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Evaluation Methodologies for Forensic Reports on Flood Damage

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Abstract: One of the most relevant current discussions in floods is the appropriate methodology for forensic reports on flood damage. Floods are natural disasters that have affected human lives since time immemorial. Nature has shown little regard for humanity's unwise occupancy of flood-prone regions and this has been clearly shown to us by sporadic flooding that causes large-scale destruction of people's property and takes numerous lives. Following a flood event, questions arise regarding the origin and range of structural corruption and damage to construction. Often, the engineer's role is two-fold. First, he/she may need to serve as a forensic engineer to evaluate the derivation of reported damage to a structure. Then, forensic experts will likely be required to calibrate the scale of the damage and provide a repair assessment for the structure. As a forensic expert or *forensic engineer, forensic expert interrogation and inquisition should designate the cause of the divergent reported illustrations of damage. When the effect of flood damage is hazardous, the reasons for damage must be made clear.*

Key words: Forensic reports · Flood warning · Damage · Precipitation · Rainfall

INTRODUCTION

Flood is a temporary covering of land by water as a result of surface waters escaping from their normal confines or as a result of heavy precipitation. Flood disasters are the result of interactions between hydrological floods and societal systems [1]. A number of studies have found that climate change is expected to result in sea-level rise and to induce more extreme weather events, causing modifications in the frequency, severity and duration of hydro-meteorological hazards [2].

In the Czech Republic, floods represent the biggest direct hazard in the field of natural disasters and they are causes for serious crisis situations during which vast material damages as well as fatalities to inhabitants in affected areas arise. During flood episodes in 1997, 1998, 2000, 2002 and 2006, the total number of 103 inhabitants died, total material damages attained to nearly 5 milliard euros [3]. Virtually after each flood event, especially in case of injury and fatalities to inhabitants as well as at occurrence of considerable material and ecological damages, the investigation of reasons is being undertaken and a possible flood damage infliction is being found out [3].

In Europe, for example, floods occur each year several times. Flood damages and loss of lives are mitigated through flood risk management. This includes the design of structural protection measures such as dikes and dams; the plan- ning of a flood resilient environment; and flood disaster management [4]. Changes in extreme precipitation and flood statistics has become a very active research area and numerous studies have been published in recent years that analyse trends in historical time series of extreme precipitation and flood discharge. Investigation of possible climate change is a primary driver for these studies [5]. With respect to changes under a future climate, climate modelling studies have shown that an increase in heavy precipitation is likely in most parts of the world in the 21st century.Decision- makers are asked to increase their efforts in the implementation of early adaptation measures and disaster management plans to recover from climate-related disasters and to deal with the impacts from present and future climate variability [6].

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Over time since the prehistoric, interactions with floods have undergone evolutionary transitions including aversion to flood risk, flood defence and flood risk management, each serving as a mindset or a paradigm. Understanding the performance of hydrological models is important for a number of reasons. From a practical perspective, it is essential to know how well streamflow and flood forecasts will perform. Annual and seasonal maximum daily discharge time series for stations in central Europe (Germany, Switzerland, Czech Republic and Slovakia) are used to examine flood frequency from a regional perspective [7].

Flood frequency data for different durations of floods are required in many practical hydrologic applications. The estimation of flood frequency as an integrated function of return period and flood duration can be accomplished by flood-duration-frequency modeling [8]. The traditional approaches to the estimation of flood frequency for dam safety assessments rely either on the definition of an extreme design storm or ‘probable maximum precipitation as an input to rainfall-runoff model, or on the estimation of a series of flood peak magnitudes fitted to a suitable distribution function. Flood forecasting may be improved by coupling atmospheric and hydrological models. To investigate the current potential of such an approach in complex mountain watersheds. Recent floods have focused attention on the role that flood plain development plays in increasing flood hazards [9].

Flood Forcasting: Flood forecasting is the use of real-time precipitation and streamflow data in rainfall-runoff and streamflow routing models to forecast flow rates and water levels for periods ranging from a few hours to days ahead, depending on the size of the watershed or river basin. Flood forecasting can also make use of forecasts of precipitation in an attempt to extend the lead-time available [10].

Sophisticated flood forecasting systems will also account for the effects of:

- Snowmelt;
- Flood plains and washlands;
- Flood defences, including control-gates etc.;
- Tidal effects near the sea and sea-surges.

To accomplish this, the range of models required needs to include appropriate snowmelt models and the types of streamflow models that work well for simple applications need the addition of hydrodynamic models [11].

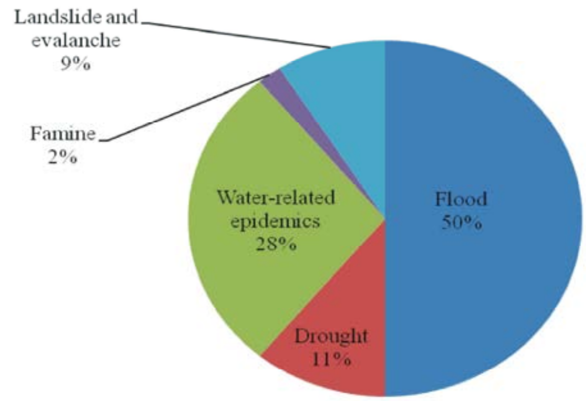

Fig. 1: The significance of flooding in the context of all water-based natural hazards. (UNESCO) World Water Assessment Programme

Flood forecasting is an important component of flood warning, where the distinction between the two is that the outcome of flood forecasting is a set of forecast time-profiles of channel flows or river levels at various locations, while "flood warning" is the task of making use of these forecasts to make decisions about whether warnings of floods should be issued to the general public or whether previous warnings should be rescinded or retracted [12].

The worldwide impact of flooding cannot be overestimated. The United Nations Educational, Scientific and Cultural Organization (UNESCO) World Water Assessment Programme provides a clear statement of the problem. Figure 1, shows the significance of flooding in the context of all water-based natural hazards.

Flood Warnings and Reducing Effects of Flood: Flood warnings, it can be argued, are the most fundamental mechanism for flood risk managementsince even where structural flood defences are provided, residual risks remain. Moreover, long established settlements are likely to remain in flood risk areas even if new development is kept out of the flood plain. Importantly flood warnings can be instrumental in preventing loss of life and injury in floods and this. public security. aspect provides a key justification for developing flood warning systems. Warning systems also have the potential to reduce flood damages and economic losses [11].

Their economic evaluation and justification can be based on the damages they save and the other economic losses that they prevent. Yet despite the high priority accorded to flood warning in flood risk management by governments, there is a lack of sound data on the benefits (and costs) of these systems [12].

Table 1: Types of flood warnings (www.metoffice.gov.uk).

 FLOOD ALERT	Indicates that flooding is possible and that people should make simple preparations and remain vigilant, check that domestic flood gates are ready to be put in place, move small valuable items upstairs, check travel plans and remain vigilant. **What it means?** Flooding is possible. Be prepared. **When it's used?** Two hours to two days in advance of flooding. **What to do?** • Be prepared to act on your flood plan. • Prepare a flood kit of essential items. • Monitor local water levels and the flood forecast on our website.
 FLOOD WARNING	Indicates that flooding of homes is expected and people should take specific actions as move/raise belonging, put in place flood board, muve to places of safty. **What it means?** Flooding is expected. Immediate action required. **When it's used?** Half an hour to one day in advance of flooding. **What to do?** • Move family, pets and valuables to a safe place. • Turn off gas, electricity and water supplies if safe to do so. • Put flood protection equipment in place.
 SEVERE FLOOD WARNING	To be used in extreme circumstances to tell people that flooding will/is posing a significant risk to life or significant disruption to communities which could also causes risk to life. **What it means?** Severe flooding. Danger to life. **When it's used?** When flooding poses a significant threat to life. **What to do?** • Stay in a safe place with a means of escape. • Be ready should you need to evacuate from your home. • Co-operate with the emergency services. • Call 999 if you are in immediate danger.

Table 2: Uncertainties in provided N-year flood discharges[3]

	Class			
	I	II	III	IV
Hydrological data	-----The standard error in [%]------			
Long-term average discharge (Q_a)	8	12	20	30
M-daily flows (Q_{30d} to Q_{300d})	10	15	25	40
M-daily flows (Q_{330d} to Q_{364d})	20	30	45	60
N-year flows (Q_1 to Q_{10})	10	20	30	40
N-year flows (Q_{20} to Q_{100})	15	30	40	60

More generally a flood risk management strategy which uses flood warnings, either solely or in conjunction with other management options, can contribute to making the occupation of floodplains and coastal flood risk zones more sustainable over time(www.metoffice.gov.uk).

Flood Warning Codes: The flood warning service has three types of warnings that will help you prepare for flooding and take action(www.metoffice.gov.uk).

Flood warning systems are one part of a larger system often termed. flood forecasting, warning and response.. The performance of flood warnings depends greatly upon floods being detected and subsequently forecast with an acceptable degree of accuracy, reliability and timeliness and warnings systems may under-perform, or indeed fail, if flood detection and/or flood forecasting is flawed in some way. The warning process may also under-perform in a variety of ways. For example, warning messages may be inadequately constructed and/or inadequately communicated to those who require them [13].

The task of the forensic expert in this case is to analyze the documents and take into account when evaluating the data that emerged from the analysis most favorably [3] see Table 2.

Hydrograph is a graphical plot of discharge (*Q*) of a river at a given location over time. it is the output or total response of a basin as Fig. 2. The peak rainfall is the time of highest rainfall. The peak discharge (the time when the river reaches its highest flow) is later because it takes time for the water to find its way to the river (lag time). The normal (base) flow of the river starts to rise (rising limb) when run-off, ground and soil water reaches the river. Rock type, vegetation, slope and situation affect the steepness of this limb. The falling limb shows that water is still reaching the river but in decreasing amounts. The run-off/discharge of the river is measured in cumecs - this stands for cubic metres per second. Precipitation is measured in mm [14].

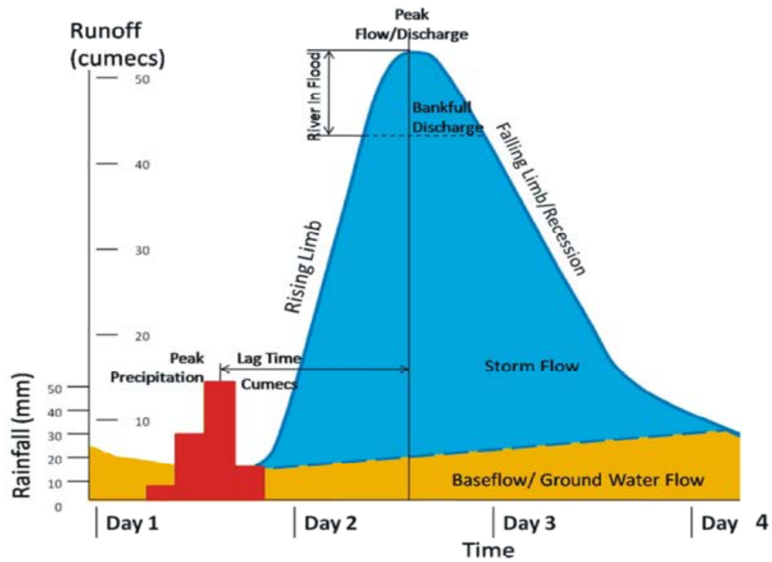

Fig. 2: The Storm Hydrograph [14]

Flood Damages: It is, of course, essential to consider all known flood damage categories in flood risk analysis and flood damage evaluation. It is therefore necessary to specify the different flood damage categories which need to be involved in the analysis. The term flood damage. refers to all varieties of harm caused by flooding. It encompasses a wide range of harmful effects on humans, their health and their belongings, on public infrastructure, cultural heritage, ecological systems, industrial production and the competitive strength of the affected economy [15].

Direct, Indirect Damages: Direct flood damage covers all varieties of harm which relate to the immediate physical contact of flood water to humans, property and the environment. This includes, for example, damage to buildings, economic assets, loss of standing crops and livestock in agriculture, loss of human life, immediate health impacts and loss of ecological goods. Direct damages are usually measured as damage to stock values. Indirect flood damages are damages caused by disruption of physical and economic linkages of the economy [16] and the extra costs of emergency and other actions taken to prevent flood damage and other losses.

Tangible, Intangibledamages: Damages, which can be easily specified in monetary terms, such as damages on assets, loss of production etc. are called tangible damages. Casualties, health effects or damages to ecological goods and to all kind of goods and services which are not traded in a market are far more difficult to assess in monetary terms. As indicated above, there are a number of different reasons why we should develop flood damage databases and therefore a number of different uses to which these databases may be put. To a certain extent these different purposes require different sorts of data, or a different structure to the database and this is something that needs consideration when designing systems to produce such a damage database [17].

Start Building a Flood Damage Database: The essential ingredients and decisions involved here are as follows[4]:

- Values of the assets at risk,
- The susceptibility of those assets to flood damage,
- Key variables affecting the extent of damage, which are likely to vary in different flooding circumstances,
- The level of aggregation of the data required,
- Some information as to flood probability, in order to convert event damages into annual average damages.

Guideline for Professional Forensic Engineering Investigations: There are a number of definitions of forensic engineering, but it can generally be defined as the application of professional engineering principles and methodologies to the investigation of failures and events, usually to determine causation. Normally, it involves the preparation of a report of findings, which may form the basis for testimony in legal proceedings as an expert witness. As per The National Academy of Forensic Engineers a forensic engineer may serve as an engineering consultant to members of the legal profession and as an expert witness in courts of law, arbitration proceedings and administrative adjudication proceedings [6].

Forensic engineering is a part of professional engineering practice that may cover all disciplines of engineering. It is a specialized set of skills that can include multi-disciplinary training in failure analysis, simulation, safety, accelerated life testing, statistical analysis, as well as knowledge of the specific engineering field [18].

The first priority is safety. The engineer should give consideration to:

- The apparent organization on site,
- The presence or absence of qualified or authorized personnel on site,
- The authority and responsibilities granted to the engineer by their client / employer,
- His or her assessment of hazards andhis or her assessment of their own ability given the apparent conditions.

The engineer is expected to act within his or her duty as a professional to cause the necessary procedures and measures to be put in place to protect him or herself, isolate people from hazards, manage hazards or eliminate hazards [13].

Professional Services to Be Provided for Preparing Forensic Report: The Forensic expert shall be appointed under the terms and conditions of the court of law, police, or who officially asked a forensic report to provide professional consultancy services to court as example.The main objective of this study is to identify quantify and communicate to decision-makers and other stakeholders the risk from flooding of land property and people. The purpose is to provide sufficient information so that appropriate and effective planning decisions can be made in terms of zoning of land for development approving applications for proposed development, the provision of flood protection scheme or the installation of flood warning scheme. The forensic report shall also consider potential social,environmental and economic impacts of future urbanization which is likely to increase surface runoff over time [12].

The main tasks to be addressed shall include but not limited to the following:

Data Acquisition:

- Overview of the current state of the knowledge and identify the need for forensic reports.
- Develop overarching data format and modeling standards;
- Acquire,organize and document best available data from various stakeholders and agencies in regard to hydrologic data and where available stream gauge data, topographic and cadastral survey data, historical flood information,environmental, catchment topography, aerial photos, necessary groundwater and surface water bathymetry (up to an extent where the boundary condition will be set),[11] land use and archaeological data etc.;
- It is the responsibility of the forensic expert to evaluate and identify any gaps, inconsistencies and discrepancies for the exiting data and shall make proposals for the rectification of these inconsistencies and discrepancies and the gaps to be filled;
- It is the responsibility of the forensic expert to contact stakeholders or any other agencies,if it is required, for gathering any new, missing or updating data;
- It is the responsibility of the forensic expert,if required, carry out additional survey/studies to acquire any necessary data [16];
- Detailed approach to the collection and assessment of data to be presented in the first meeting with„ court of law, police, the insurance company, etc.“ and to be included in the Methodology Statement Report no more than two weeks after the meeting. The forensic expert shall identify any required additional data and add it as a part of the Methodology Statement Report for the „court of law, police, the insurance company, etc.“to approve;„court of law, police, the insurance company, etc.“, or any other agencies shall reserve the copyright of any provided or collected data and the forensic expert shall not use the said data for purposes other than what have been mentioned in expert evidence documents[19].

Data Analysis:

- Watershed Analysis Mapping of existing and potential "flood plain" areas covering the entire Country. Identification of catchment boundaries and drainage routes and existing infrastructure.The plan should indicate the size of catchments or sub-catchments areas and low lying areas where the runoff collects[19].
- Prepare a Digital Terrain Model (DTM),using Digital Topographic Database with detailed ground survey

of structures. The results of the data collection and the DTM shall be organized and stored in a Geographic Information Systems (GIS).The expert shall, at as early a stage as possible, submit all (DTM) data and plans to the Project Coordinator to enable verification and approval by „court of law, police, the insurance company, etc.

- Identify the potential for development of secondary flood plain areas. Confirm if these areas are critical for storage-attenuation or if partial or complete urbanization is feasible.
- Investigate tidal surge,storm surge levels, combined tide and storm surge, effects of climate change, design ocean water level to establish appropriate for flood assessment.
- Combined with urban development plans or strategies, indicate the potential risk and magnitude of flood problems and develop strategy to limit the impacts of existing flooding problems to acceptable levels[9].
- Preserve and enhance where possible, the natural function of the floodplain to convey flood waters and/or sustain flood dependent ecosystems through the use of building codes etc.
- Undertake a comprehensive assessment of available data in the region relating to climate change and establish relevant parameters e.g. potential rise in sea level and changes in rainfall intensity for their application in the hydrologic and hydraulic models of this flood study. These otential changing parameters as a result of climate change must be validated and peer reviewed before their application [19].

Hydrological Modeling: The hydrology of arid and semi-arid areas is very different from that of humid areas. The hydrological characteristics of arid areas as Saudi Arabia may present problems for conventional methods of analysis.Rainfall data and findings of this study must be used as the basis for derivation of flood hydrograph and development of appropriate methods for hydrological analysis and flood design[14].The main tasks to be addressed shall include but not limited to the following [4]:

- Development of methodology for hydrological modeling;
- Selection of hydrological model;
- Selection of design average recurrence interval; Also investigate potential impact of climate change on the design.
- Determination of flood hydrograph and prediction of the impact of floods using industry standard floodplain modeling software tools.Potential effects of climate change scenarios shall be taken into consideration such as sea level rise;
- Calibration of the model with actual flow records is strongly recommended;
- Modeling shall be presented in report form which shall also include modeling methodology,model building, model validation and calibration;
- Perform quality control/quality assurance on the results, make any necessary corrections and establish base flood elevations [5].

Hydraulic Modeling: The following steps (but not limited to) shall be undertaken by the consultants[14]:

- Development of methodology for hydraulic modeling;
- Selection of hydraulic model;
- A dynamic and flexible hydraulic modelling approach shall be applied that incorporates both one and two dimensional hydraulic models to provide the most appropriate description of flooding within the study area. The one-dimensional model shall be used for scenario and sensitivity testing.Once the system behaviour has been determined, the more detailed two-dimensional model shall be used to verify the results and provide more detailed flooding information[2];
- Flood inundation mapping for the selected design ARIs;
- Flood heights at all key locations as approved by the client shall be determined for all ARI floods based on hydraulic modeling; and assess the potential impacts of climate change to demonstrate the sensitivity of an area to increased flows or sea levels.

Prepare a Flood Study Report: Preparea FloodStudyReportsummarizingtheworks carried out. The exactscopeand format of thesereports shall be agreed with the client. In thisrespect,theconsultant shall submit acomprehensive"tableof content"covering all aspects of the study prior to preparationof the report. Thereportshallalsocontain butnot limited tothe following [6]:

- Copies of the comments made during the presentation,on all submissions and corresponding actions taken;
- Copies of all the correspondences with the authorities and the client, technical notes and minutes of the meetings; and

- Calculations, computation, assumptions, graphs, charts and models etc.
- The reportshouldbecomprehensive enough toprovidedata information,studies, analysesand recommendations inconjunction with the other elementsof these projects.
- As part of thereporting,the consultant must produce an appropriate "ExecutiveSummary" document (notmore than 50pages) for theuseby seniormanagementand higher authorities for general awarenessas well as decisionmaking and relevantinvestment for mitigatingall potential flooding problems[13].
- All reports, analyses,calculations,drawings or any form of data prepared, produced inrelationtoforensic report.

CONCLUSIONS AND DISCUSSION

Flood problems are often the subject of expert assessment. The reason is the considerable material damage and damage to health and lives of people caused by flooding area. Difficulties in the assessment stems primarily from the significant uncertainty the available evidence. This uncertainty increases improves as the time between flood events and report processing. In doing so, in practice, this time often varies from 2 to 10 years.

However in general, the significantly better substrates can be provided if the assessmentthere is already an event in the investigation of the Police than in the case of judicial proceedings. Although it depends on the individuality of the sponsor, It can be generally stated that, in providing substrates is significantlyflexible cooperation with the Police than during other proceedings. Another important fact is the long lifetime of hydraulic structures and in many cases even today unsatisfactory values historically considered design parameters.

They correspond to the former knowledge of hydrological conditions, but also sometimes less intense use of the protected area. Assessment is needed in these cases bind to contemporary regulations (standards, laws, decrees), which are in older waterworks difficult securable.Experience shows that practically never be fulfilled authority required processing time (eg. 30 days). The assessment is always providing additional documentation, which is more time consuming. Therefore in many cases, flood reports replenishment within the additions are designed based on updated documents to add information and the opinions.

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