

# HISTORIC MAPS PROMOTE RECENT FLOOD RISK RESEARCH – THE CASE OF THE UPPER ELBE RIVER

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## ABSTRACT

At the Leibniz Institute of Ecological and Regional Development (IOER) in Dresden scientists work to investigate landscape dynamics and their cumulative environmental effects. Historic flood maps are important sources of information when evaluating past floods and making comparison with more recent ones. There exist two maps documenting historic Elbe floods in Saxony in 1845 and 1890, and their contents have been analysed and compared with recent flood data of 2002.

This paper will discuss both the specific characteristics of such unique historic maps and the problems of their incorporation into the GIS workflow, including the derivation of land use from the maps and its verification. Geodata overlay of various flood events allows statements to be made about the development of flood risk in spatially differentiated areas. This valuable geodata has been placed on the internet for access by the public, planners and researchers.

## 1. INTRODUCTION

In a river basin like the Upper Elbe, changes in the land use greatly affect the flood risk to areas. Therefore analysis and evaluation of previous floods is one indispensable task of recent flood risk research and management. Historic maps provide spatial information about the former state of landscape, depending on the scale and content of the maps as well as the accuracy of survey at that time. At the Leibniz Institute of Ecological and Regional Development ([www.ioer.de](http://www.ioer.de)) scientists of various disciplines work together on detailed analysis of the physical processes caused by changes in land use and their cumulative environmental effects.

The location of the study area “Upper Elbe river basin”, including both the city of Dresden and the area Saxon Switzerland, is displayed in the following figure.

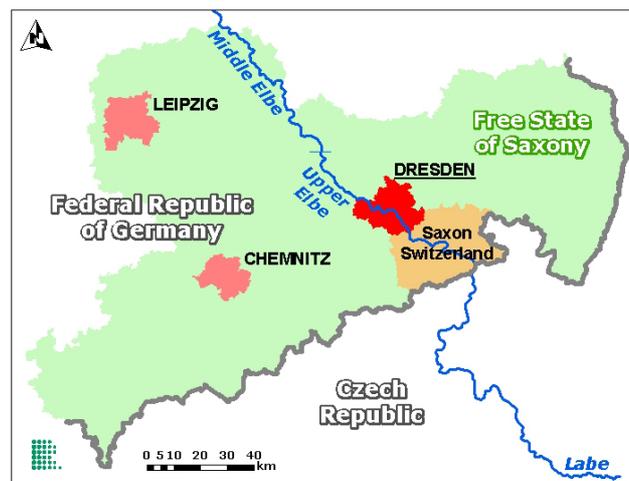


Figure 1: Location of the study area in Saxony

## 2. HISTORIC FLOOD EVENTS

The Elbe flood of August 2002 is often considered to have been the largest flooding affecting the Upper Elbe since the beginning of data collection in the 18<sup>th</sup> century. But is this in fact accurate? An answer to the question can be found by investigating the parameters of historic flood events. Christian Gottlieb Pötzsch completed his “Chronologic History of the Great Water Floods of the Elbe Stream for a Thousand and more Years” in 1784 [Pötzsch 1784]. This source includes quantitative water levels at the gauges of Meissen, Dresden and Pillnitz from the year 1500. Pötzsch himself established a daily survey at the gauge Augustusbrücke (centre of Dresden) in 1776 [Fügner 2003]. A compilation of collected (and where necessary converted) water levels and calculated / estimated flow rates of great floods in the Upper Elbe region (with a water level of more than 8 meters in Dresden) is displayed in the following table.

Date	Water level [m]	Flow rate [m <sup>3</sup> /s]
07.02.1655	8.38	app. 4800
01.03.1784	8.57	app. 5200
24.02.1799	8.24	app. 4400
31.03.1845	8.77	app. 5700
03.02.1862	8.24	app. 4490
06.09.1890	8.37	app. 4350
17.08.2002	9.40	4680 [gauging]

Figure 2: Selected historic and recent flood parameters in Dresden at gauge Augustusbrücke  
(Source: Sächsisches Landesamt für Umwelt und Geologie)

## 3. MAPS OF HISTORIC FLOOD EVENTS

Historic flood maps are important sources when evaluating past floods and making comparisons with more recent ones. Precisely mapped flooded areas allowing detailed spatial analysis are of course the most valuable. There exist two detailed maps documenting historic Elbe floods in Saxony: Werner’s Elbe map showing the flooded areas of March 1845 (Fig. 3) and Rilke’s map presenting the flooded areas of September 1890 (Fig. 4). Both maps cover the Upper Elbe river basin, including today’s Dresden city as well as the area Saxon Switzerland.

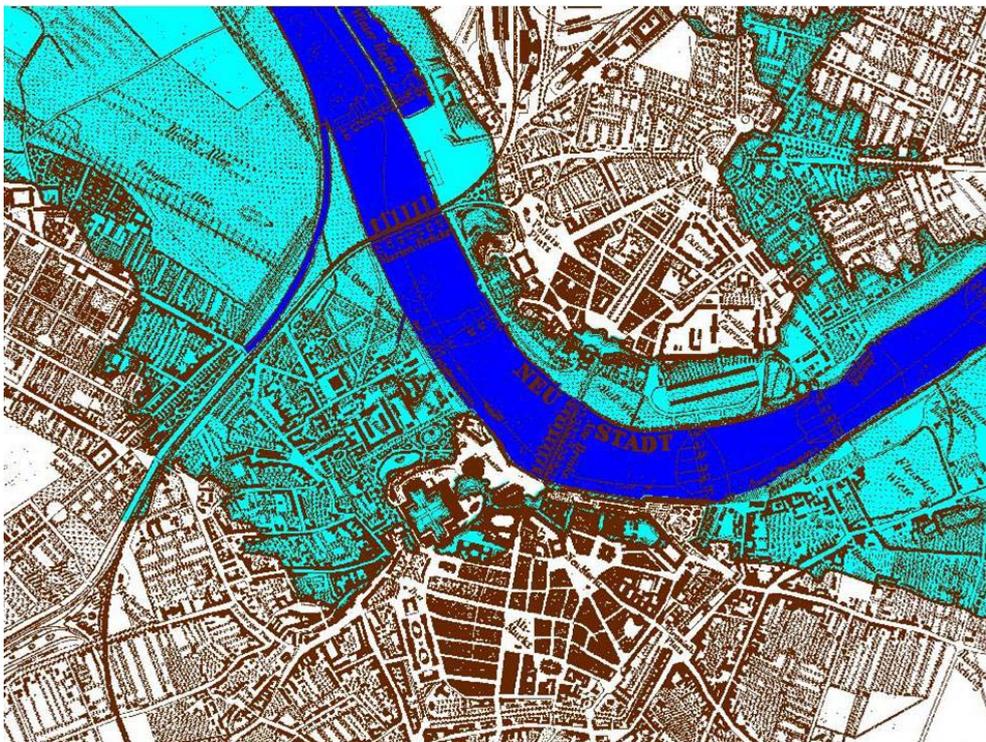


Figure 3: Elbe Flood Map 1845 “Karte des Elbstromes des Königreiches Sachsen mit Angabe des durch das Hochwasser vom 31sten März 1845 erreichten Überschwemmungsgebietes“ – Detail of Dresden city  
(Source: Sächsische Landes- und Universitätsbibliothek Dresden)

The destructive flood of 31st March 1845 was the motive for accurate mapping of flooded areas, especially with regard to the potential dangers for future construction in the city of Dresden. The 15 sections of this well-known cartography at a scale of 1:12,000 were produced as a lithographic print by A.W. Werner in the years 1850-59. The water bodies and flooded areas were coloured with various blue tones. Hand-drawn Elbe maps 1:4,800 and copies of the Saxon mile sheets 1:12,000 provided a cartographic basis. Included are also profiles of the longitudinal axis of the Elbe river [Stams 1994].

The Elbe flood of 6th September 1890 was documented by Rilke in an unique map of scale 1:10,000, probably sometime in the last decade of the 19<sup>th</sup> century. This little known map (rediscovered by IOER scientists) contains topographic information of only a small strip along the river Elbe. Various topographic maps provided a cartographic basis. There are also cross section profiles shown at selected locations. All single map sheets are stuck onto paper board and bound together to form a leporello fold by bookbinder. Small wedges were also inserted to achieve an optimal connection between two map sheets.

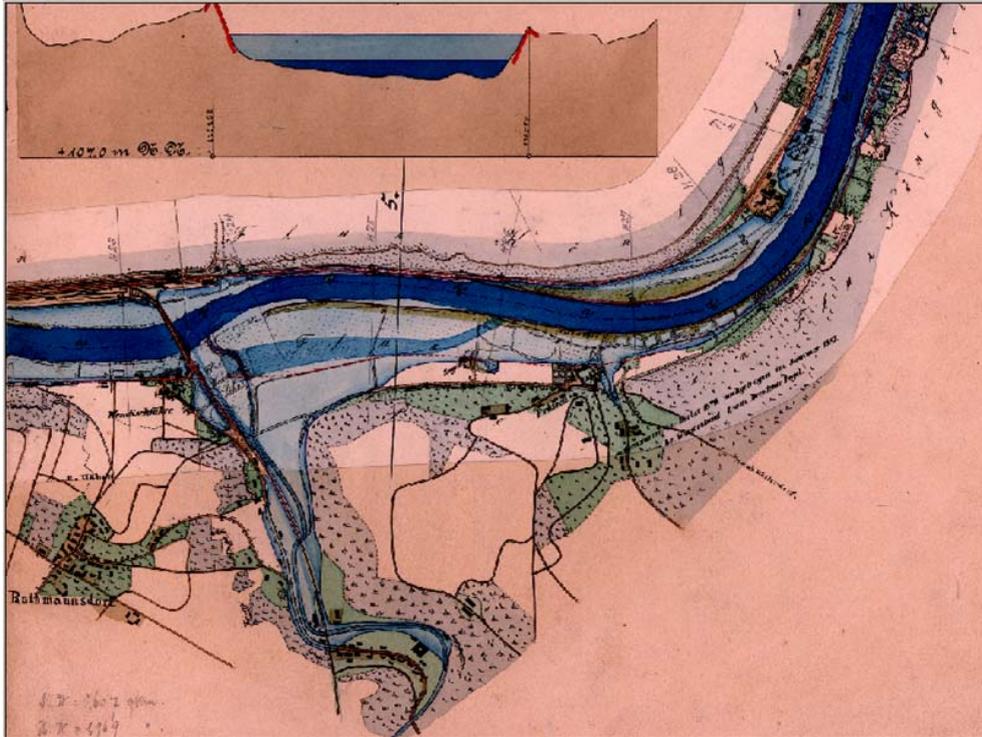


Figure 4: Elbe Flood Map 1890 “Karte des Elbstromes im Königreich Sachsen enthaltend die Situation bis zur Überschwemmungsgrenze des Hochwassers vom 6. September 1890“ – Detail from Saxon Switzerland (Source: Wasser- und Schifffahrtsamt Dresden)

#### 4. DIGITAL PROCESSING OF HISTORIC MAPS

The contents of these two historic maps were analysed in the context of recent flood data from 2002. To realise this the map sheets had first to be translated into digital form to allow integration into a Geographical Information System (GIS). The main procedures of digital processing (workflow) of the historic Elbe maps are represented in Figure 5.

The **work steps 1 to 4** were to allow the preparation of geodata. Here the search for suitable maps in libraries and archives - an often underestimated task - is regarded as a separate 1<sup>st</sup> step.

The 2<sup>nd</sup> step consisted of the scanning process: Copies of the single sheets (sections) of the flood map 1845 were separately scanned with a resolution of 400 dpi (full scale barrel scanner). The case of the flood map 1890 was slightly more complicated as only one original leporello copy exists. Separate A3 parts of this map were overlapped scanned with the help of a flat bed scanner. The scanning process of both historic maps thus produced digital raster files (TIFF format). For further processing these files were transformed into the widely used Erdas IMG format.

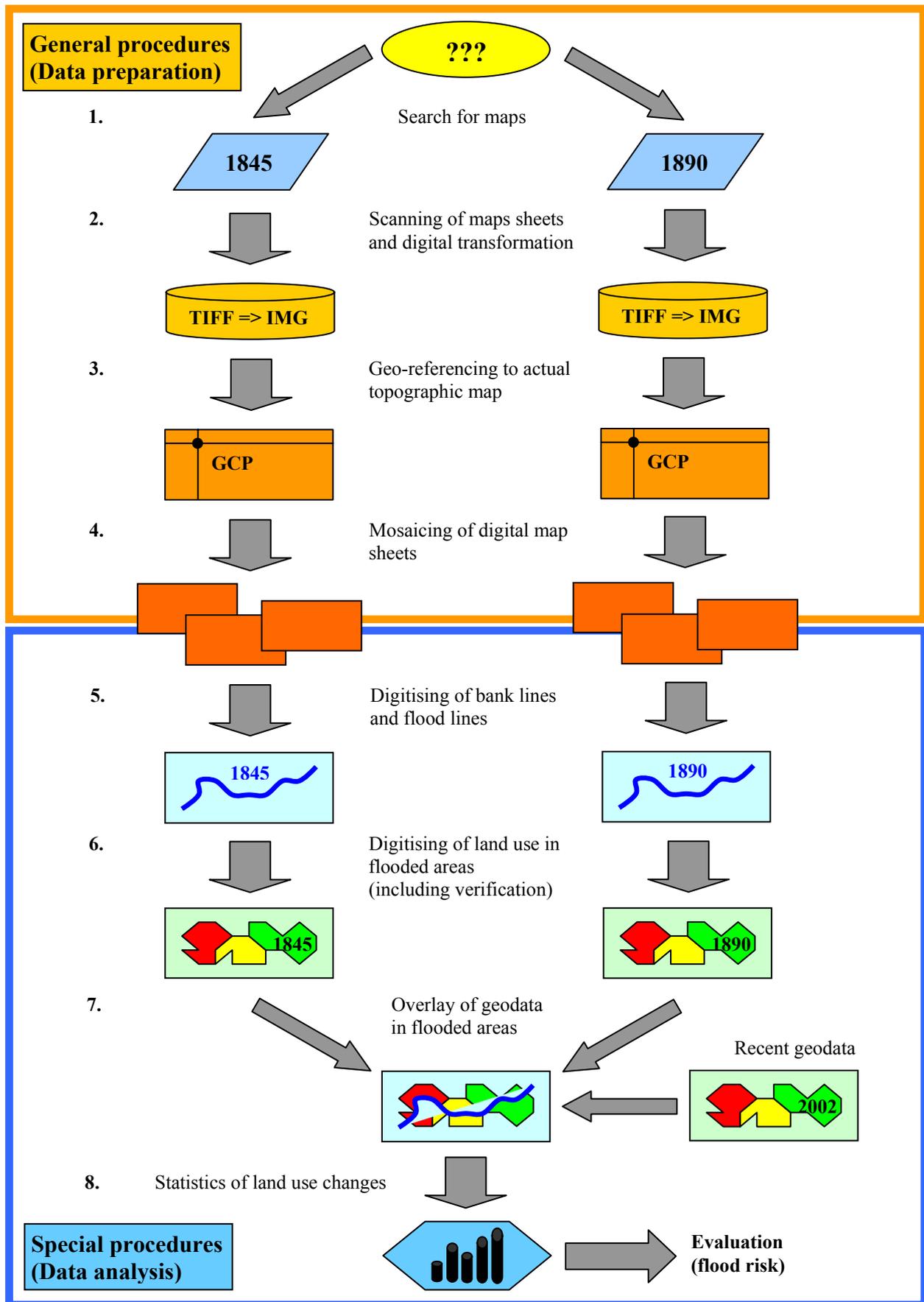


Figure 5: Digital processing of the historic Elbe maps (workflow)

Special problems had to be solved during the 3<sup>rd</sup> step (geo-referencing) as it was difficult to determine suitable ground control points (GCP) in both the historic maps (because of their small map area) and in the actual topographic map 1:10,000 (criteria: adequate number of points, spatial distribution, clear perceptibility, reference to recent topography). These difficulties could be resolved with the help of the Geo Correction Tool of Erdas Imagine software.

The 4<sup>th</sup> work step provided four map mosaics (also an application of Erdas Imagine): the Elbe river in the urban area of Dresden (1845 and 1890) as well as in Saxon Switzerland (1845 and 1890).

The **work steps 5 to 8** were special procedures of this GIS project for data analysis. The most important thematic information of both historic maps is provided by the flooded area. Therefore the 5<sup>th</sup> step consists of mosaic based (in particular, cases sheet based) digitising of the bank lines and flood lines (with ArcView GIS). Their transformation into polygons was carried out with respect to special cases (isles in the stream course, isles in the flooded area and external depressed areas).

The 6<sup>th</sup> step allowed the acquisition of land use data from the flooded areas. At the IOER considerable expertise is available for the derivation of geo information from historic maps [see Walz & Schumacher 2003; Witschas 2003; [www.ioer.de/nathist](http://www.ioer.de/nathist)]. This knowledge has been used here, especially regarding the interpretation of Werner's Elbe map of 1845 (containing signatures of the Saxon mile sheets). The method of temporal backward directed editing was applied, starting from a recent land use database available at the Leibniz Institute. The different classes of land use / land cover in the flooded areas are orientated on the classification scheme of CORINE Land Cover – Level 2 [Mohaupt-Jahr & Keil 2004]. Figure 6 shows a detail of Werner's Elbe map of 1845 in transparent form, with the flooded areas coloured according to their historic land use. A summation of the geodata is possible, to indicate, for example, settlement areas and open space only.

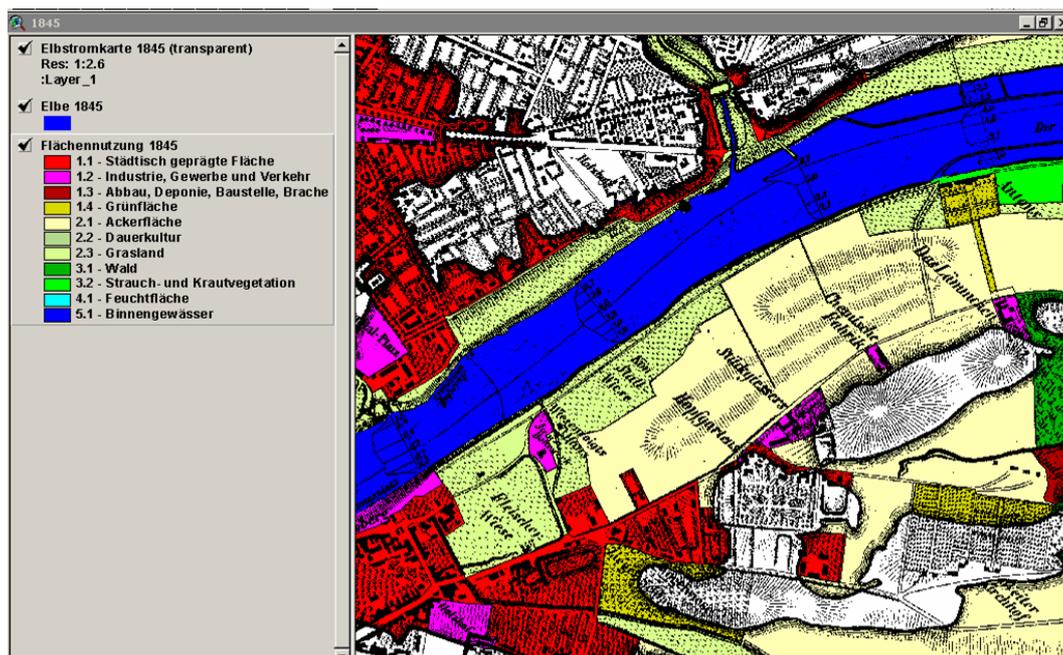


Figure 6: Classification of land use in the flooded area 1845 – Detail upstream the centre of Dresden

Both Werner's map showing the Elbe flood of 1845 and Rilke's map on the flood of 1890 were produced some years after the events. Detailed inspection of these maps reveals that the topographic basis includes elements from a later date. A careful verification of map contents with the help of secondary literature [e.g. Dresdner Geschichtsverein 2002] was therefore necessary. The correct land use data (geometry and / or attributes) had to be modified in the GIS; in particular, some polygons were eliminated from the historic geo database.

The 7<sup>th</sup> work step was the overlay of geodata in the flooded areas from 1845 and 1890 (digitised from the historic maps) with recent geodata. On this basis a comparison of historic flood events to the Elbe flood of August 2002 could be realised.

Finally, the 8<sup>th</sup> step (statistical analysis of land use changes) provided aggregate information about the development of settlements in the Upper Elbe river basin. This forms a valuable basis to help evaluate the development of flood risk.

## 5. RESULTS AND CONCLUSIONS OF GIS ANALYSIS

Geoinformatics can make an important contribution to preventive flood protection. That also applies to calculation of flood scenarios with determined annualness (based on digital elevation data and terrestrial surveys of river transverse profiles). After the flood of 2002, IOER scientists were contracted by the environmental authority of the municipality of Dresden to calculate such GIS-supported scenarios [Meinel et al 2003]. The results of the scenario (100-year event), with implicit planning restrictions regarding land use, were presented as a separate map of the environmental atlas at a scale 1:50,000 [Landeshauptstadt Dresden 2002].

Geodata overlay of flooded areas of 1845, 1890 and 2002 in a GIS allows conclusions to be drawn about the development of spatial differentiated flood risk. Thus comparatively large swathes of the flooded area of 1845 to the east of the Dresden city centre were not affected in 2002. A detailed cartographic report for all of the 31 municipal districts can be found in a diploma thesis [Terne 2003]. Our own GIS-supported investigations for the entire modern urban area show that the flooded area in August 2002 was slightly larger than in September 1890, but significant smaller than in March 1845 (Fig. 7). At first this appears surprising, in particular considering the water levels at gauge Augustusbrücke (Fig. 2).

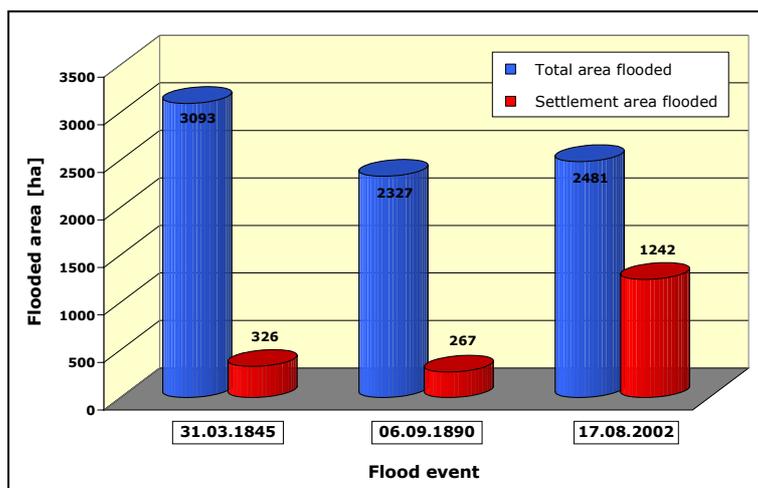


Figure 7: Flood plains of the river Elbe in the municipality of Dresden

But this phenomenon can be explained: upon studying land use changes, particularly in the settlement areas, a sharp increase in built-up areas can be seen after 1890, during the period of rapid industrial expansion. Furthermore, alterations to the stream channel during the middle of the 19<sup>th</sup> century caused changes in the river profile of the Elbe. Finally, each of these three flood events was unique, whereas characteristic differences between summer floods and winter floods (breaking river ice) exist. In this context the results from a long-term survey of the Elbe and Oder rivers are interesting [Mudelsee et al 2003]: There has been a significant decrease in the occurrence of winter flooding in both rivers, while summer floods show no trend.

However, any major flood today will affect much larger areas of human settlement than previously. The potential for damage (material and financial values per area unit) has multiplied in line with the development of new suburbs. Therefore an important task of urban and regional planning is preventive flood protection for a catchment basin. In case of the (Upper) Elbe river this necessitates cross-border cooperation between Czech and German experts.

## 6. INTERACTIVE MAP PRESENTATION

To provide information for the public, as well as planners and researchers, this valuable geodata is published on the internet. WebGIS supports the interactive exploration of historic and recent flooded areas affecting the Upper Elbe.

This website offers spatial information about the Elbe floods of 1845, 1890 and 2002, both in the areas of the state capital Dresden and Saxon Switzerland (river km 0 ... 70). The interactive maps (ArcIMS) show the river Elbe, the extent of the floods and the land use in the flooded areas, based on the corresponding topography (scale 1:25,000). The user is able to zoom into the maps to examine any particular zone of interest and to combine topographic and thematic geodata of various flood events. It is also possible to get selected results of GIS analysis. Additional information (e.g.

IOER “7-Points Programme for Flood Protection in the Elbe Catchment Basin” [Leibniz-Institut 2002] and spatial positioned photos of the flood of 2002) are included in the web presentation.



Figure 8: Website <http://map.ioer.de/website/hochw/index.htm>

This IOER interactive map presentation was launched exactly two years after the highest water level of the “Flood of the Century” in Dresden (17<sup>th</sup> August 2004). Within one month more than 1,000 people world-wide had explored the historic Elbe maps, making this one of the most visited websites of the Leibniz Institute of Ecological and Regional Development.

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## **BIOGRAPHY**

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1962 – 1974    Schooling in Leuna and Merseburg  
1974 – 1978    Studies at Technical University of Merseburg (Information systems)  
1978            Graduate engineer (Diploma thesis in Statistics)  
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1984 – 1991    Research associate for mathematical methods and geographic information systems (Institute of Geography and Geoecology of the Academy of Science, Leipzig)  
1988            Postgraduate studies at geographic institutes in Czechoslovakia (Praha, Brno and Bratislava)  
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