

STEREOPHOTOGRAMMETRIC AERIAL SURVEYS OF WAVES

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ABSTRACT

Increasing frequencies and heights of high tide floods during the last 30 years are menacing the port of Hamburg, Germany.

In order to inventorize the causes and their effects two aircrafts fly stereo-photogrammetric surveys synchronously during high tide flood and storm conditions. By means of photogrammetric evaluation methods the three dimensional wave geometry and the inclination of the water level can be measured and be mapped topographically. The paper discusses the technical solutions and the experience of the project.

1. INTRODUCTION

Major parts of the large city of Hamburg are situated in the branching network of the river Elbe near its mouth. The urban area in its current administrative boundaries cover 748 km² of which roughly one third is at or below sea level, and mainly comprises the two arms of the Elbe with their natural tributaries and the marshland along them. Most of this low-lying area is protected against storm tides by some 100 km of dikes and coastal embankments. At present, the minimum required height of these constructions is generally +7.20 m above mean sea level.

During the last few years, in particular, doubts have been expressed about the safety of these dikes and the necessary minimum heights in the event of storm tides. The reasons which have triggered this discussion are as follows:

1. Storm tides now tend to be faster, higher and more frequent than was the case 30 years ago. The highest storm tide to date reached +6.45 m in 1976.
2. Some scientists consider a relative increase in the sea level to be likely in the very near future.

2. PRESENT STATUS OF INVESTIGATION

For several years now, the relevant authorities in Hamburg have been giving some consideration to this situation, especially with respect to an increase in the height of all dikes and coastal embankments in the city's catchment area of the river Elbe. Such measures will be implemented before 1996 for 60 km of dikes, involving a sum of DM 180 million. Investigations are currently under way regarding the remaining 40 km of flood protection facilities.

The following scientific analyses are of relevance for the decisions which must be made:

1. Mathematical model computations on potential water levels during storm tides.
2. Spot measurements of water levels and wave heights in connection with storm tides.

Two different approaches have been taken to establish the influence of waves on flood protection facilities during storm tides: one involves the use of mathematical simulation models

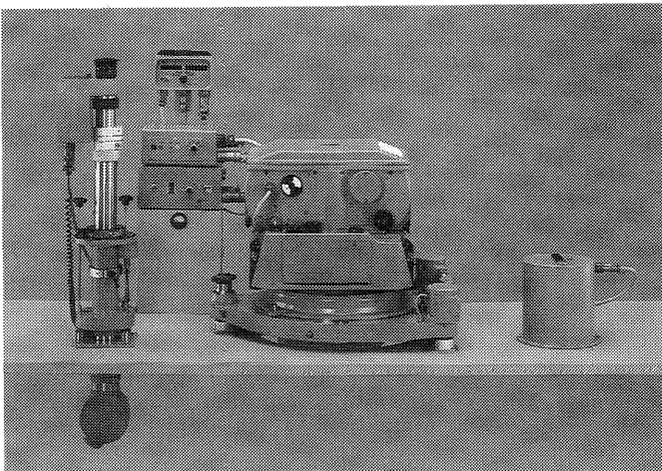


Fig. 1:
RMK A 15/23 from Carl Zeiss, Oberkochen. Two perfectly identical aerial survey camera configurations of this type were used in the project. The synchronous activation of all technical functions was triggered by the equipment in the rear aircraft and transmitted by radio to the front aircraft.

the other consists in observation by photoflights.

The concrete objective was the extensive, synoptic determination, in both qualitative and quantitative terms, of acute changes in the water level caused by floods and storm tides and their direct effects on dikes and coastal embankments. This can be achieved by stereophotogrammetric methods. The project described in the following has been under way since late 1986.

3. GENERAL SITUATION

The specified task essentially consisted in the production of three-dimensional contour line maps of the wave geometry, including the sloping of water levels, in storm tide conditions in the Hamburg urban area. These events occur most frequently during the winter months of each year, between October and March.

3.1 Meteorological conditions

The conditions under which stereophotogrammetric wave spectrum photography must be performed are determined by the client's specific requirements: with western and north-western gales and hurricanes over the Elbe estuary, wind forces of 8 to 9 are reached in Hamburg. This results in storm tide levels of more than +4m above MSL, the effects of which merit investigation.

4. GOALS

Within the framework of the specified starting conditions, the aim was to record not only storm tide events directly on the dikes and coastal constructions, but also the dynamics of freely moving waves in deep sea at a considerable distance from the coast.

For purely technical reasons, this goal can only be achieved with the aid of two tandem synchronized airplanes, which permit simultaneous photography and thus ensure synoptic coverage of all water surfaces in the Elbe area over their total width. The following paragraphs describe how the technical problems involved were solved.

4.1 Survey aircraft

The first requirement for synchronous photoflights covering the full width of the Elbe region in storm tide conditions is the availability of two equally powerful, twin-engined airplanes of a similar type with camera ports in their floors for vertical photography.

4.2 Photoflight planning

The planning and performance of the photoflights were geared to the envisaged task, the meteorological conditions and the topography of the branching network of the river Elbe. This was taken as a basis for fixing the meeting points of the two airplanes and for selecting photoflight distances of the maximum possible length, in up-wind east-west direction, with as few changes in course as possible.

4.3 Survey camera equipment

A vital requirement was the installation of two perfectly identical aerial survey cameras with accessory equipment in the two airplanes. In the project described here, two fully equipped RMK A 15/23 cameras from Carl Zeiss were used (Fig.1).

4.4 Synchronous triggering in the two RMK A 15/23 cameras

Carl Zeiss, Oberkochen, kindly placed the RMK circuit diagrams at the disposal of the Technical University of Berlin which was then able to produce the transmitter and receiver system for the wireless transmission of all trigger signals. The Federal Post Office in Germany made the trial radio frequency of 147.170 MHz available. The necessary radio signals were accepted by the active interval computer of the aircraft flying at the rear and to the receiver of the front aircraft, which synchronously transmitted all trigger commands to the front RMK system. This transmission technique was subjected to repeated testing both in the university's laboratory in Berlin and, after installation in the two airplanes, on the ground and in flight.

4.5 Aerial films

In view of the previously described photoflight requirements in storm tide conditions, mainly prevailing during the winter, the flights performed between 8 a.m. and 6 p.m. necessitated extremely fast, high-resolution panchromatic films. Films of the type Agfa Aviphot Pan 200 were used for the test flights with satisfactory results.

4.6 In-flight communication

Throughout the trial phase on the ground and in the air, all parties involved in the tests were in permanent radio contact on the specified frequencies in order to ensure mutual monitoring of the operational reliability of the complete technical equipment. This mainly consisted such as flying altitudes, horizontal distances between the two airplanes, speed, photoflight navigation, drift, and identical settings in all technical instruments involved.

5. HORIZONTAL DISTANCE MEASUREMENTS DURING THE PHOTOFLIGHT

The in-flight horizontal distance measurement between the two airplanes presented a special technical problem. It was one of the minimum 60% overlap of the photos along the flight, which is absolutely necessary for the subsequent stereoplotting process. Several different methods were tested.

5.1 Split-image distance measurement

With respect to the accuracy requirements, the use of split-image rangefinders to offer a perfectly workable solution. During the test flights, however, the practical implementation proved to be extremely difficult. Due to pronounced double motions of the aircraft, especially in turbulence,

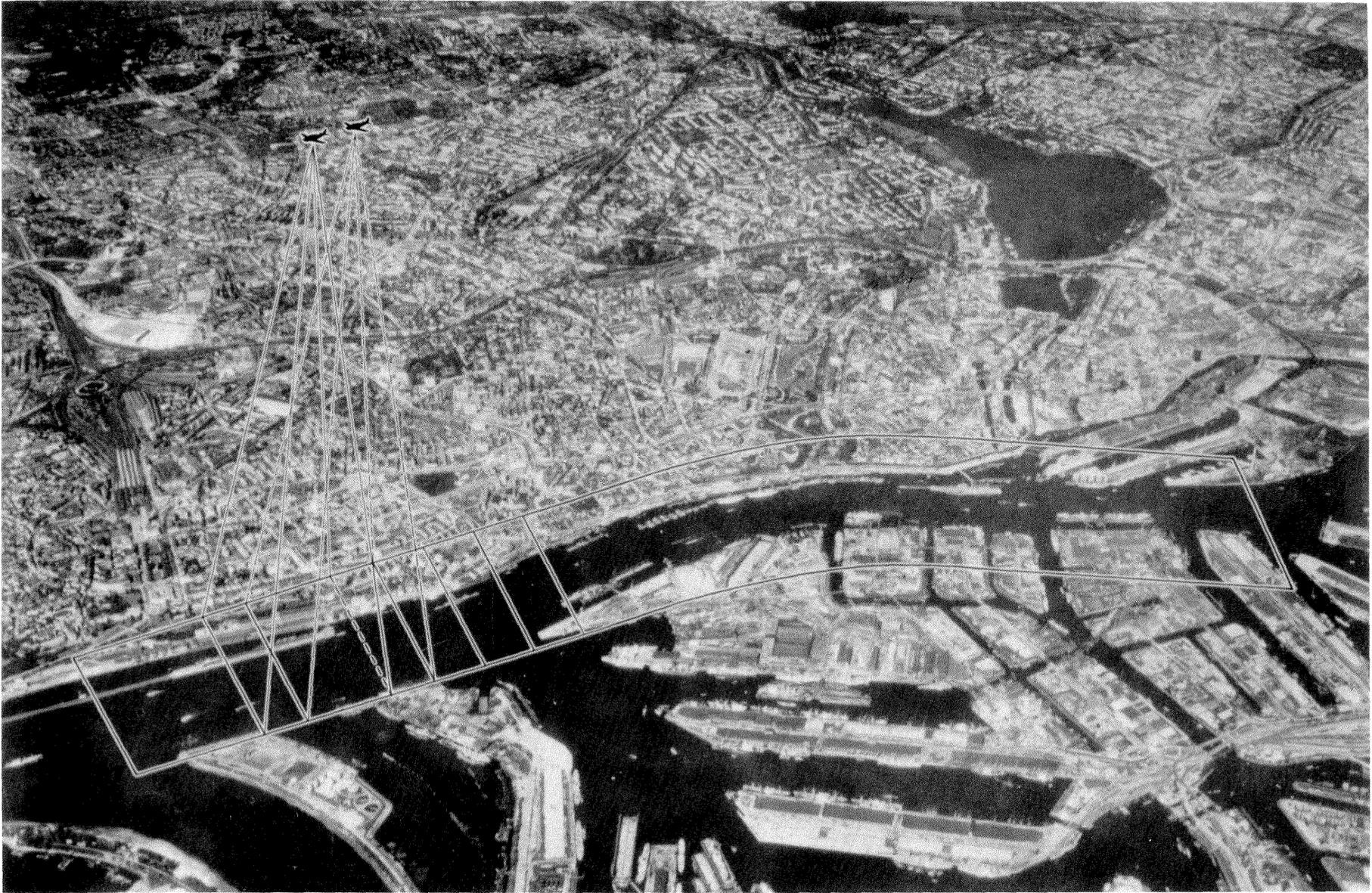


Fig. 2:
Schematic of a photoflight with two tandem-synchronized airplanes over the river Elbe
in the Hamburg urban area

the measurements took too long, and involved unacceptable inaccuracies and overlong time intervals for the subsequent check measurement.

5.2 Radar distance measurements

Several tests for horizontal distance measurement were performed with a radar instrument installed in the nose of the rear aircraft. Despite continuous antenna tracking, however, the test results were anything but satisfactory. The excessive scattering of the radar signal reflection on the outer skin of the front aircraft resulted in considerable, out-of-tolerance variations in the distance measurements and in overlong repetitive measurements times.

5.3 Infrared distance measurement

Carl Zeiss kindly supplied one of the first instruments of the current Eldi 10 electronic distance meters and also assisted in the tests. At the Technical University of Berlin, the Eldi was converted into a hand-held instrument coupled with an optical sighting telescope for tracking and measurement over long distances. Reflecting foil was glued onto the tail assembly of the front airplane for the envisaged measurements between the two airplanes. In addition, special reflectors were attached to the data transmission antenna on its underside. This configuration has been successfully used since then. During the flight, the tail assembly of the front aircraft is sighted with the telescope while the measurement is triggered at the same time. Within seconds the result is available for monitoring of the specified distances between 300 and 400 m is approx. +/- 50 cm.

6. IN-FLIGHT ALTITUDE CHECKS

During the test flights, the flying altitude, which was precomputed on the basis of the required photo scale, was checked by radio contact between the two airplanes using their altimeters and the parallel devices in the two survey cameras.

7. PHOTO SCALE

The photo scale was optimally adapted to the topographic requirements, i.e. the varying width of the Elbe river in the area to be investigated, and to the project conditions. To permit each arm of the Elbe and its dike tops marked by control points to be covered by a film strip, the ideal scale for the RMK A 15/23 was found to be 1 : 6000, corresponding to an altitude of 920 m (Fig. 2). In an actual storm tide situation, however, the low clouds and poor lighting and viewing conditions necessitate adaptation of the scales to between 1 : 4000 and 1 : 8000, corresponding to altitudes of 610 to 1220 m.

8. PHOTO PLOTTING

The panchromatic aerial photos obtained in the flights at scales between 1 : 4000 and 1 : 8000 and with a 60% longitudinal overlap were finally processed into contour line maps of the wave geometry in the Elbe region. The client's specification was the standard scale of 1 : 5000. The 1 : 5000 map material was therefore used as a horizontal orientation basis. The necessary control points on the dikes and coastal embankments were kindly made available by the land registry of Hamburg. To cross-check the accuracies, stereoplotting of the photos was performed on different Carl Zeiss instruments at the University in Berlin and in the company's headquarters in Oberkochen. The accuracy specified by the client for the wave height was +/- 10 cm. Compliance with this tolerance was verified independently at Carl Zeiss and at the land registry in Hamburg. Both confirmed that the accuracy specifications had been met.

9. SUMMARY OF THE RESULTS

The following shows the most important results obtained for this project, which - as previously mentioned - has been under way since late 1986:

1. The project performed in the Elbe catchment area of the city of Hamburg proved that aerial stereo surveys of waves are feasible. They help to create the basis for decisions on the construction of dikes and flood protection facilities.
2. Two identical, synchronously operating aerial survey cameras from Carl Zeiss, Oberkochen, were used in two airplanes for the first time.
3. The end products were contour line maps of the wave geometry at a scale of 1 : 5000.
4. The measuring accuracy for the wave height and the slope of the water surface ranged within the +/- 10 cm specified by the client.
5. The information and experience gained here are also applicable to other coastal regions of the North Sea and Baltic Sea, wherever active coastal dynamics give rise to a rapid change in the landscape.
6. A further prospective field of application is the formation of waves caused by moving ships.

The overall project was initiated, supported and sponsored by Mr. Kroker, director of the flood protection section of the Hamburg Planning Department. Special thanks are therefore due to him. I also would like to express my thanks to the following gentlemen, without whose kind assistance, advice and support this project would not have been possible:
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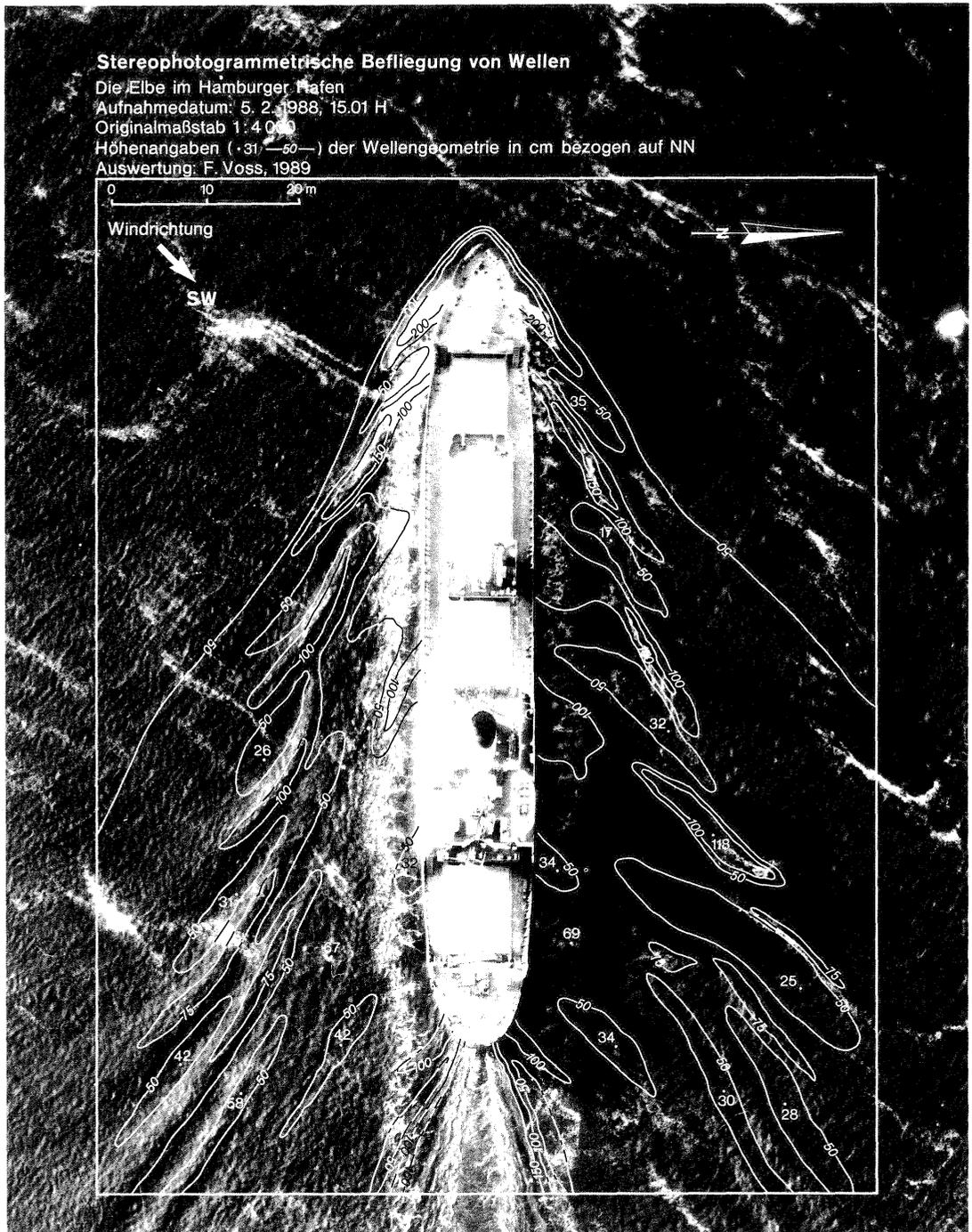


Fig. 3:
 Contour line map obtained by
 photogramtric plotting
 using the Carl Zeiss Planicom