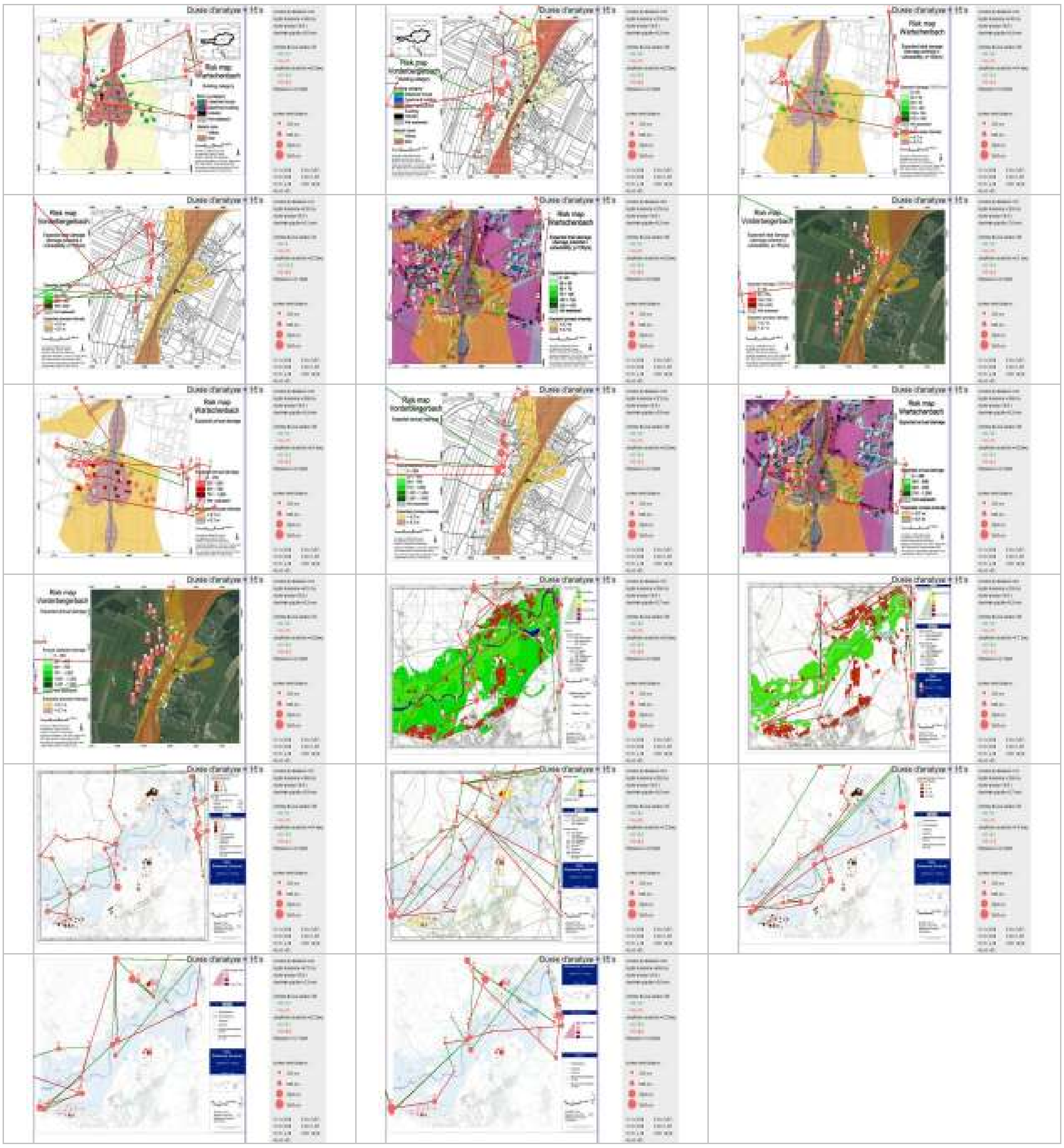
ERTL Maximilian



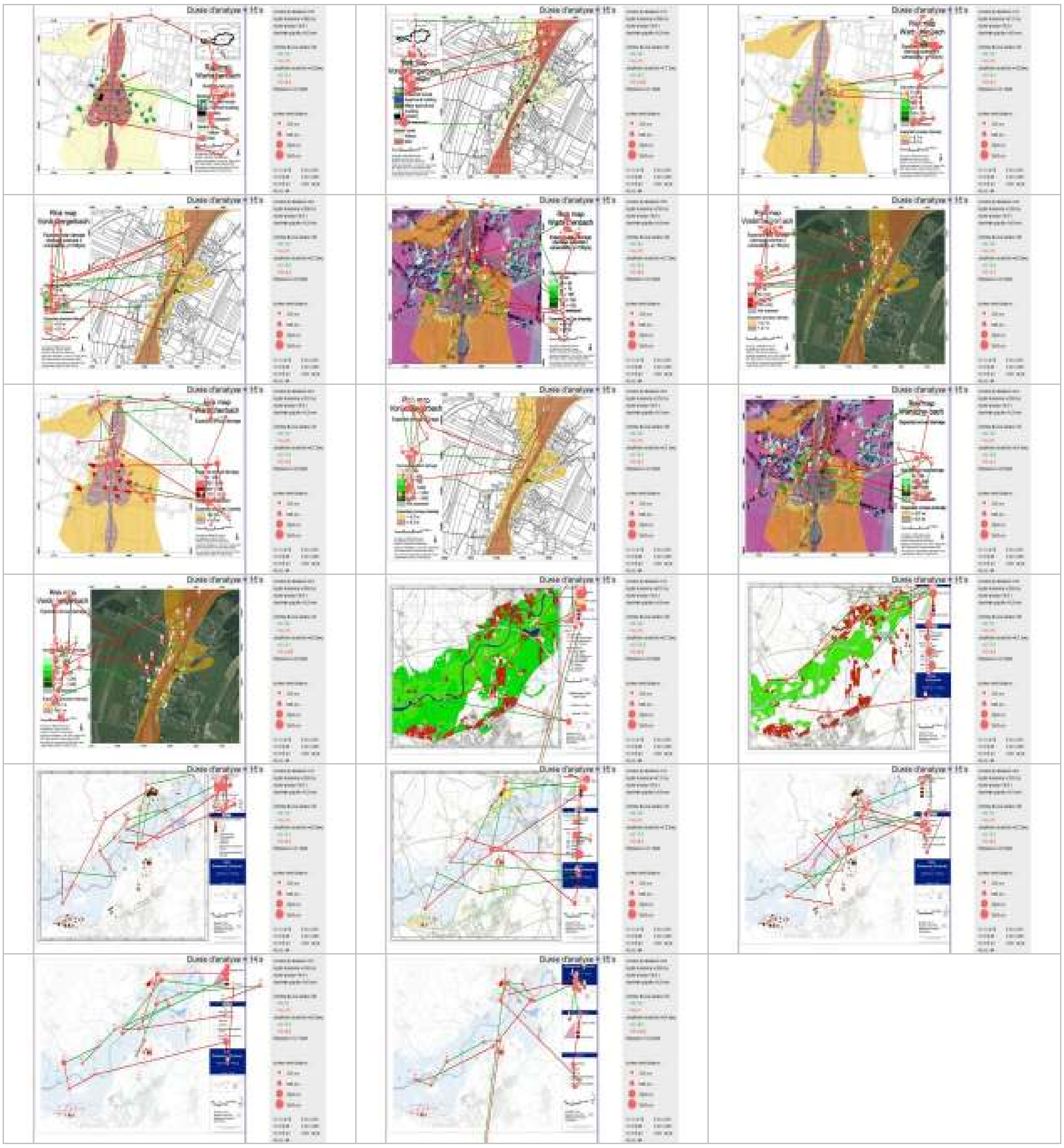
PANZIRSCH Michele



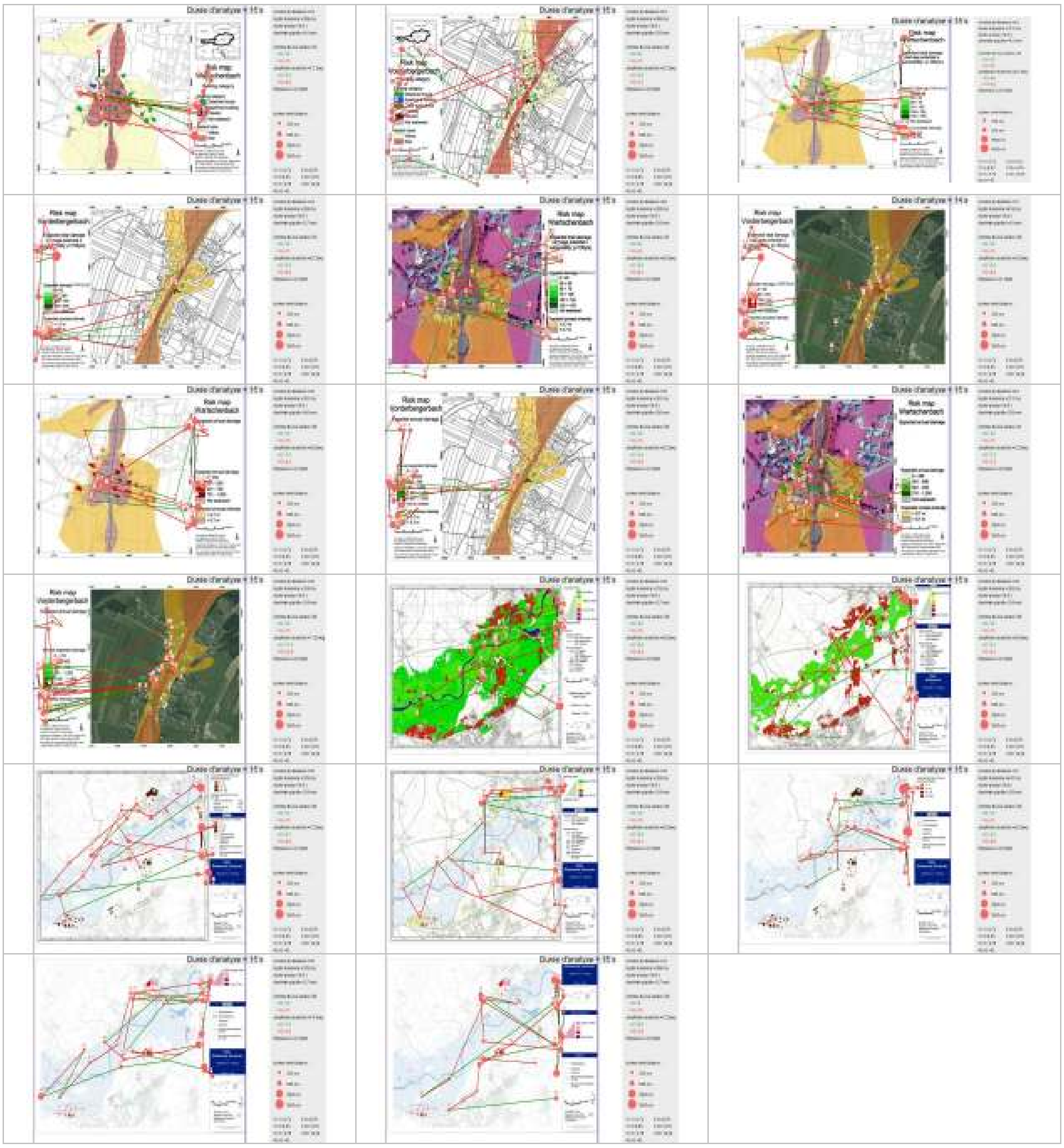
DORNER Wolfgang



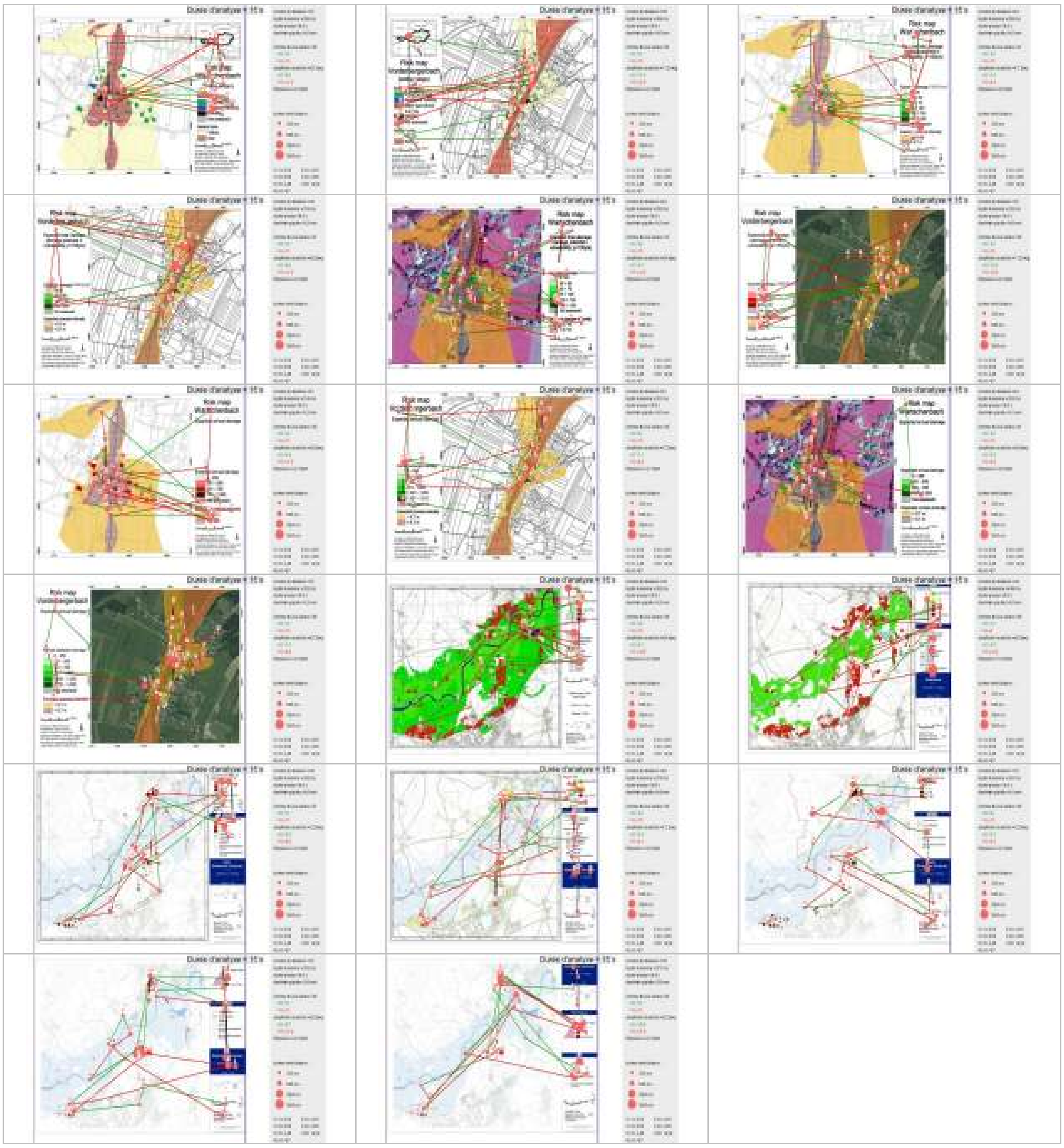
HAGEMEIER Maria



MERZ Gabriele



SCHIESSL Werner



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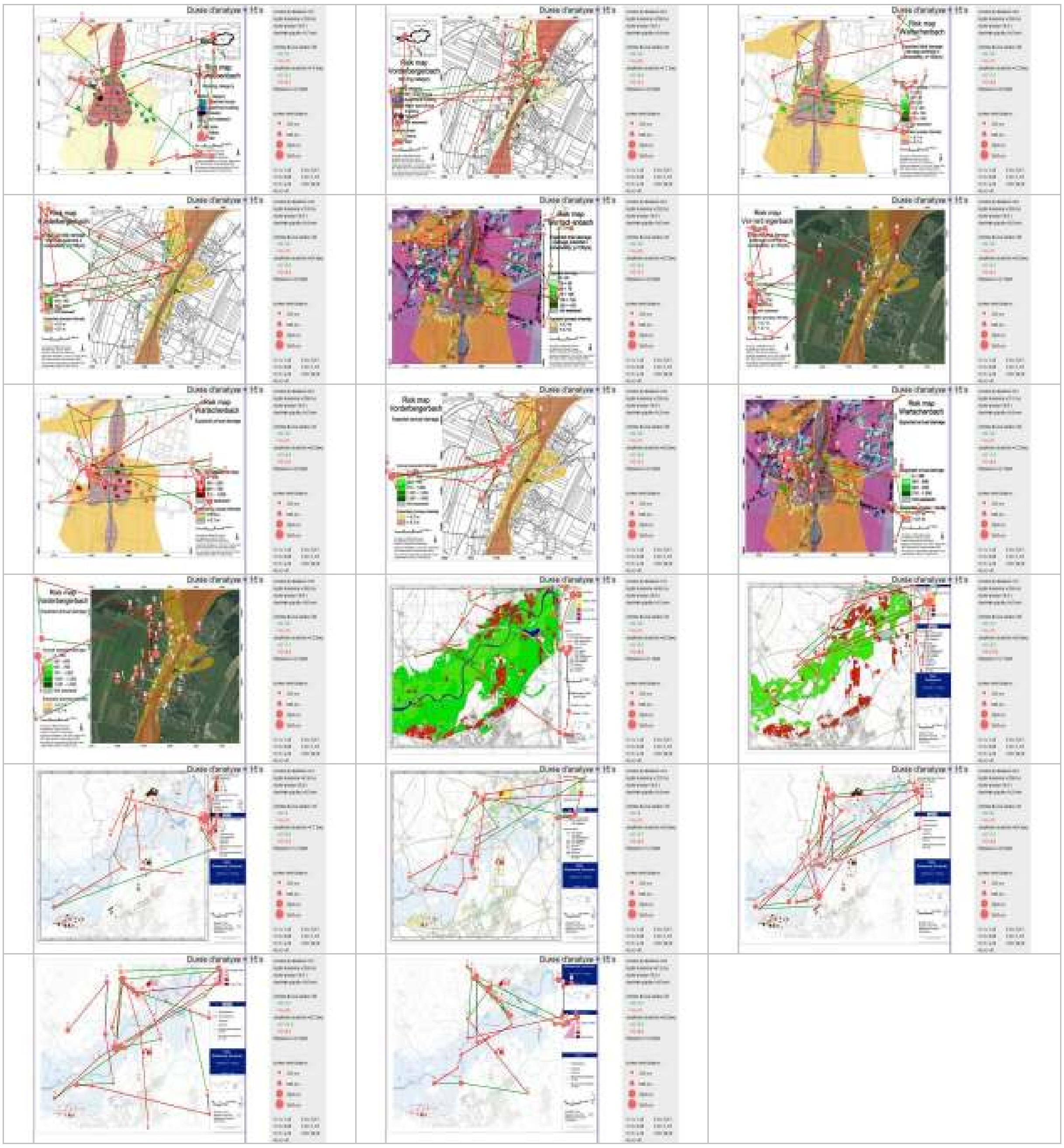
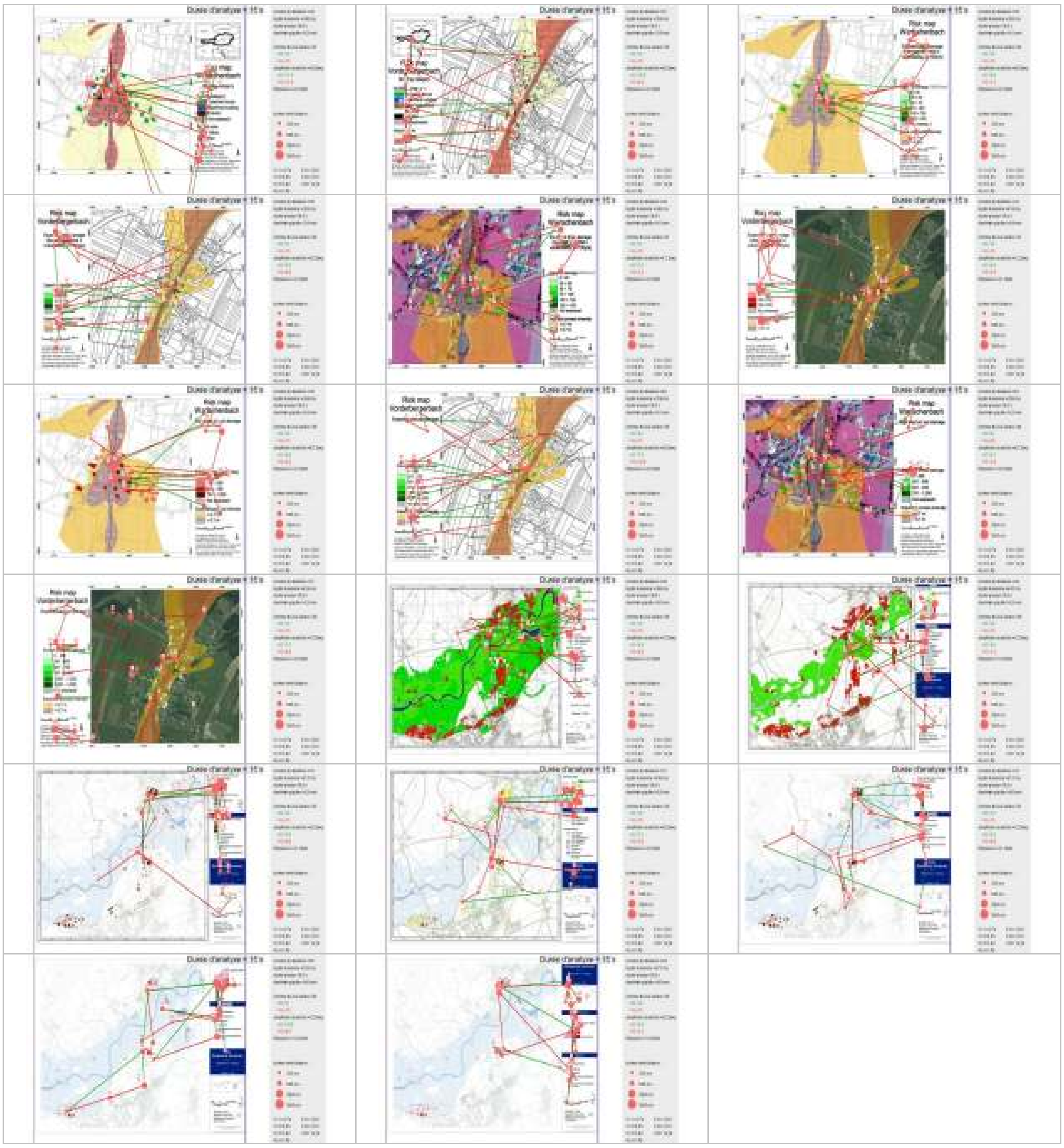
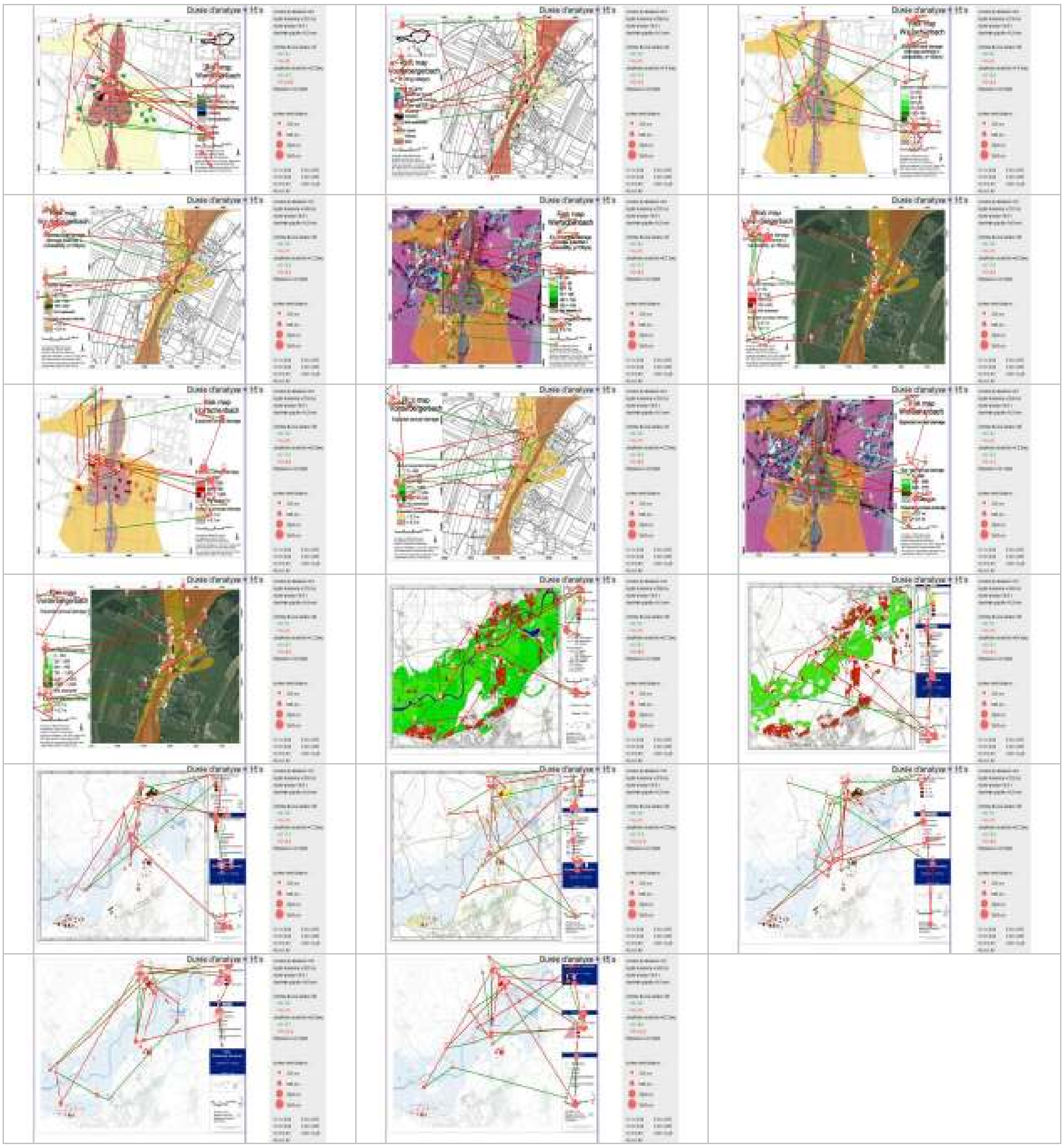


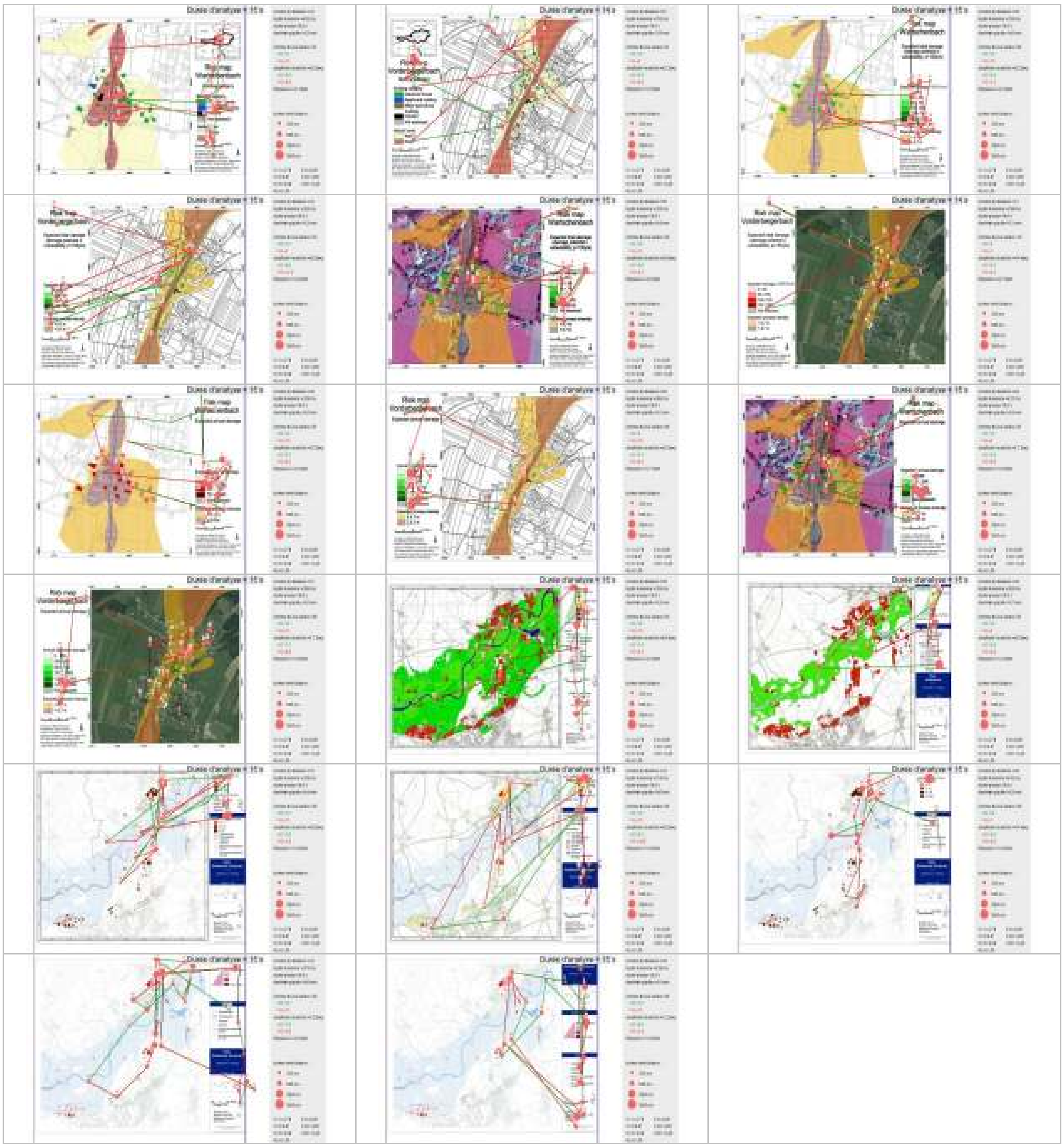
BAPTISTE Hervé



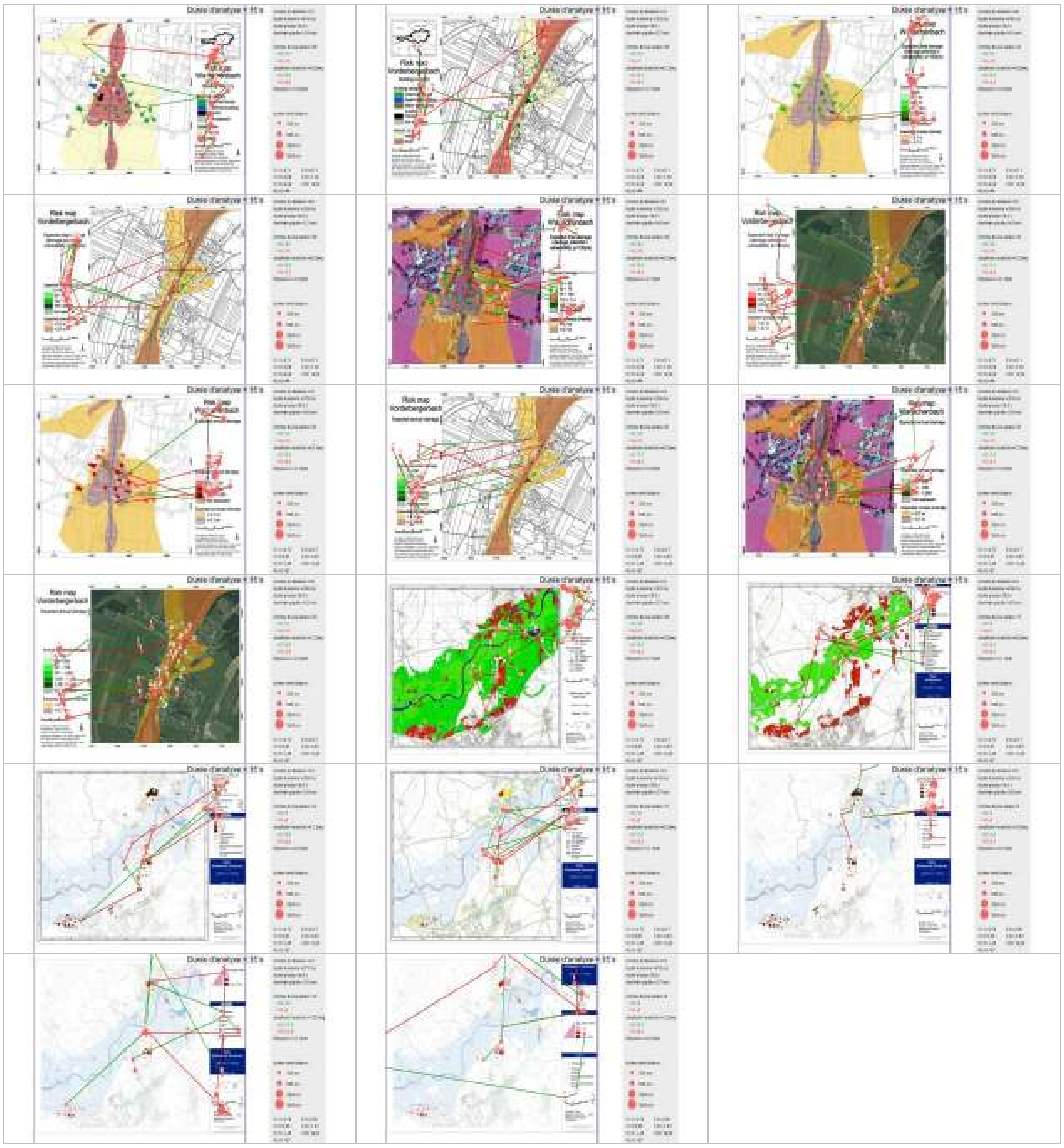
BOIS Nathalie



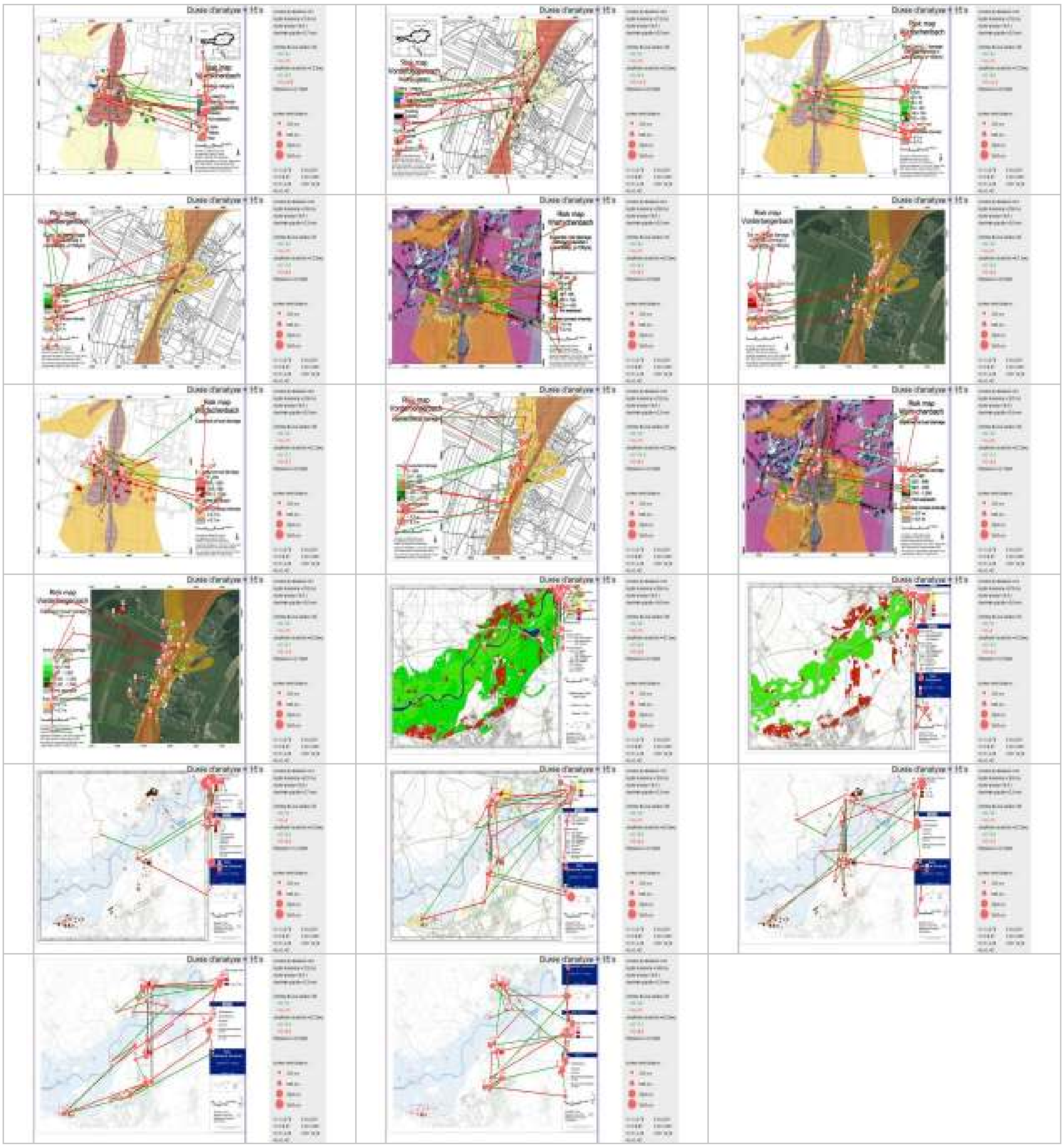
LARRIBE Sebastien



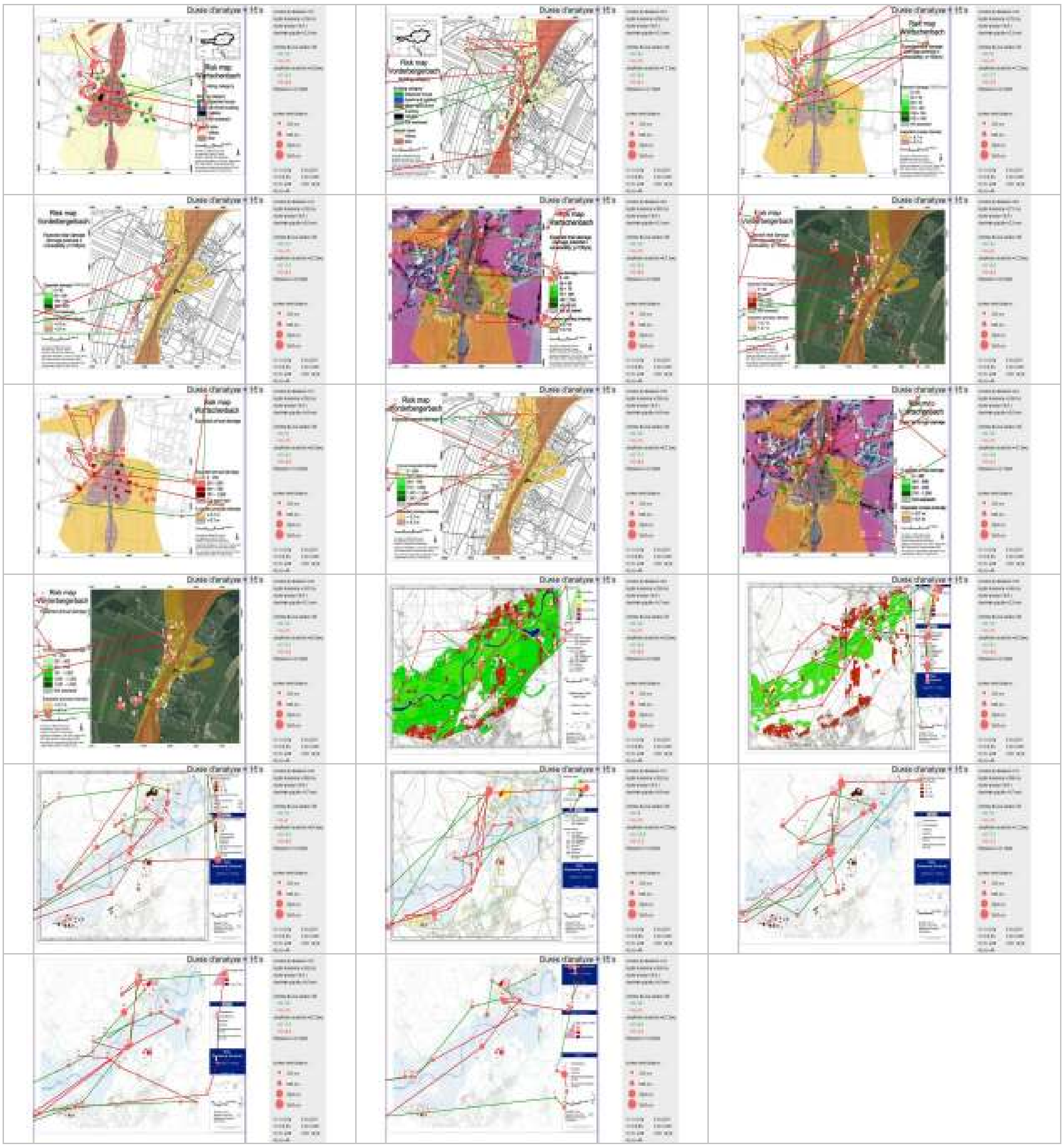
BUREL Béatrice



DUCROCQ Jessica

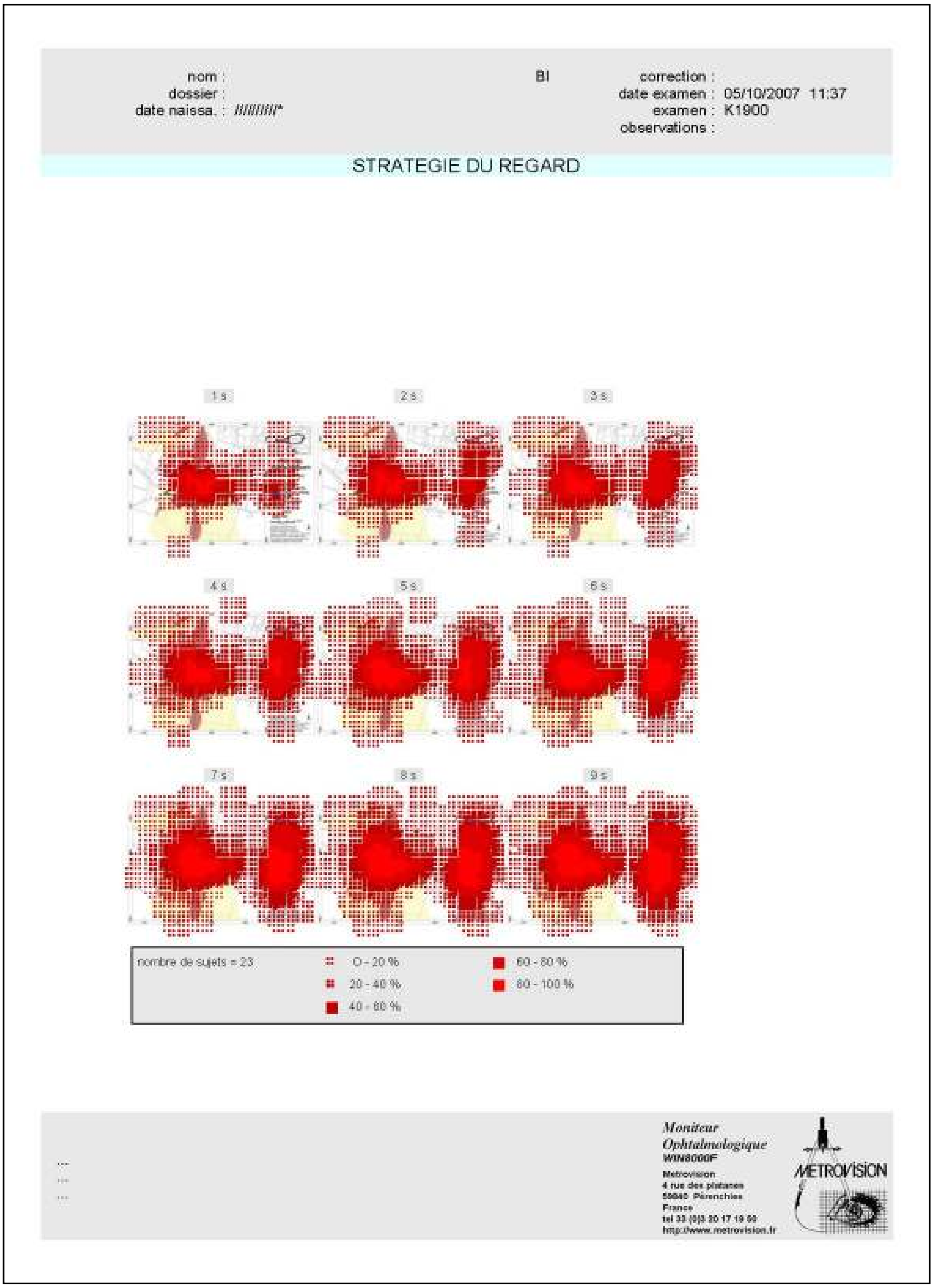


SELLAMI Lousia

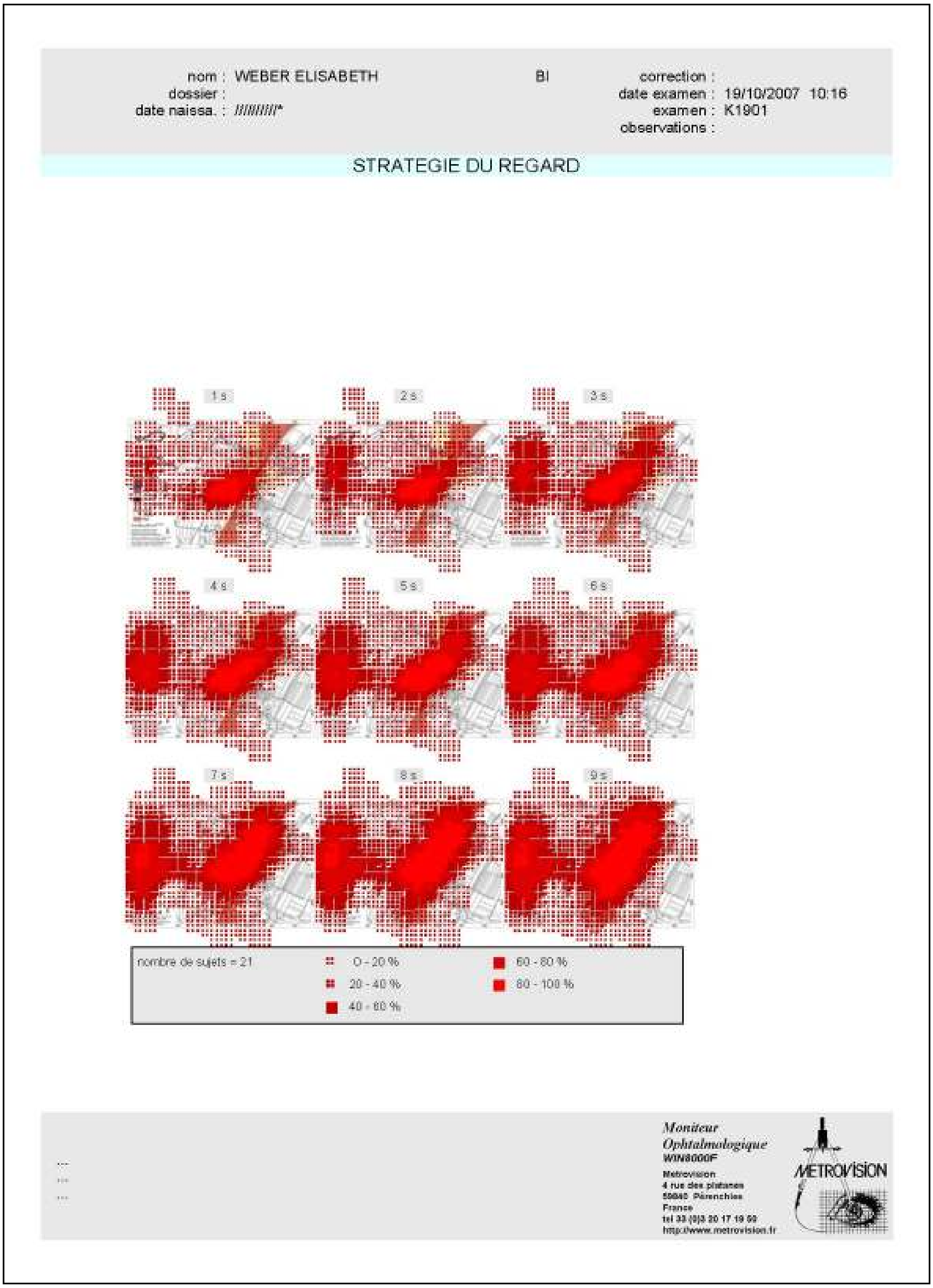


Results of dynamic analyses [%]

Map 1



Map 2


nom : WEBER ELISABETH
BI
dossier :
date naissa. : /////////*
correction :
date examen : 19/10/2007 10:16
examen : K1901
observations :
STRATEGIE DU REGARD
1 s
2 s
3 s
4 s
5 s
6 s
7 s
8 s
9 s
nombre de sujets = 21
0 - 20 %
20 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %
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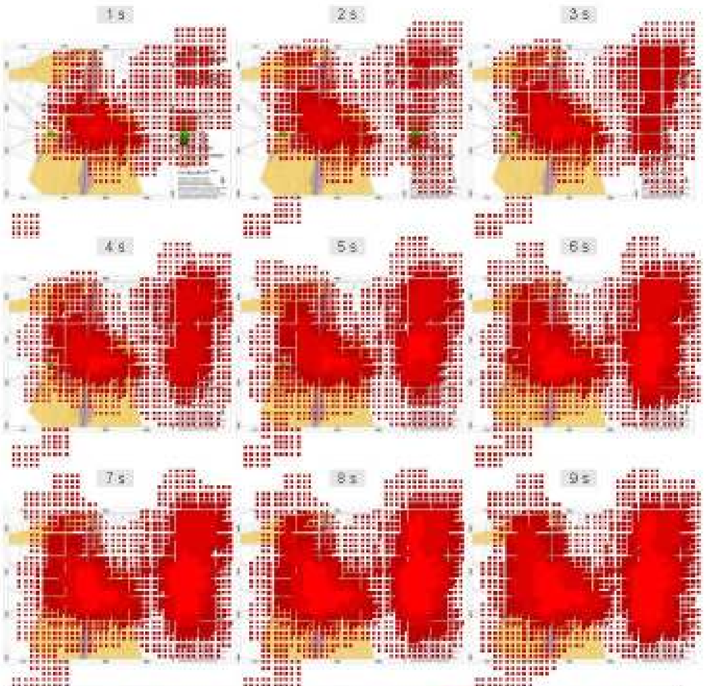
Map 3

nom : WEBER ELISABETH   BI   correction :
dossier :   date examen : 19/10/2007 10:19
date naissa. : //////////*   examen : K1902
observations :

STRATEGIE DU REGARD



nombre de sujets = 21   0 - 20 %   20 - 40 %   40 - 60 %   60 - 80 %   80 - 100 %

...
...
...

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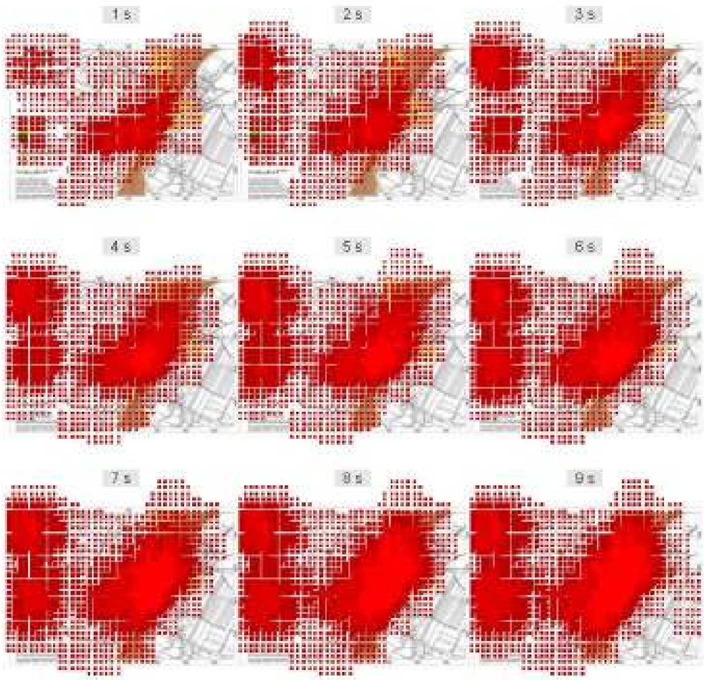
Map 4

nom : WEBER ELISABETH
dossier :
date naissa. : //////////*

BI

correction :
date examen : 19/10/2007 10:19
examen : K1903
observations :

STRATEGIE DU REGARD



nombre de sujets = 21	0 - 20 %	60 - 80 %
	20 - 40 %	80 - 100 %
	40 - 60 %	

...
...
...

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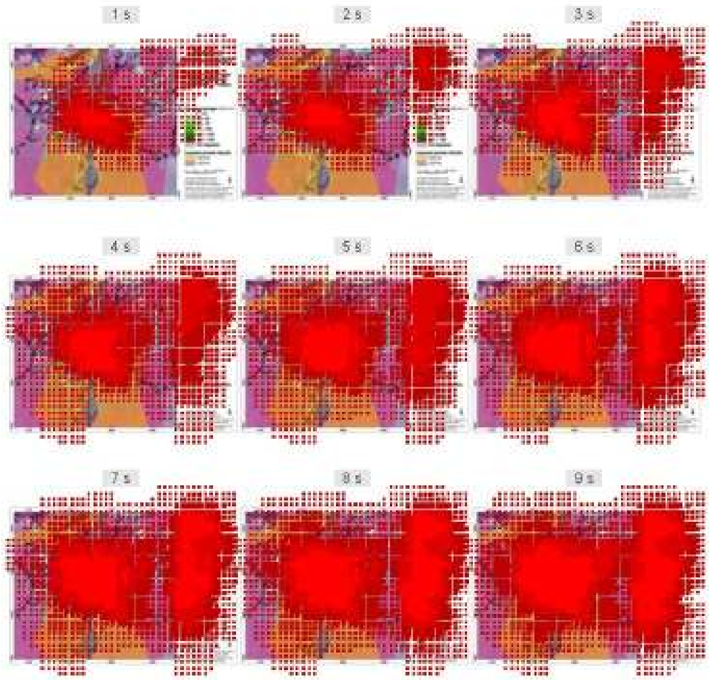
Map 5

nom : WEBER ELISABETH BI
dossier :
date naissa. : //////////*

correction :
date examen : 19/10/2007 10:20
examen : K1904
observations :

STRATEGIE DU REGARD



nombre de sujets = 21

- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

...
...
...

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Map 6

nom : WEBER ELISABETH

dossier :

date naissa. : /////////*

BI

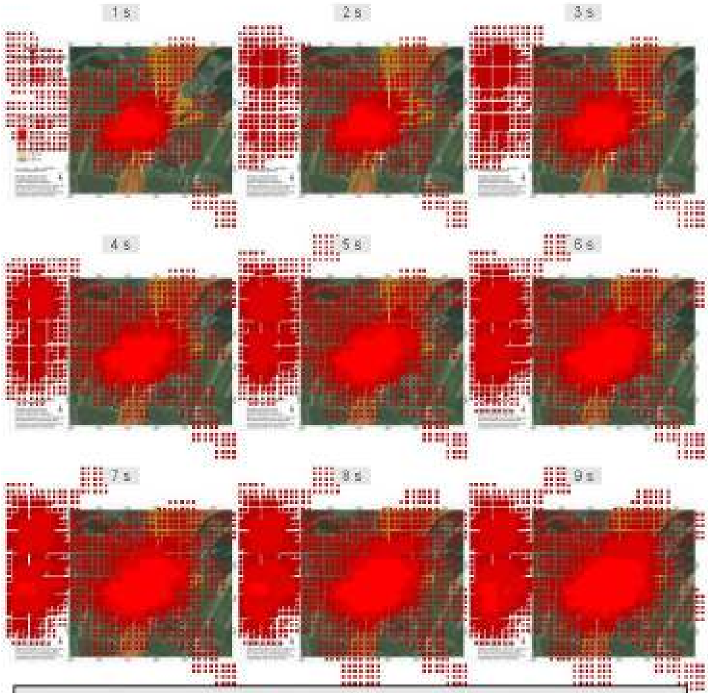
correction :

date examen : 19/10/2007 10:22

examen : K1905

observations :

STRATEGIE DU REGARD



nombre de sujets = 21

	0 - 20 %	60 - 80 %
	20 - 40 %	80 - 100 %
	40 - 60 %	

...
...
...

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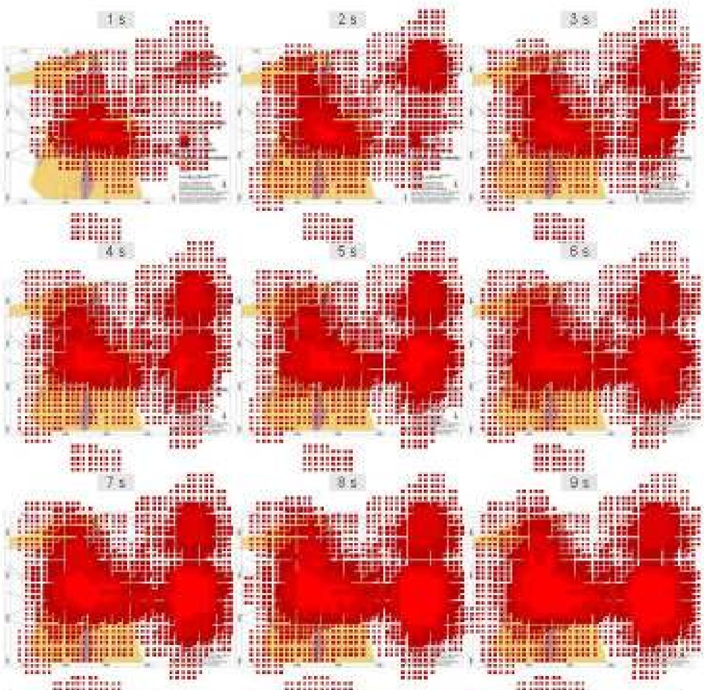
Map 7

nom : WEBER ELISABETH   BI
dossier :
date naissa. : //////////*

correction :
date examen : 19/10/2007 10:25
examen : K1906
observations :

STRATEGIE DU REGARD



nombre de sujets = 21
0 - 20 %
20 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %

...
...
...

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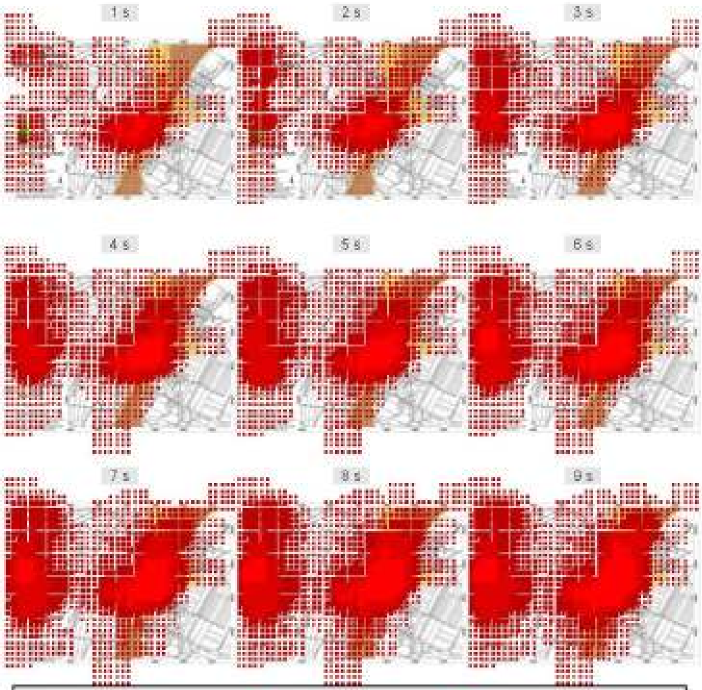
Map 8

nom : WEBER ELISABETH BI
dossier :
date naissa. : //////////*

correction :
date examen : 19/10/2007 10:26
examen : K1907
observations :

STRATEGIE DU REGARD



nombre de sujets = 21
O - 20 %
20 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %

...
...
...

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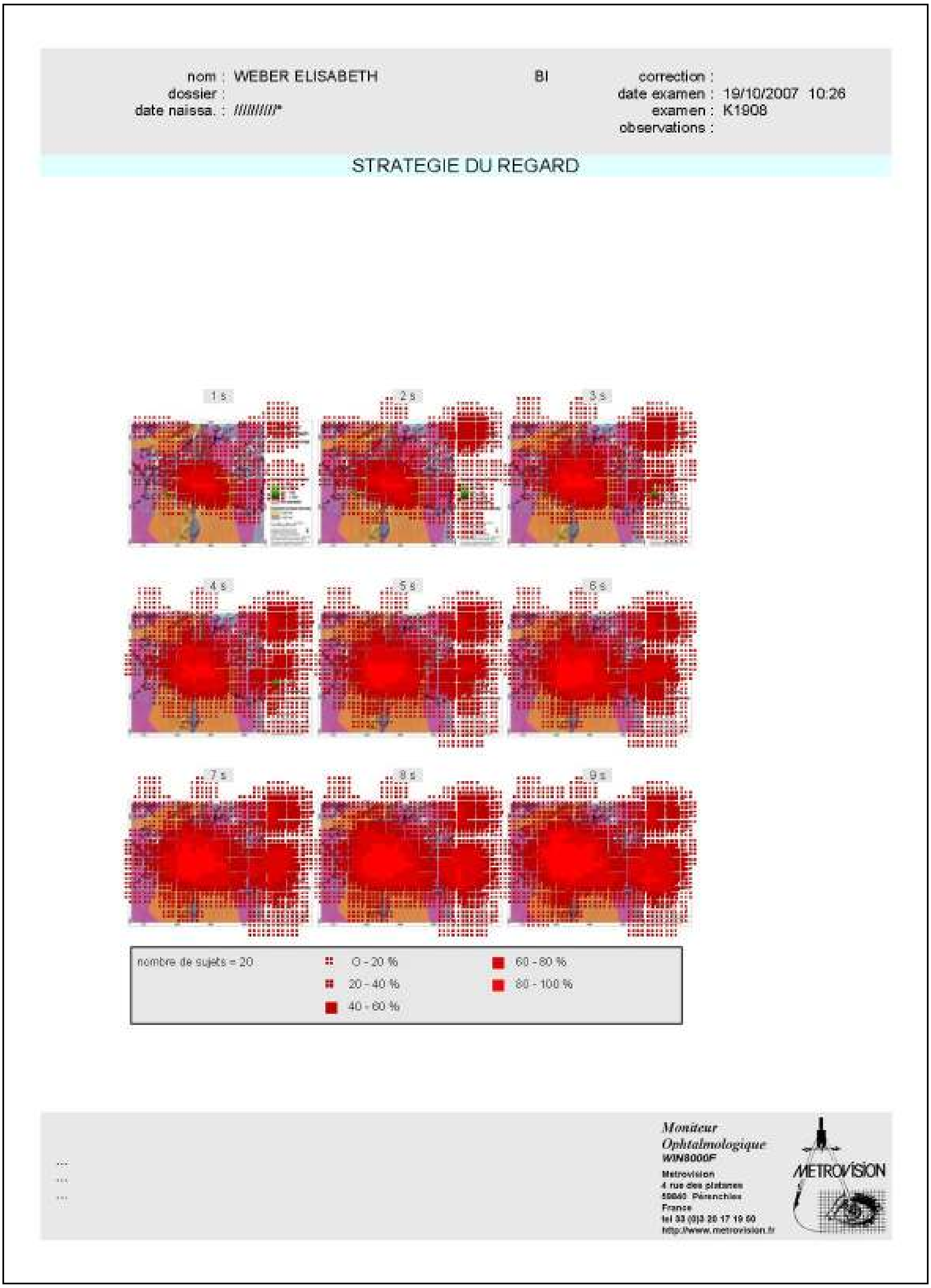
Map 9


nom : WEBER ELISABETH
BI
dossier :
date naissa. : /////////*
correction :
date examen : 19/10/2007 10:26
examen : K1908
observations :
STRATEGIE DU REGARD
1 s
2 s
3 s
4 s
5 s
6 s
7 s
8 s
9 s
nombre de sujets = 20
0 - 20 %
20 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %
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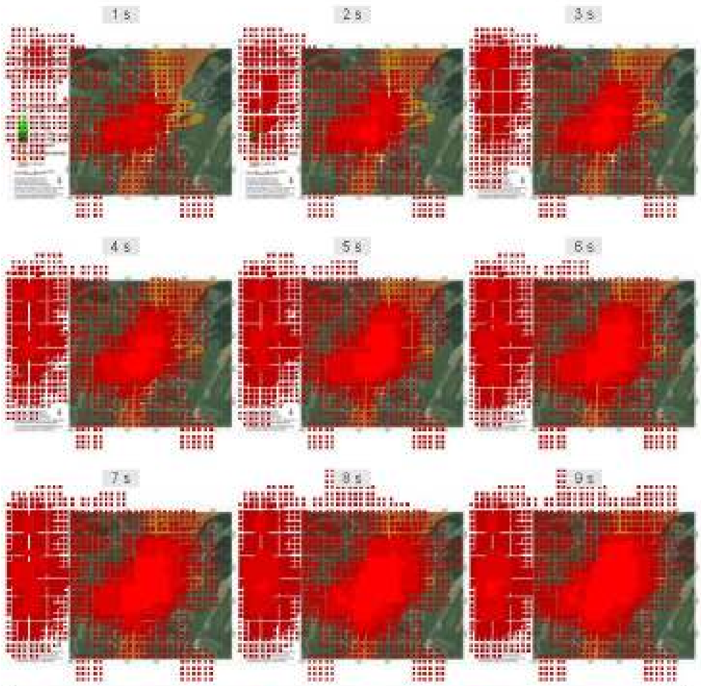
METROVISION

Map 10

nom : WEBER ELISABETH   BI   correction :
dossier :   date examen : 19/10/2007 10:27
date naissa. : //////////*   examen : K1909
observations :

STRATEGIE DU REGARD



nombre de sujets = 21
0 - 20 %
20 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %

...
...
...

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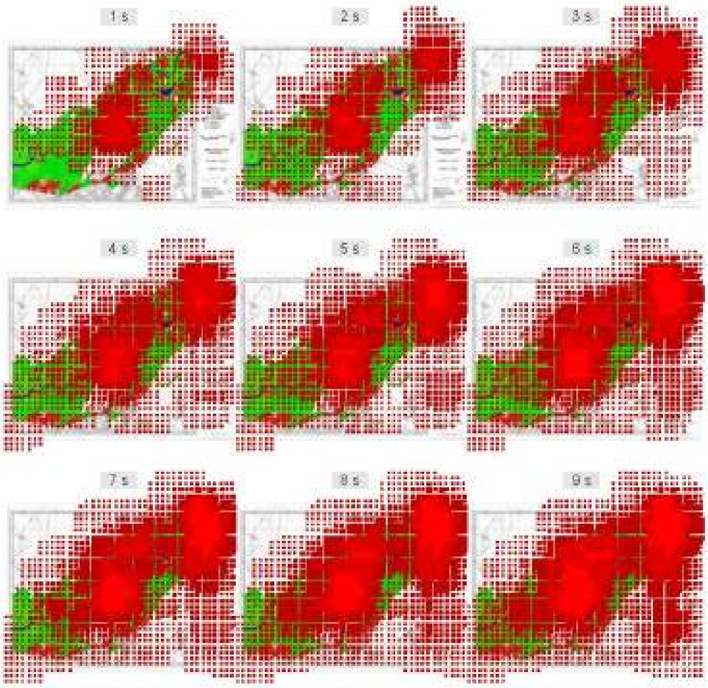
Map 11

nom :
dossier :
date naissa. : //////////*

BI

correction :
date examen : 05/10/2007 15:30
examen : K1910
observations :

STRATEGIE DU REGARD



nombre de sujets = 22

0 - 20 %
20 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %

...
...
...

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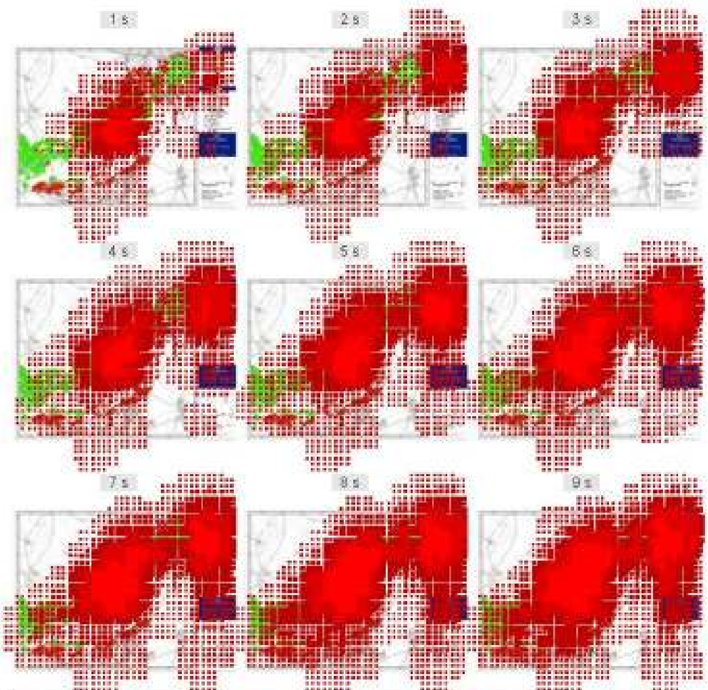
Map 12

nom : WEBER ELISABETH   BI
dossier :
date naissa. : /////////*

correction :
date examen : 19/10/2007 10:30
examen : K1911
observations :

STRATEGIE DU REGARD



nombre de sujets = 22
O - 20 %
20 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %

...
...
...

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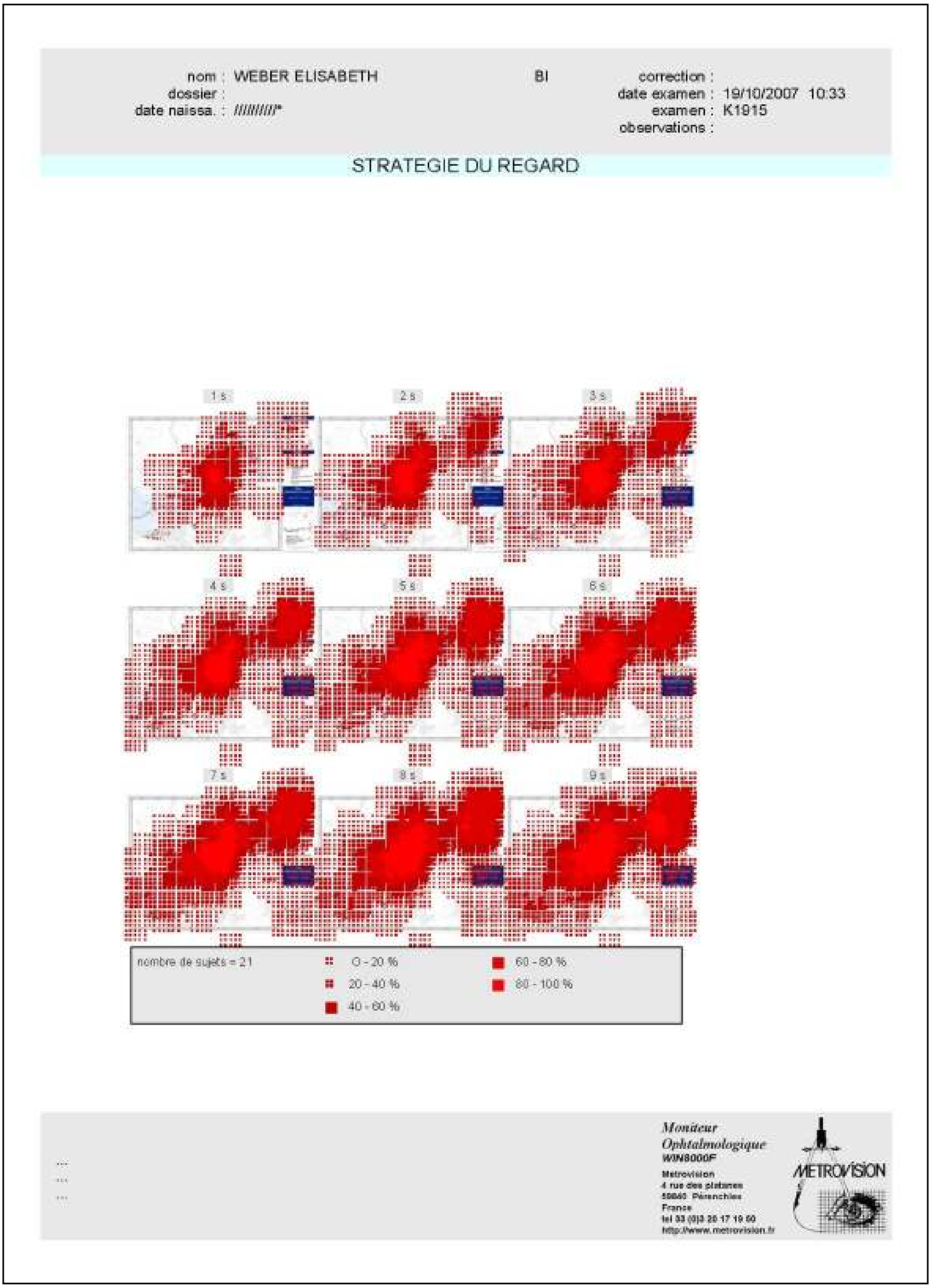
Map 13


nom : WEBER ELISABETH
dossier :
date naissa. : /////////*
BI
correction :
date examen : 19/10/2007 10:33
examen : K1915
observations :
STRATEGIE DU REGARD
1 s
2 s
3 s
4 s
5 s
6 s
7 s
8 s
9 s
nombre de sujets = 21
0 - 20 %
20 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %
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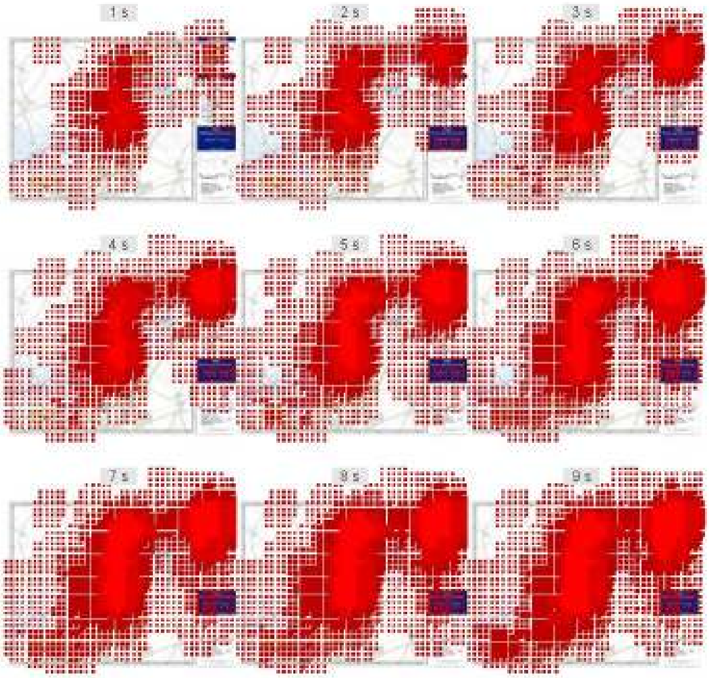
Map 14

nom : WEBER ELISABETH
dossier :
date naissa. : //////////*

BI

correction :
date examen : 19/10/2007 10:35
examen : K1916
observations :

STRATEGIE DU REGARD



nombre de sujets = 21

- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

...
...
...

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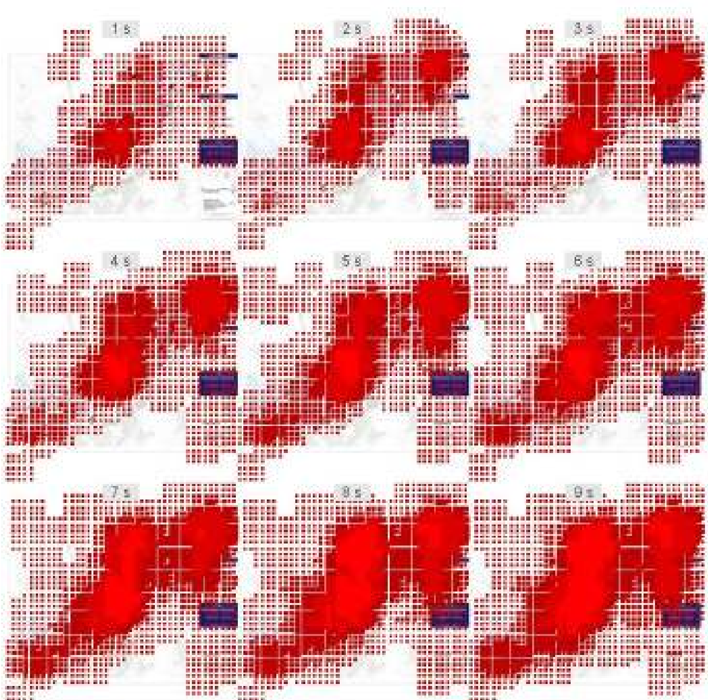
Map 15

nom : WEBER ELISABETH BI
dossier :
date naissa. : /////////*

correction :
date examen : 19/10/2007 10:35
examen : K1917
observations :

STRATEGIE DU REGARD



nombre de sujets = 21

0 - 20 %
20 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %

...
...
...

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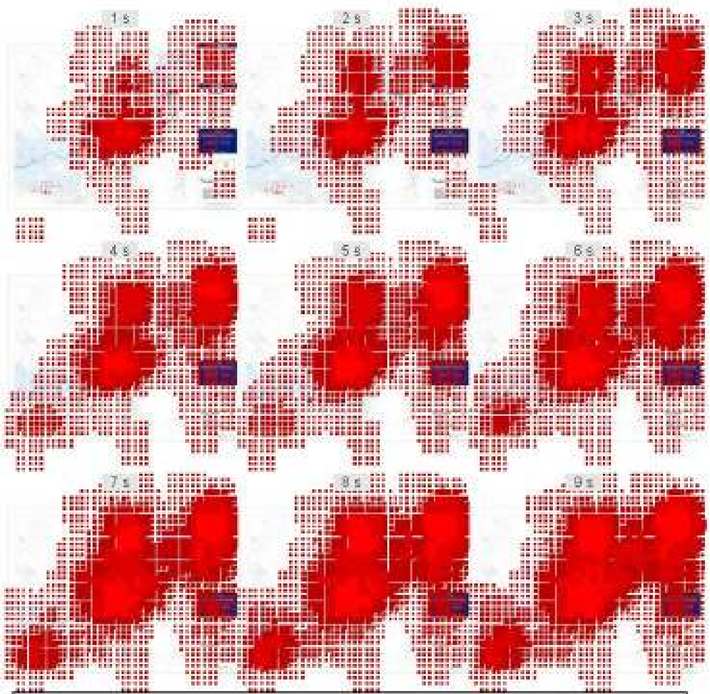
Map 16

nom : WEBER ELISABETH BI
dossier :
date naissa. : /////////*

correction :
date examen : 19/10/2007 10:36
examen : K1918
observations :

STRATEGIE DU REGARD



nombre de sujets = 21	0 - 20 %	60 - 80 %
	20 - 40 %	80 - 100 %
	40 - 60 %	

...
...
...

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METROVISION

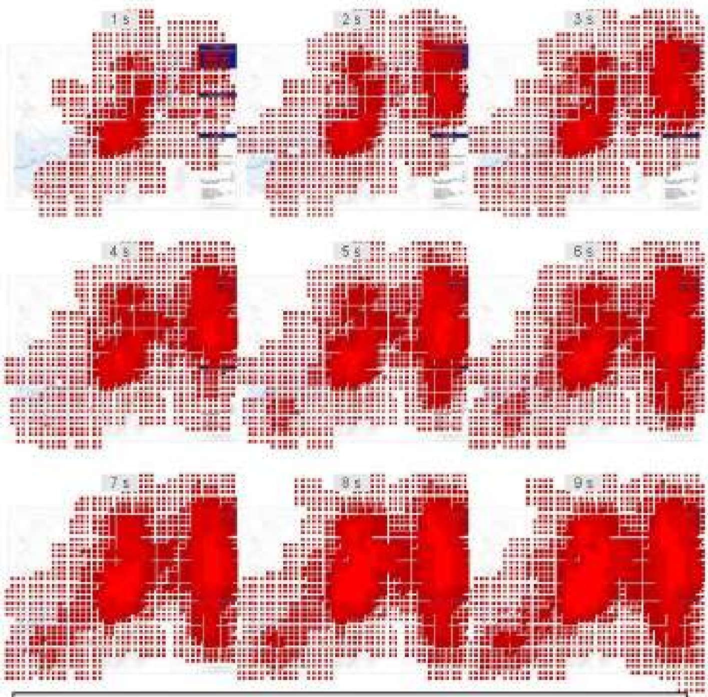
Map 17

nom : WEBER ELISABETH
dossier :
date naissa. : /////////*

BI

correction :
date examen : 19/10/2007 10:37
examen : K1920
observations :

STRATEGIE DU REGARD



nombre de sujets = 21

- 0 - 20 %
- 20 - 40 %
- 40 - 60 %
- 60 - 80 %
- 80 - 100 %

...
...
...

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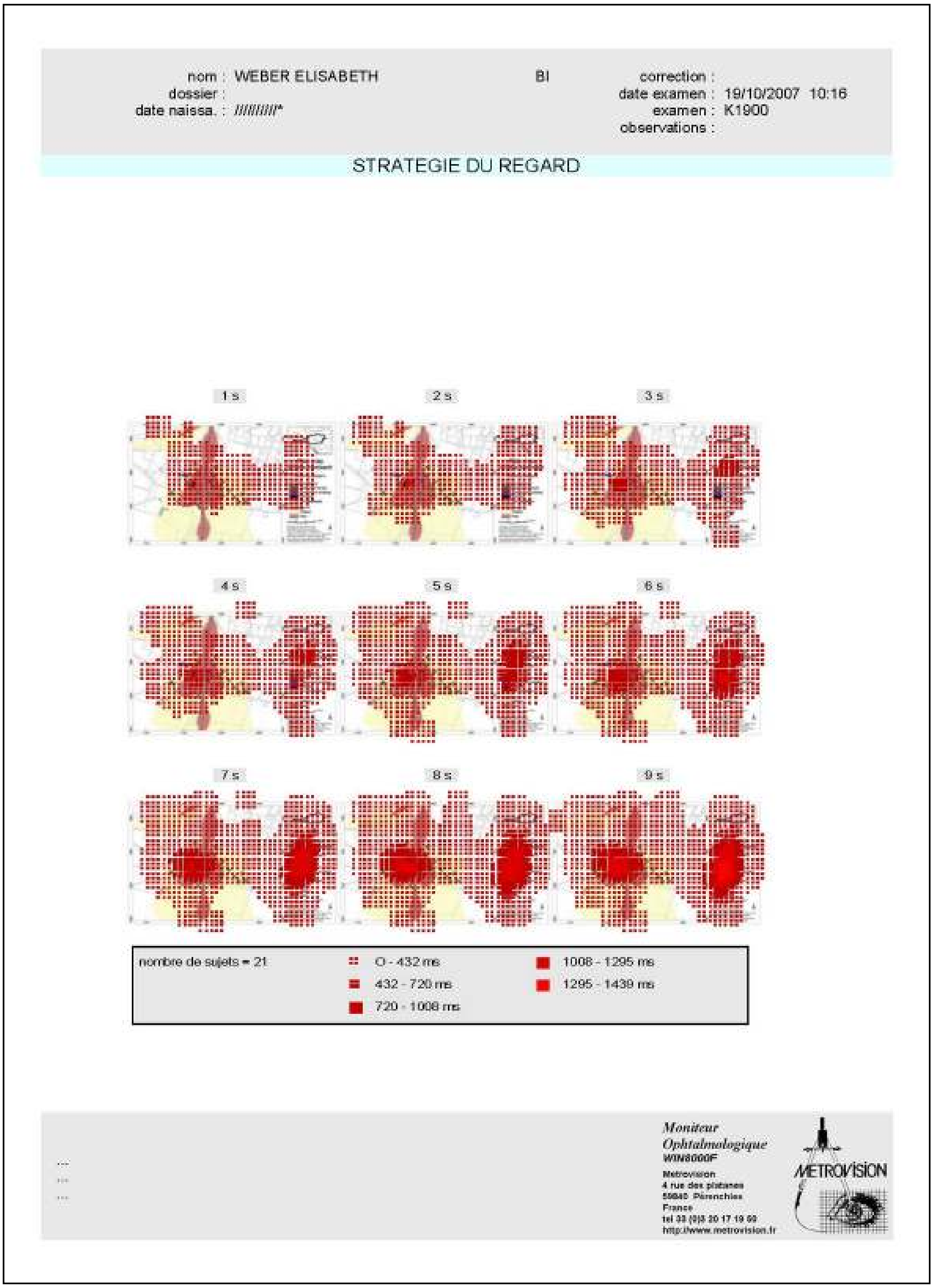
Results of dynamic analyses [ms]

Map 1

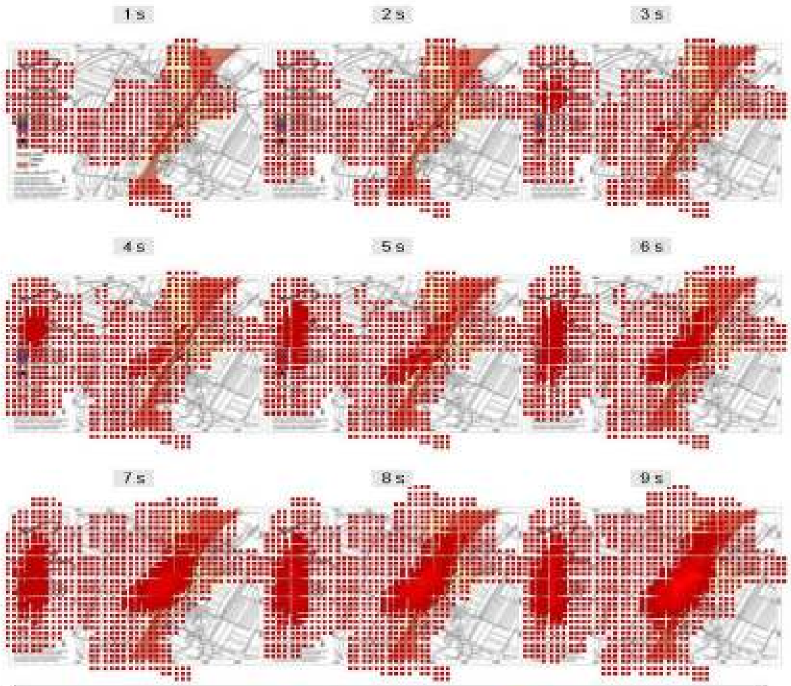


Map 2

nom : WEBER ELISABETH BI
dossier :
date naissa. : //////////*

correction :
date examen : 19/10/2007 10:16
examen : K1901
observations :

STRATEGIE DU REGARD



nombre de sujets = 21

- 0 - 314 ms
- 314 - 524 ms
- 524 - 734 ms
- 734 - 943 ms
- 943 - 1048 ms

...
...
...

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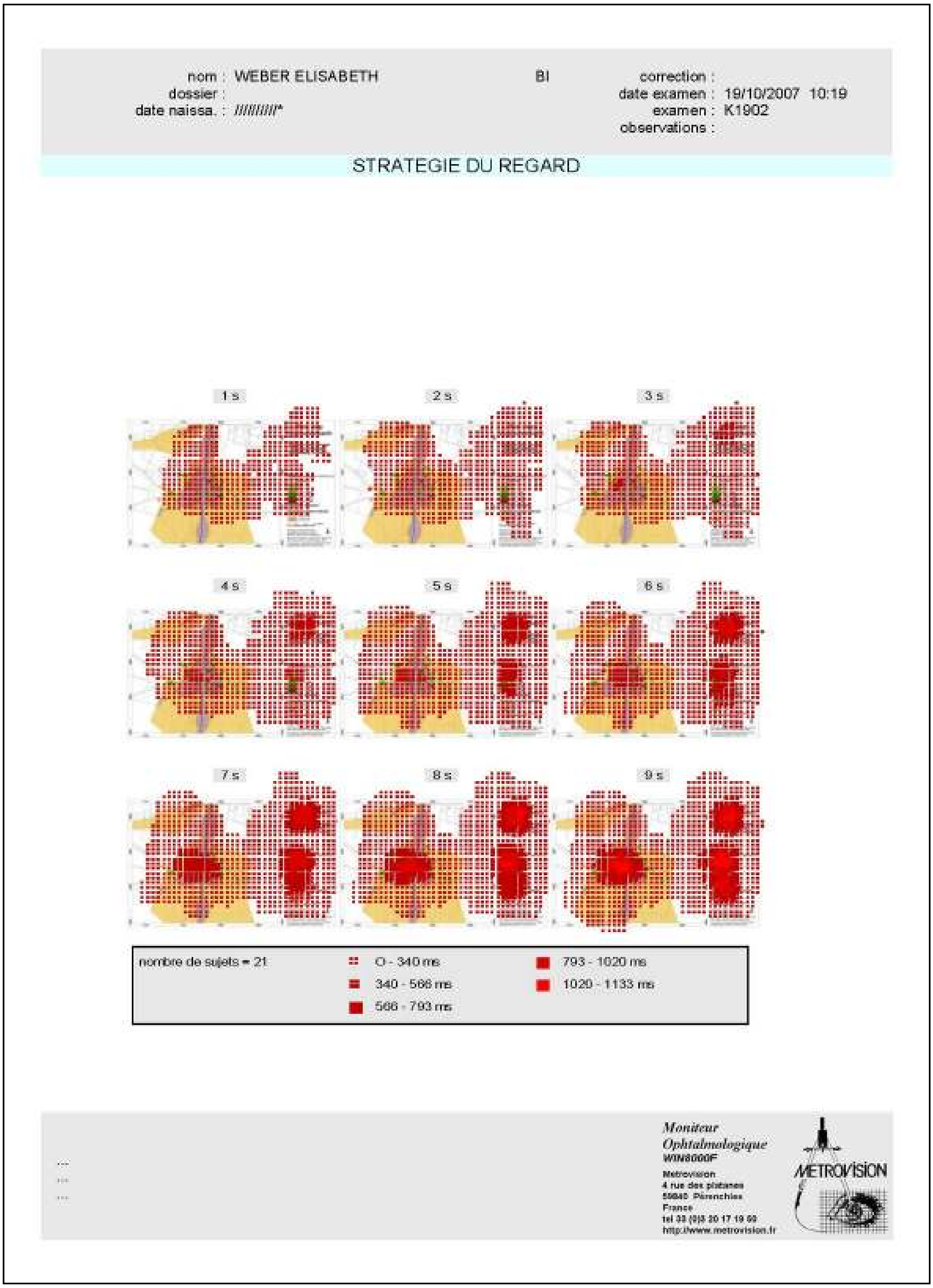
Map 3


nom : WEBER ELISABETH
BI
dossier :
date naissa. : //////////*
correction :
date examen : 19/10/2007 10:19
examen : K1902
observations :
STRATEGIE DU REGARD
1 s
2 s
3 s
4 s
5 s
6 s
7 s
8 s
9 s
nombre de sujets = 21
O - 340 ms
340 - 566 ms
566 - 793 ms
793 - 1020 ms
1020 - 1133 ms
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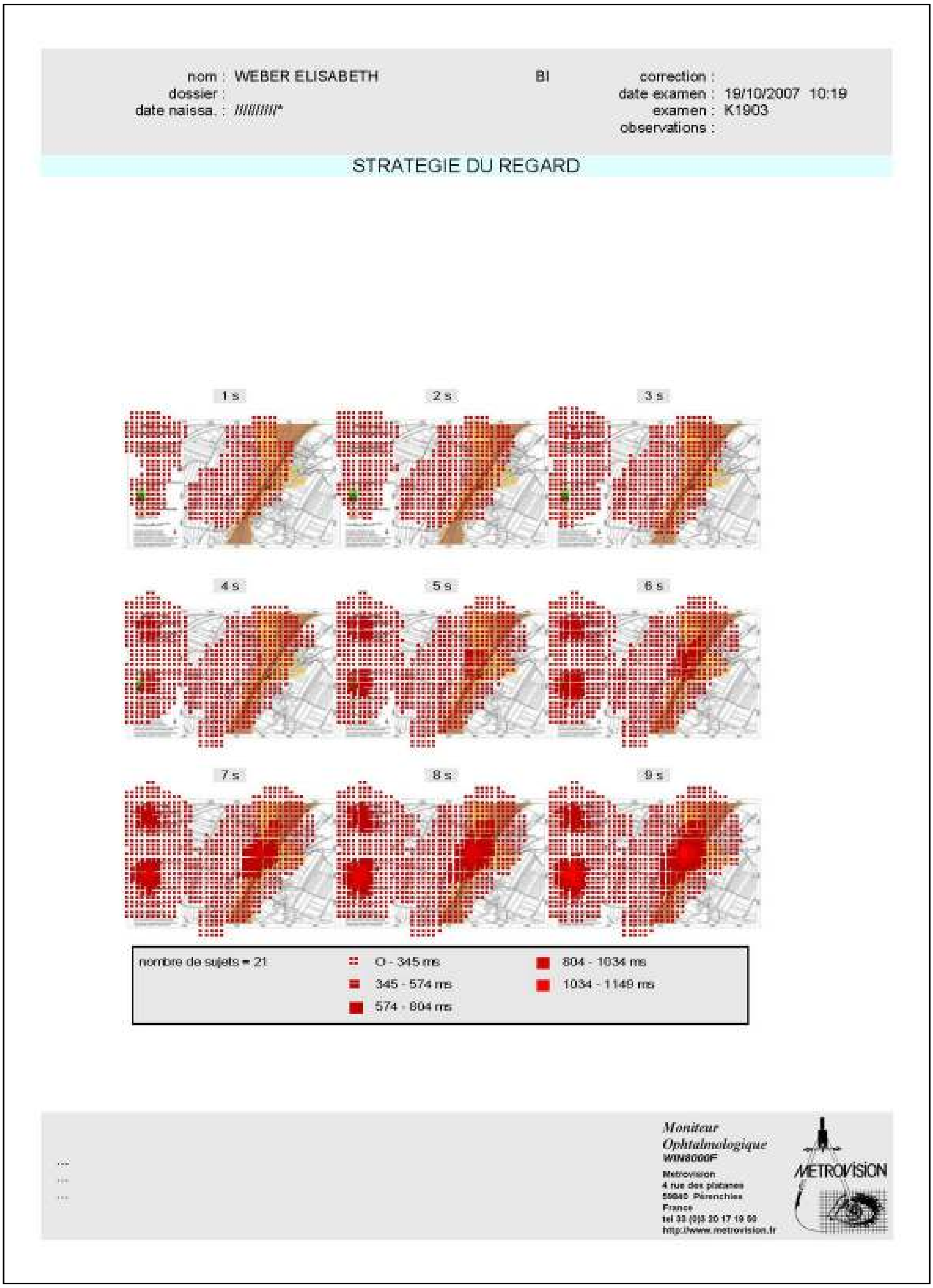
Map 4


nom : WEBER ELISABETH
dossier :
date naissa. : //////////*
BI
correction :
date examen : 19/10/2007 10:19
examen : K1903
observations :
STRATEGIE DU REGARD
1 s
2 s
3 s
4 s
5 s
6 s
7 s
8 s
9 s
nombre de sujets = 21
O - 345 ms
345 - 574 ms
574 - 804 ms
804 - 1034 ms
1034 - 1149 ms
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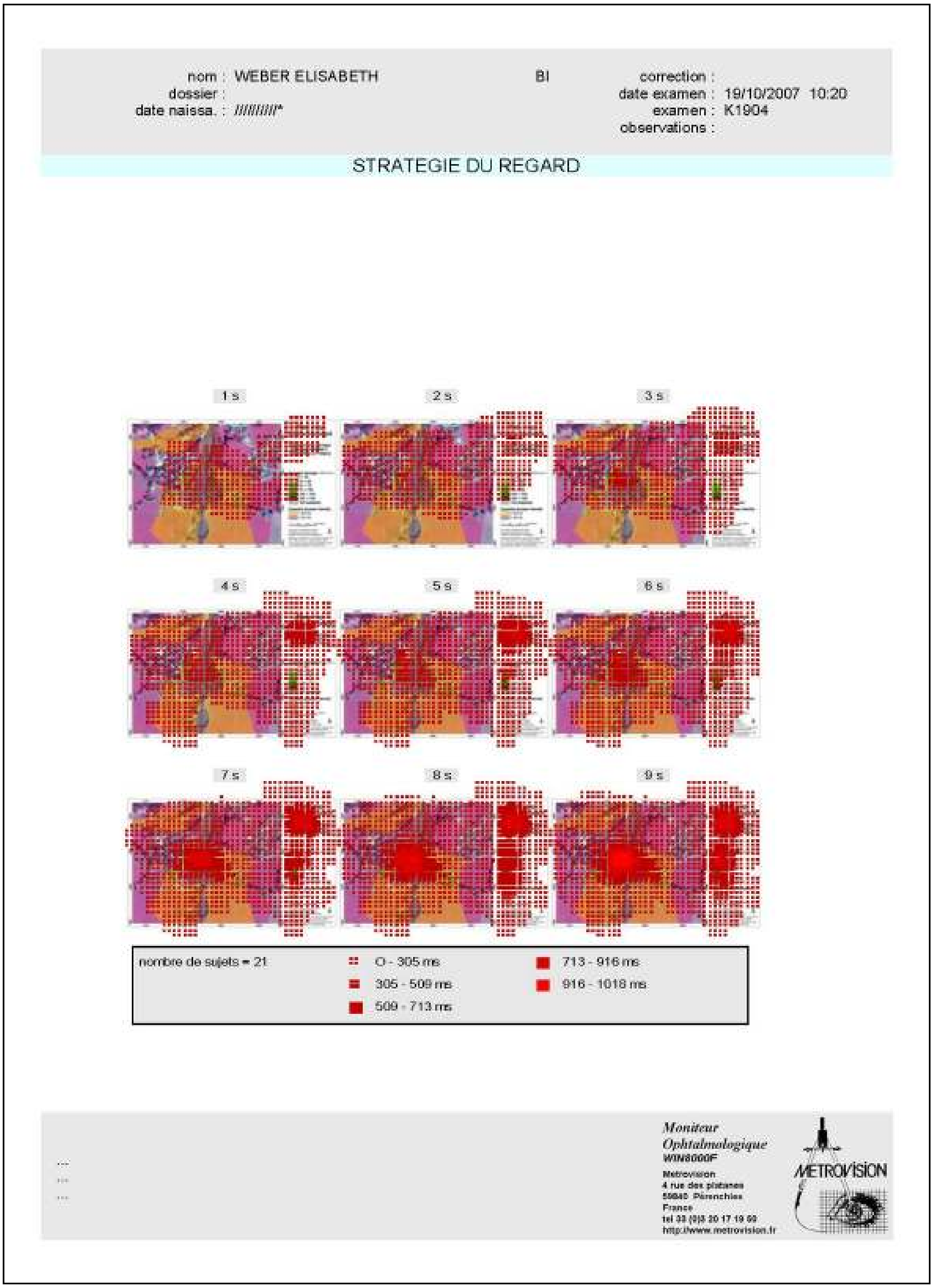
Map 5


nom : WEBER ELISABETH
dossier :
date naissa. : //////////*
BI
correction :
date examen : 19/10/2007 10:20
examen : K1904
observations :
STRATEGIE DU REGARD
1 s
2 s
3 s
4 s
5 s
6 s
7 s
8 s
9 s
nombre de sujets = 21
O - 305 ms
305 - 509 ms
509 - 713 ms
713 - 916 ms
916 - 1018 ms
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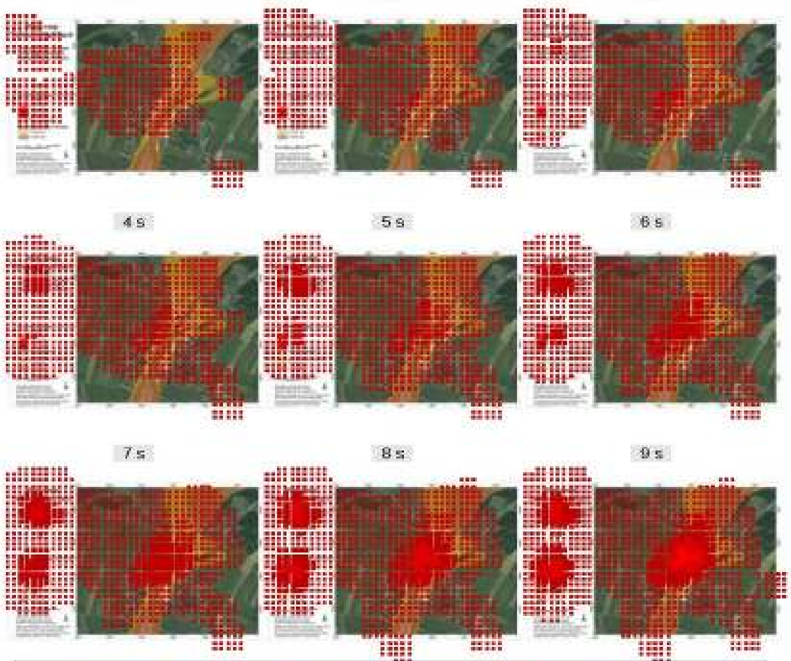
Map 6

nom : WEBER ELISABETH BI
dossier :
date naissa. : //////////*

correction :
date examen : 19/10/2007 10:22
examen : K1905
observations :

STRATEGIE DU REGARD



nombre de sujets = 21	O - 330 ms	769 - 989 ms
	330 - 549 ms	989 - 1098 ms
	549 - 769 ms	

...
...
...

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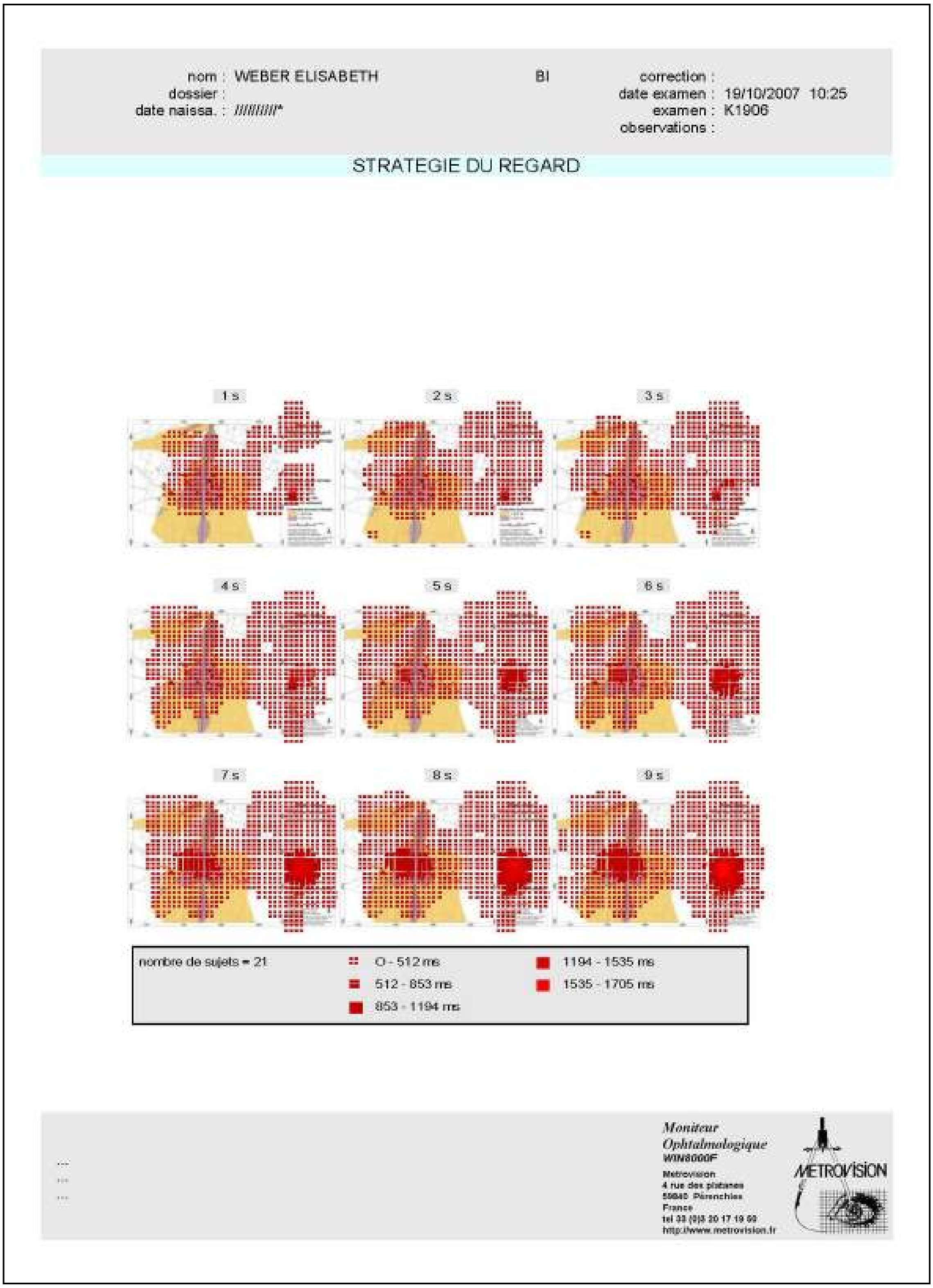
Map 7


nom : WEBER ELISABETH
dossier :
date naissa. : //////////*
BI
correction :
date examen : 19/10/2007 10:25
examen : K1906
observations :
STRATEGIE DU REGARD
1 s
2 s
3 s
4 s
5 s
6 s
7 s
8 s
9 s
nombre de sujets = 21
0 - 512 ms
512 - 853 ms
853 - 1194 ms
1194 - 1535 ms
1535 - 1705 ms
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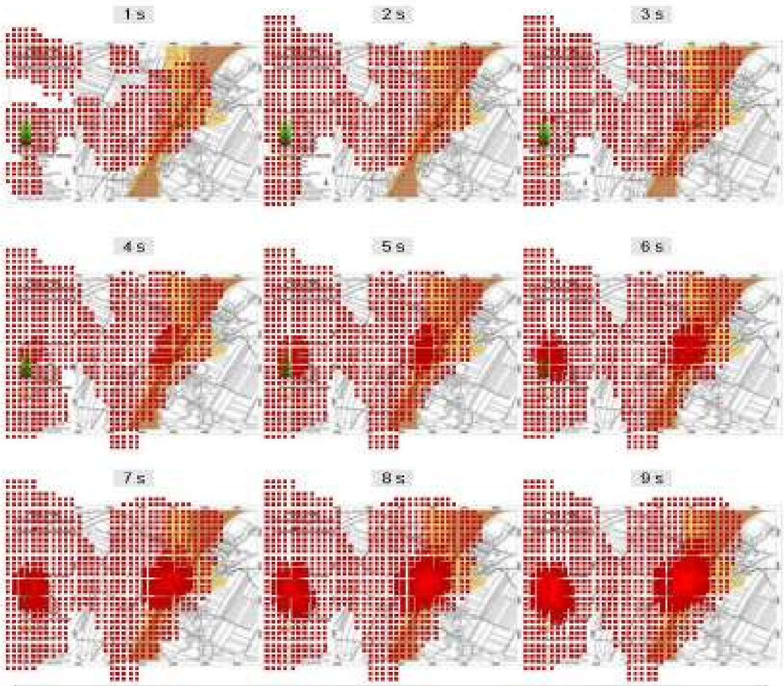
Map 8

nom : WEBER ELISABETH   BI
dossier :
date naissa. : ////////*

correction :
date examen : 19/10/2007 10:26
examen : K1907
observations :

STRATEGIE DU REGARD



nombre de sujets = 21

- 0 - 351 ms
- 351 - 585 ms
- 585 - 818 ms
- 818 - 1052 ms
- 1052 - 1169 ms

...
...
...

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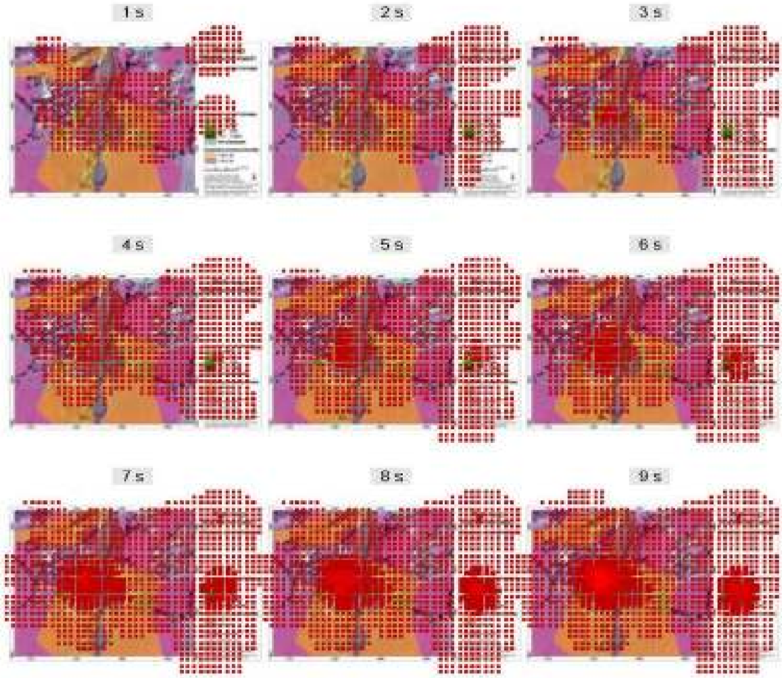
METROVISION

Map 9

nom : WEBER ELISABETH BI
dossier :
date naissa. : //////////*

correction :
date examen : 19/10/2007 10:26
examen : K1908
observations :

STRATEGIE DU REGARD



nombre de sujets = 21

- 0 - 389 ms
- 389 - 649 ms
- 649 - 909 ms
- 909 - 1168 ms
- 1168 - 1298 ms

...
...
...

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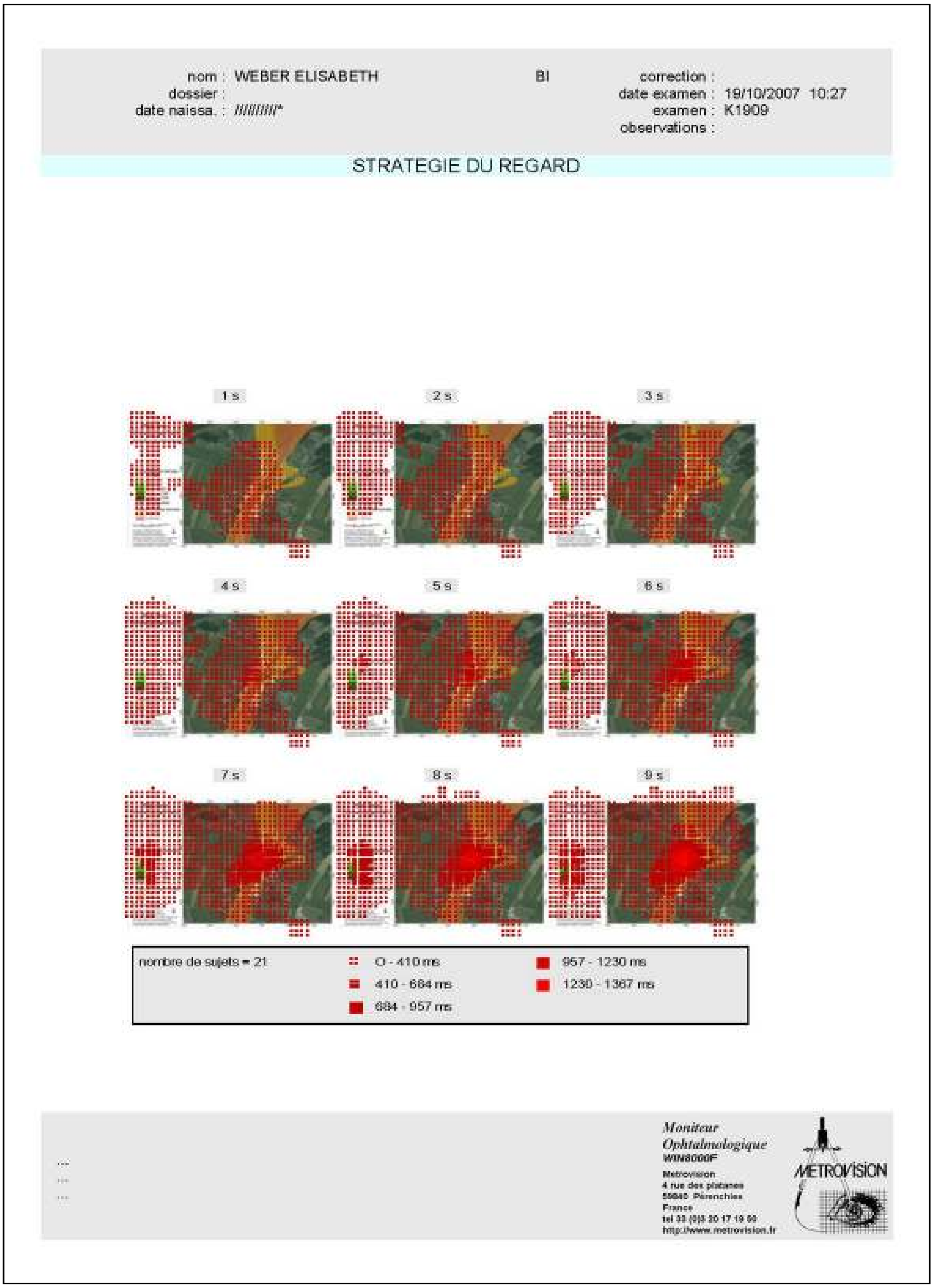
METROVISION

Map 10


nom : WEBER ELISABETH
dossier :
date naissa. : //////////*
BI
correction :
date examen : 19/10/2007 10:27
examen : K1909
observations :
STRATEGIE DU REGARD
1 s
2 s
3 s
4 s
5 s
6 s
7 s
8 s
9 s
nombre de sujets = 21
O - 410 ms
410 - 684 ms
684 - 957 ms
957 - 1230 ms
1230 - 1367 ms
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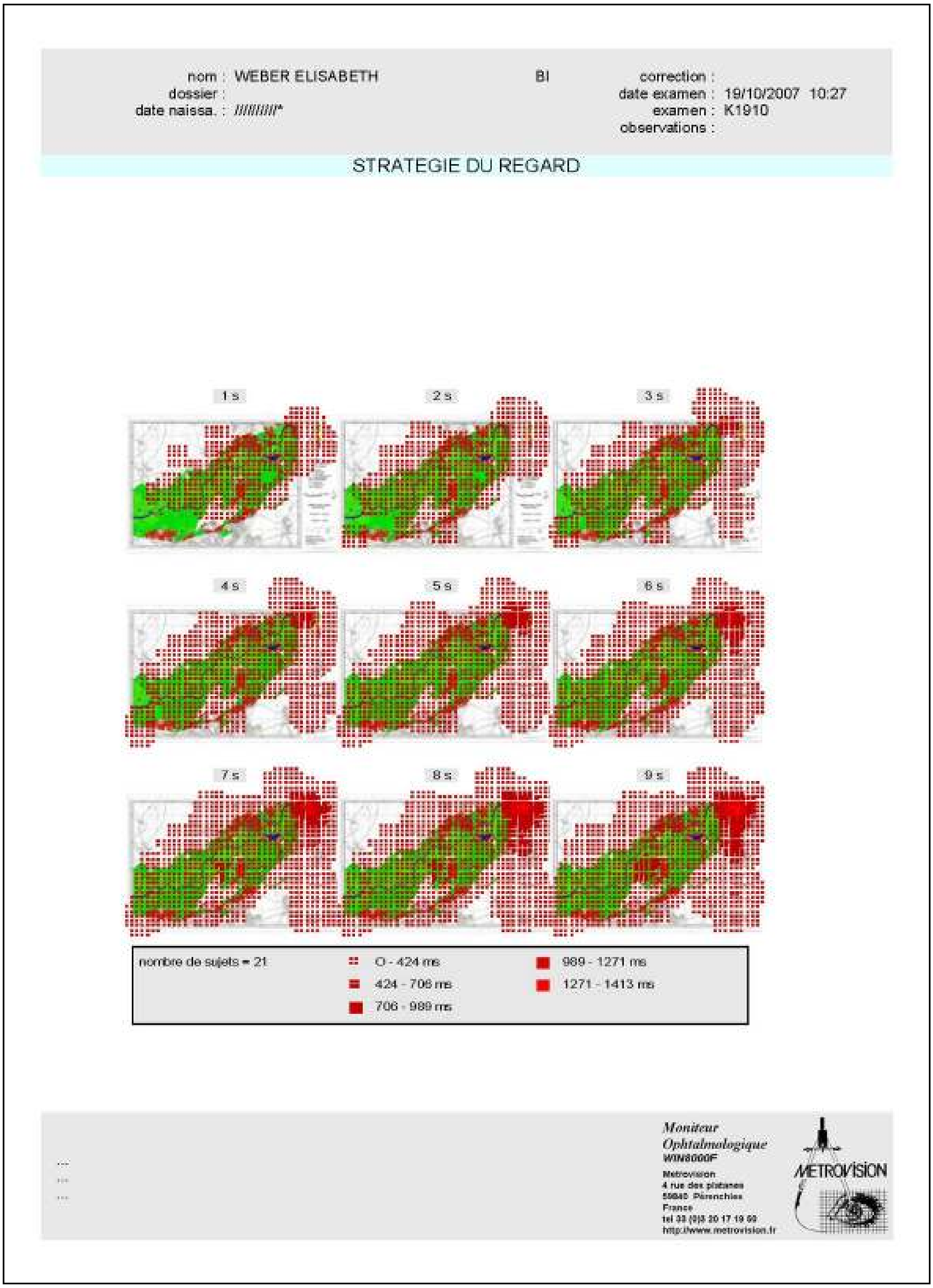
Map 11


nom : WEBER ELISABETH
BI
dossier :
date naissa. : //////////*
correction :
date examen : 19/10/2007 10:27
examen : K1910
observations :
STRATEGIE DU REGARD
1 s
2 s
3 s
4 s
5 s
6 s
7 s
8 s
9 s
nombre de sujets = 21
0 - 424 ms
424 - 706 ms
706 - 989 ms
989 - 1271 ms
1271 - 1413 ms
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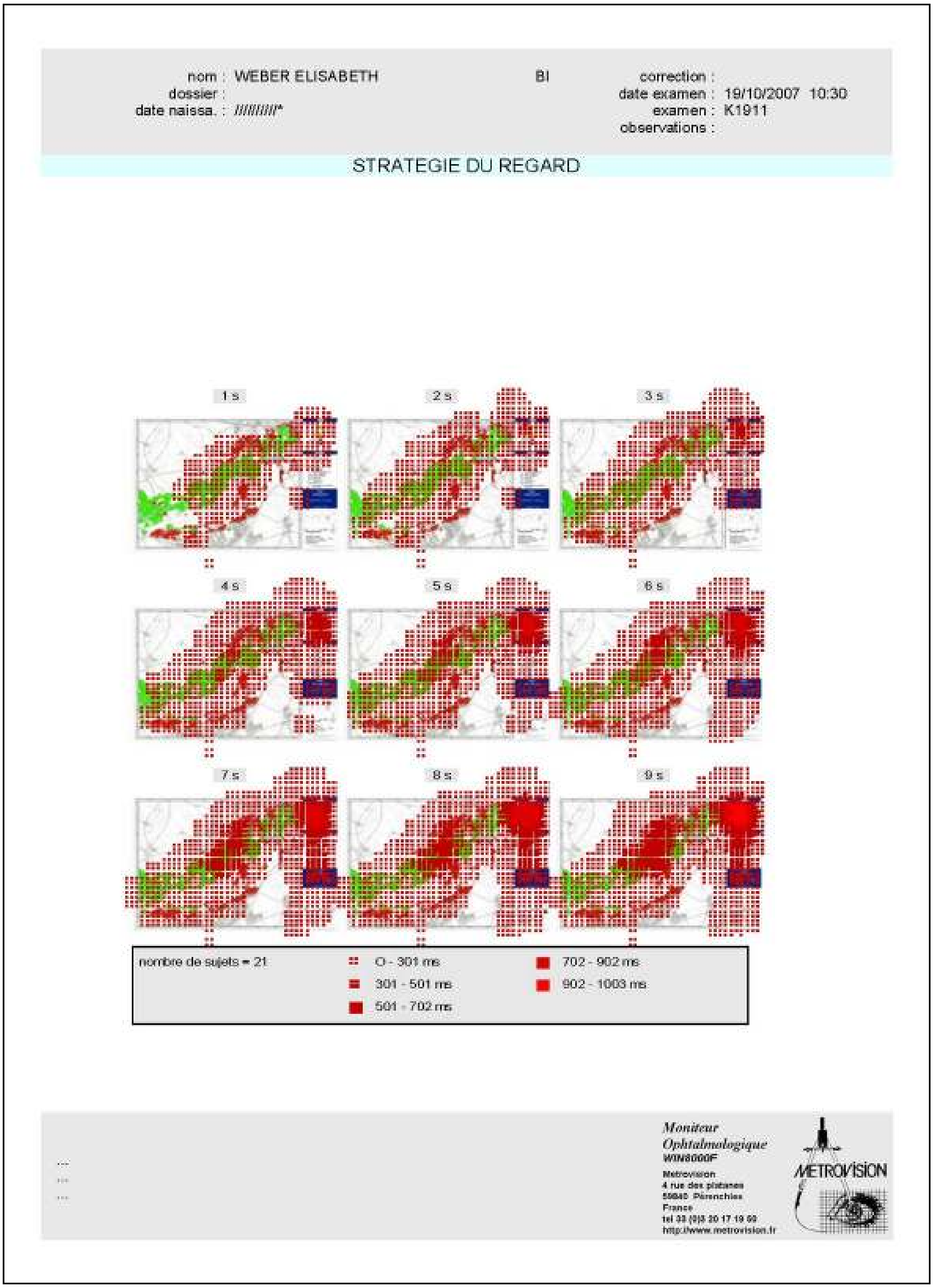
Map 12


nom : WEBER ELISABETH
BI
dossier :
date naissa. : //////////*
correction :
date examen : 19/10/2007 10:30
examen : K1911
observations :
STRATEGIE DU REGARD
1 s
2 s
3 s
4 s
5 s
6 s
7 s
8 s
9 s
nombre de sujets = 21
O - 301 ms
301 - 501 ms
501 - 702 ms
702 - 902 ms
902 - 1003 ms
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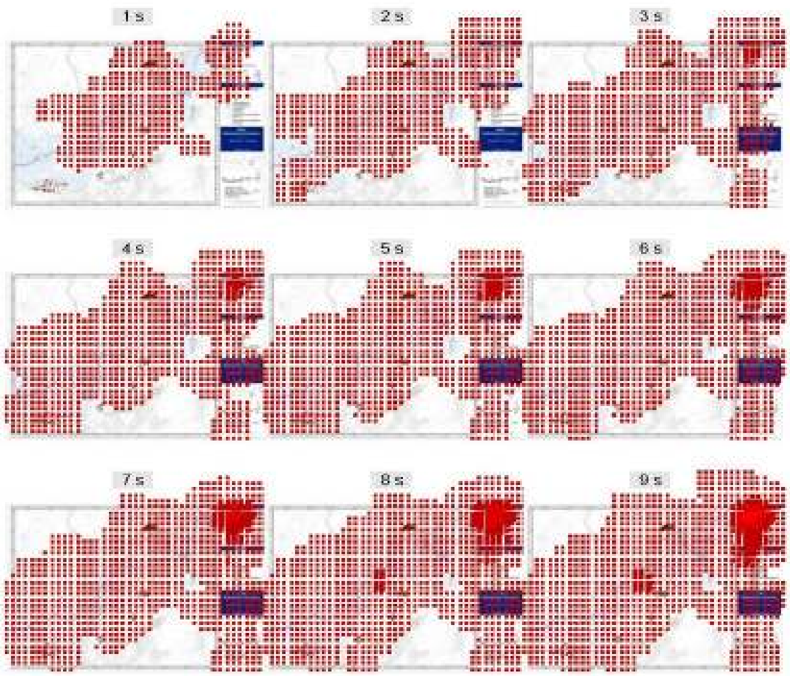
WIN8000F
Metrovision
4 rue des platanes
59840 Pérenchies
France
tel 33 (0)3 20 17 19 60
http://www.metrovision.fr
METROVISION

Map 13

nom : WEBER ELISABETH   BI
dossier :
date naissa. : ///////////*

correction :
date examen : 19/10/2007 10:33
examen : K1915
observations :

STRATEGIE DU REGARD



nombre de sujets = 21	O - 489 ms	1141 - 1467 ms
	489 - 815 ms	1467 - 1630 ms
	815 - 1141 ms	

...
...
...

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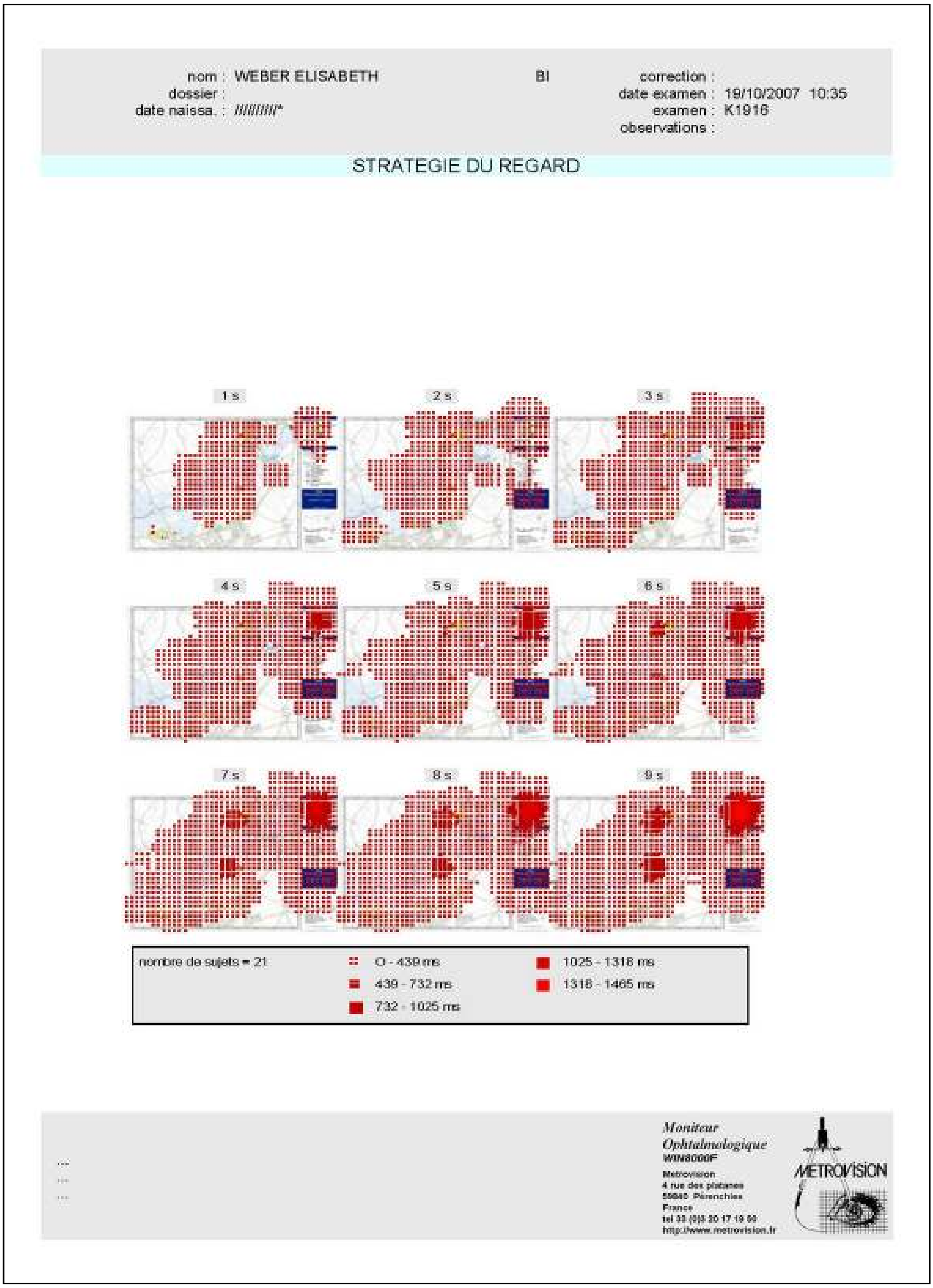
Map 14


nom : WEBER ELISABETH
dossier :
date naissa. : /////////*
BI
correction :
date examen : 19/10/2007 10:35
examen : K1916
observations :
STRATEGIE DU REGARD
1 s
2 s
3 s
4 s
5 s
6 s
7 s
8 s
9 s
nombre de sujets = 21
0 - 439 ms
439 - 732 ms
732 - 1025 ms
1025 - 1318 ms
1318 - 1465 ms
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WIN8000F
Metrovision
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59840 Pérenchies
France
tel 33 (0)3 20 17 19 60
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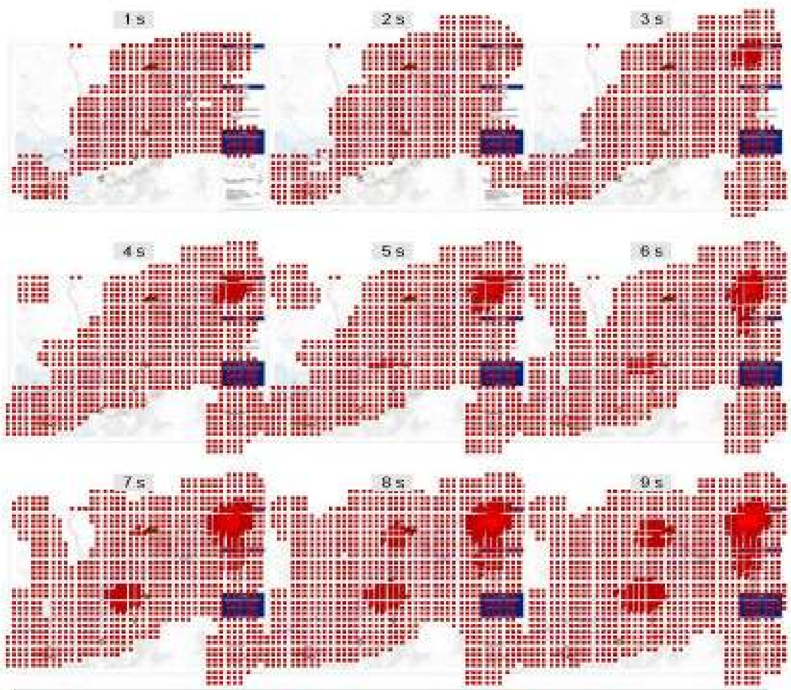
Map 15

nom : WEBER ELISABETH   BI   correction :
dossier :   date examen : 19/10/2007 10:35
date naissa. : //////////*   examen : K1917
observations :

STRATEGIE DU REGARD



nombre de sujets = 21	O - 386 ms	900 - 1157 ms
	386 - 643 ms	1157 - 1285 ms
	643 - 900 ms	

...
...
...

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France
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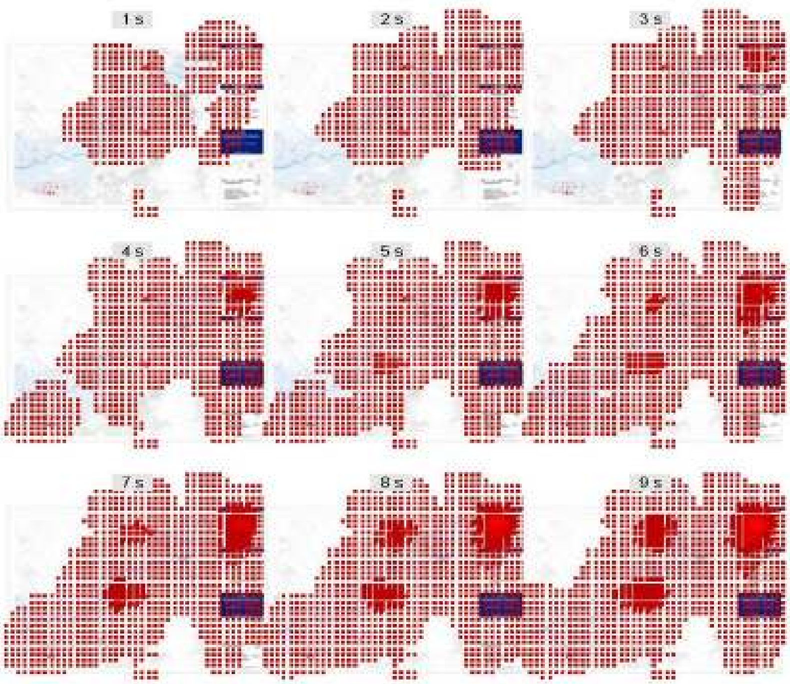
Map 16

nom : WEBER ELISABETH BI
dossier :
date naissa. : ////////*

correction :
date examen : 19/10/2007 10:36
examen : K1918
observations :

STRATEGIE DU REGARD



nombre de sujets = 21

- O - 353 ms
- 353 - 588 ms
- 588 - 823 ms
- 823 - 1058 ms
- 1058 - 1175 ms

...
...
...

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France
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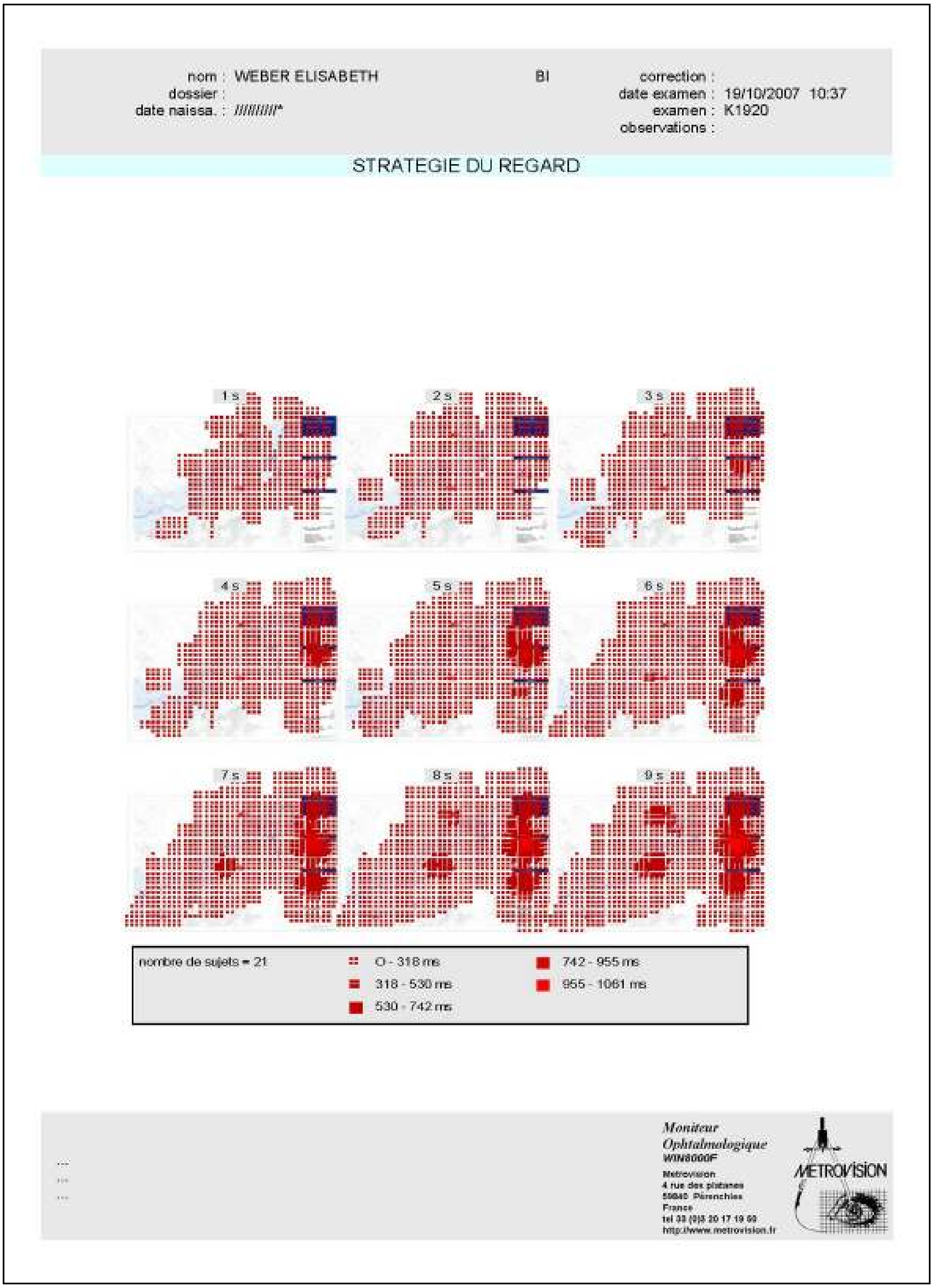
Map 17


nom : WEBER ELISABETH
dossier :
date naissa. : //////////*
BI
correction :
date examen : 19/10/2007 10:37
examen : K1920
observations :
STRATEGIE DU REGARD
1 s
2 s
3 s
4 s
5 s
6 s
7 s
8 s
9 s
nombre de sujets = 21
O - 318 ms
318 - 530 ms
530 - 742 ms
742 - 955 ms
955 - 1061 ms
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WIN8000F
Metrovision
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France
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Cognitive survey

Integrate, Consolidate and Disseminate
European Flood Risk
Management Research

ERA-NET CRUE Funding Initiative

Development of Flood Risk in Mountain Catchments and Related Perception - RISKCATCH

Sven Fuchs, University of Natural Resources and Applied Life Sciences, Vienna (A)
Wolfgang Dorner, Karl Spachinger, University of Applied Sciences, Deggendorf (D)
Kamal Serrhini, Juliette Rochman, Aude Bignard, UTC, Université de Tours UMR 6173 CITERES, Tours

Survey on flood maps perception

CHU Bretonneau
TOURS, October 19, 2007

I. Marital status

Gender: ☐ Women ☐ Men
Nationality: ☐ Austrian ☐ German ☐ French ☐ Other:
Age: ☐ 20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60 years

Which is your highest level of studies?

…………………………………………………………………………………………

Main professional activity:
☐ Policy maker (elected official, decision maker)
☐ Civil servant
☐ Researcher or teacher
☐ Other: ……………………………………………………………

II. Use of maps

A. Frequency of use of maps in your professional activity?

Less than one once per year	Once per year	Once per month	Once per week	More than one once per week

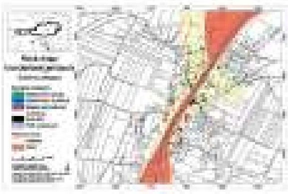
B. The maps used in your activity are:

☐ Generally realized by you
☐ Generally realized by your team or service
☐ Generally realized by external units
☐ Only from external sources
☐ Others: ……………………………………………………………

C. In your professional activity, maps are mainly:

☐ An illustration
☐ A tool of research
☐ A tool of decision
☐ Others: ……………………………………………………………

III. For each map below:



Complex:
Easy — Difficult
☐ ☐ ☐ ☐ ☐

Density of information:
Low — High
☐ ☐ ☐ ☐ ☐

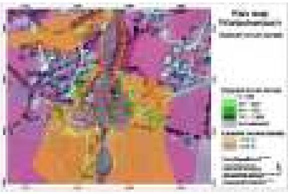
Innovative:
Weak — Strong
☐ ☐ ☐ ☐ ☐

Aesthetic:
Weak — Strong
☐ ☐ ☐ ☐ ☐

Decisional interest:
Weak — Strong
☐ ☐ ☐ ☐ ☐

What do you understand of the map message?

Others comments:



Complex:

Easy — Difficult

Density of information:

Low — High

Innovative:

Weak — Strong

Aesthetic:

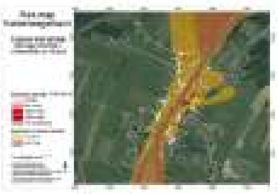
Weak — Strong

Decisional interest:

Weak — Strong

What do you understand of the map message?

Others comments:



Complex:

Easy | | | | Difficult

Density of information:

Low | | | | High

Innovative:

Weak | | | | Strong

Aesthetic:

Weak | | | | Strong

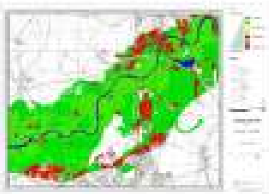
Decisional interest:

Weak | | | | Strong

What do you understand of the map message?

Others comments:

5



Complex:
Easy — Difficult

Density of information:
Low — High

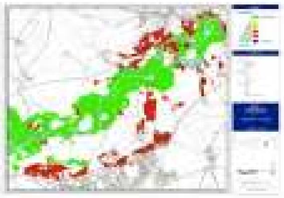
Innovative:
Weak — Strong

Aesthetic:
Weak — Strong

Decisional interest:
Weak — Strong

What do you understand of the map message?

Others comments:



Complex:
Easy Difficult

Density of information:
Low High

Innovative:
Weak Strong

Aesthetic:
Weak Strong

Decisional interest:
Weak Strong

What do you understand of the map message?

Others comments:

RISKCATCH – Graphic semiology, *Survey form* – CHU Tours, October 19, 2007

Complex:
Easy Difficult

Density of information:
Low High

Innovative :
Weak Strong

Aesthetic:
Weak Strong

Decisional interest:
Weak Strong

What do you understand of the map message?

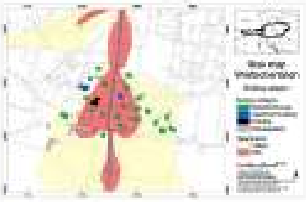
Others comments:

8

IV. Comparisons of maps:

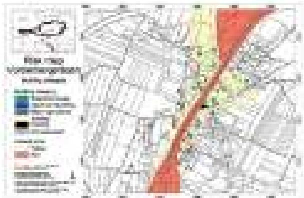
A. To mapping "*Building category*", do you prefer the legend on the right or on the left?

Legend: On the right



☐

On the left



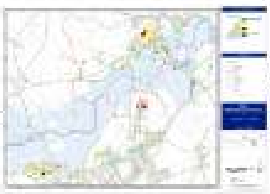
☐

Why?

☐ Easier to read (map reading habits…)
☐ Suitable for communicating a message to a wide audience (population, policy maker, researchers…)
☐ Innovative as it looks different from the maps generally used in my professional activity
☐ Others: ………………………………………………………………………………

B. Which map do you prefer in terms of positions of the title and simplifications of the legend and the squaring?

With squaring



Detailed legend
Title on bottom

☐

Without squaring

Title on top
Simplified legend

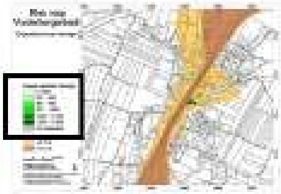
☐

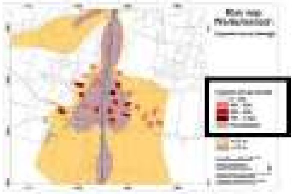
Why?

☐ Easier to read (map reading habits…)
☐ Suitable for communicating a message to a wide audience (population, policy maker, researchers…)
☐ Innovative as it looks different from the maps generally used in my professional activity
☐ Others: ………………………………………………………………………………

C. For the legends "*Expected annual damage*" below, do you prefer 7 or 5 color gradations?

7 classes of colors





5 classes of colors

☐ ☐

Why?

☐ Easier to read (map reading habits, more attractive…)

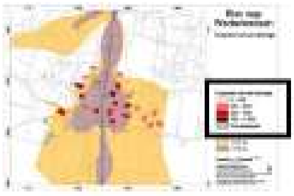
☐ Suitable for communicating a message to a wide audience (population, policy maker, researchers…)

☐ Innovative as it looks different from the maps generally used in my professional activity

☐ Others: ……………………………………………………………………………………………

D. For the legends "*Expected annual damage*" below, do you prefer red or green gradations?

GREEN gradation



RED gradation

☐ ☐

Why?

☐ Easier to read (map reading habits, more attractive…)

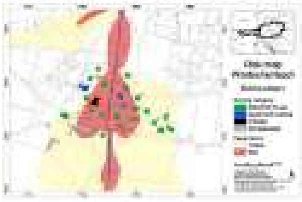
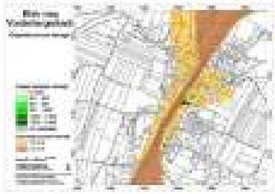
☐ Suitable for communicating a message to a wide audience (population, policy maker, researchers…)

☐ Innovative as it looks different from the maps generally used in my professional activity

☐ Others: ……………………………………………………………………………………………

E. For the flood risk maps below, which scale do you prefer (1/2500 or 1/5000)?

Scales :

1 / 2 500 (1 cm on map – 25 m on ground)	1 / 5 000 (1 cm on map – 50 m on ground)
	
☐	☐

Why?

☐ Easier to read (map reading habits…)

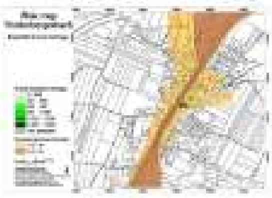
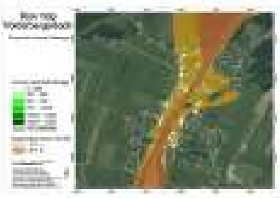
☐ Suitable for communicating a message to a wide audience (population, policy maker, researchers…)

☐ Innovative as it looks different from the maps generally used in my professional activity

☐ Others: ……………………………………………………………………………………

F. To mapping "*Expected annual damage*", which background do you prefer?

Background:

Register plan	Coloured Ortho Photography	Infrared Ortho Photography
		
☐	☐	☐

Why?

☐ Easier to read (map reading habits, more attractive…)

☐ Suitable for communicating a message to a wide audience (population, policy maker, researchers…)

☐ Innovative as it looks different from the maps generally used in my professional activity

☐ Others: ……………………………………………………………………………………