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Trends in hydrologic prediction for the design of hydraulic projects

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Abstract

Determination of runoff and related design discharges under past and future conditions are key elements for the design of flood defense, watercourse demarcation, urban stormwater, road drainage systems. Prediction is difficult and involves high uncertainty, especially for ungaged watersheds. Advanced computer capabilities provided by GIS and hydrologic modeling software facilitate computations and allow for the comparison of results by different approaches. Still many empirical relations are included, based on limited field data developed decades ago. Ministry of Infrastructure and Transportation, Greece, is in the process of updating design guidelines for hydraulic projects, including hydrologic computations. Special Secretariat for Water, Ministry of the Environment and Energy, for the implementation of 2007/60/EU Floods Directive published idf relations for all areas of Greece, based on advanced methodology. Internationally there is a trend towards risk-based design. The basic form of risk-based optimization is economic optimization aiming at minimization of the lifetime cost of the project. Climate change impacts is an additional issue that has to be addressed and research for the development of related guidelines is still under way in many countries. Economic and climate change projections also involve high uncertainty.

Keywords: hydrologic prediction, peak discharge, design guidelines, hydraulic projects

1 Introduction

One of the main objectives of Hydrology Studies is estimation and prediction of runoff and related design discharges under past and future conditions, key elements for the design of flood defense, watercourse demarcation, urban stormwater, road drainage systems.

In Greece guidelines for hydrology and hydraulic projects are given in PD696 (FEK 301A/1974), while demarcation studies of watercourses are carried out according to Law 4258 (FEK 94A/2014) and specifications published in FEK428B/2017. Ministry of Infrastructure and Transportation, is currently in the process of updating design guidelines for hydraulic projects, including hydrologic computations. Specifications for the deliverables of Hydraulic Studies were published recently in FEK 1047B/2019.

For implementation of 2007/60/EU Floods Directive in Europe, more and more advanced methodologies and related software are used for the development of Flood Hazard Maps. In Greece the Special Secretariat for Water, Ministry of the Environment and Energy, is responsible for the required flood risk assessment and the implementation of the Floods Directive 2007/60/EC. For the development of Flood Risk Management Plans (FRMP) and Flood hazard Maps (FHM) specific guidelines were issued on the methodology and assumptions to be used for the derivation of IDF curve, flood hydrographs, design rainfall distributions and routing, and IDF relations were published for use for all areas in Greece.

Internationally there is a trend towards risk-based design. The basic form of risk-based optimization is economic optimization aiming at minimization of the lifetime cost of the project. After more than fifty years Chow's Handbook of Applied Hydrology has been revised (Singh, 2017) and expanded to include many new developments and applications, with topics covering Geographical Information Systems, Artificial Neural Networks, Predictive Uncertainty Assessment and Decision Making, Risk-Reliability Analysis, Scaling and Fractals, Hydroclimatology: Global Warming and Climate Change, Sediment and Pollutant Transport, Environmental Flows, etc, and in Part Future, Extra-terrestial water and Social Hydrology, among others.

2 Climate Change

The Ministry of the Environment and Energy, Greece, states that on a national level, tackling climate change is a main priority for the Government and the Ministry as Climate Change has already noticeable impacts, such as rising temperatures and sea level (due to the melting of Polar ice), and a more frequent occurrence of floods and storms. These impacts will have an effect, among others, on the balance of the ecosystem, water and food supply, public health, industry, agriculture and infrastructure. Evidence of recent scientific research, by the Intergovernmental Panel for Climate Change, 5th Assessment Report, (IPCC, AR5), has affirmed the negative impact of climate change. Dealing with climate change demands actions for the reduction of greenhouse gas emissions (mitigation) and adaptation to prepare for the changes we cannot avoid.

There is ongoing research in many countries by agencies in order to assess the cost of adaptation and develop new guidelines for the design and maintenance of affected infrastructure. For this purpose analysis including non-stationarity of time series, downscaling of climate models, inventory of structures, including design features, and maintenance practice, are needed. Of particular interest are reports related to highways and railways by EU (2012), TRB (2014). USACE (2016) issued a guidance for incorporating climate change impacts to inland hydrology in civil works studies, requiring qualitative analysis, whereas for changes other than climate that affect hydrology, reference is made to guidance dated to 1994. Economic and climate change projections also involve high uncertainty. USEPA has developed a Climate Assessment Tool that can perform simulations by applying a set of plausible changes to a historic data set.

3 Main Issues

3.1 Methods of peak discharge estimation

In Greece methods to be used, presently include the rational method, the Fuller formula and hydrograph development in cases of large basins that should be divided into subbasins. The use of the rational method should be limited to small basins and the use of empirical methods like Fuller eliminated from general use. Complex hydrologic systems should be analyzed using hydrographs. Advanced computer capabilities provided by GIS and hydrologic modeling software facilitate computations, using DEMs, spatial averaging of soil, moisture, and land use data, and allow for the comparison of results by different approaches, as well as estimation of the predicitve uncertainty arising from the parameters involved.

3.2 Time of concentration

While the time parameter is crucial, most empirical relations used were developed decades ago based on limited field data. There are indications that time of concentration decreases with increasing period of return. A modified Giandotti' s formula has been developed and is being used in the FRMP in Greece. Results can be comparable with Kirpich' s formula if appropriate computation of the slope parameter is used.

3.3 Rainfall

Methodologies for determination of idf curves using appropriate distribution including all durations and return periods are currently used and appropriate in combination with both the rational method and hydrographs. Trends from long time series need to be reviewed for climate change indications. Time distribution for design purposes can be easily varied through software use. For PMP estimation should be based on the WMO (2009) report.

4 Software Use

Both free and commercially available software for hydrologic time series analysis and simulation facilitates hydrologic studies, but needs to be carefully used taking into account assumptions and limitations involved. In Greece many free software packages have been developed by ITIA research team of NTUA (Hydrognomon, Zygos, Pythia etc.). Free software by USACE Hydrologic Engineering Center, like HECHMS, HECRAS are widely used and regularly updated with additional capabilities. Benchmarking is important and combined efforts by different countries are giving good results, like the research document (USACE, 2018) that summarizes how HEC-RAS performed in the 2D modeling benchmark tests developed by the UK's Joint Defra Environment Agency.

5 Conclusions

Trends in hydrologic prediction for the design of hydraulic projects include the use of advanced methodologies, software, estimation of the predicitve uncertainty arising from the parameters involved.

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