Updating hydrologic studies and the impact on hydraulic design

DANIIL E.[1*] and MICHAS S.[1]

[1]HYDROEXIGIANTIKI, Evias 3, 15125 Marousi, Greece

*corresponding author:
e-mail: edaniil@hydroex.gr, info@hydroex.gr

Abstract Flood events causing damages, fatalities, trigger new flood protection studies. Updated hydrologic study conforming with recent developments is required. Implementation of 2007/60/EU Directive led to Preliminary Flood Risk Assessment and Flood Risk Management Plans, establishment of related guidelines and point precipitation IDF relations for all stations in Greece, often giving higher rainfall depths. Use of the CN method for hydrologic losses gives more than proportional increases in the resulting discharge predictions. Comparing past and future conditions (2000-2018) has been facilitated by available landcover data through the Copernicus program, while designer's judgment is still needed to predict further trends in land practices/ urban development. Evaluation of climate change effect is often required for project financing. Main issues are sea level rise, increase of precipitation extremes, associated landslide risk. Current predictions involve high uncertainty. Precipitation trends investigated reveal no evidence of climate change effect, due to limited records. It is suggested that confidence limits are used instead. Urban networks designed for low return periods is difficult to be upgraded. Main watercourses' flood protection design has to account for the anticipated worsening of runoff to achieve the required level of flood protection and resilience. Case studies for two major streams in Greece are presented.

Keywords: hydrologic prediction, flood protection, hydraulic design, IDFs, past and present conditions

1 Introduction

In Greece the Special Secretariat for Water, Ministry of the Environment and Energy, is responsible for flood risk assessment and the implementation of the 2007/60/EU Floods Directive. Implementation of the Directive led to Preliminary Flood Risk Assessment and Flood Risk Management Plans (FRMPs), establishment of uniform related guidelines (e.g. storm duration, rainfall distribution) and the development of point precipitation IDF relations, expressed in the same form, for all meteorological stations in Greece. According to specifications these idf curves should be used with appropriate adjustments for elevation and spatial integration.

Use of hydrologic models using hydrographs and the CN method for hydrologic losses is widespread, while the use of the rational and empirical methods tends to become limited to small catchments.

Issues of the effect of climate change affect the hydraulic design for flood protection, although a national policy is still under development. Increasing resilience of existing stormwater systems is a new parameter in the design.

2 Hydrologic issues

Hydrologic study should provide design discharges for the required return periods for the hydraulic design. Newly available data (e.g. extended time series) and methodologies (hydrologic model, assessment of parameters using GIS, new idfs), as developed for the FRMPs, should be taken into account.

2.1 Discharge Determination

In Greece according to national guidelines relating to stormwater projects (PD696/74) the methods to be used include the rational method, the Fuller formula and hydrograph development in cases of large basins that should be divided into subbasins. The guidelines are presently under revision, while FRMPs have to be taken into account. Recently the use hydrologic models, including more subbasins, with hydrographs, in new hydrologic studies has become more widespread, facilitated also by the availability of open access software.

Use of the new idfs often results in higher rainfall depths/ intensities and with the combination of the CN method for hydrologic losses result in more than proportional increase of the corresponding design discharge.

2.2 Return period

Training works of main watercourses are designed for a return period of 50yrs (which is also used for demarcation according to recent guidelines). Stormwater systems are designed for T=2~10 yrs. Bridge pier protection works against erosion should be designed for T=500yrs. In most cases the design is based on steady flow equal to the peak flow discharge.

Peak discharge return period is assumed equal to that of precipitation. Rainfall distribution may differentiate the resulting peak. In recent implementation of the Flood Directive for flood risk assessment in Greece the following were adopted: T=50 high probability with alternating blocks distribution, T=100 average probability with alternating blocks distribution and T=1000 low probability with worst profile distribution.

2.3 Assessment of storm events' return period

As extreme storm events often indicate the need for new protection works and trigger new studies, the question of the estimation of the return period of the event arises. Given the non-uniformity of the storm and the lack of discharge data, only indications can be given by back-calculation from IDFs using the most critical time period of the storm. In the case where only daily data is available adjustment should be made for sample size and the uncertainty is higher.

3 Hydraulic design

3.1 Watercourses flowing through urban areas

Existing training works of watercourses flowing through cities in most cases are designed for a lower return period/ design discharge compared to that required according to recent developments. Also the main channel of ephemeral watercourses is formed to accommodate common floods, appearing a few times a year, floods of high return period most often are associated with inundation of overbank areas and shallow water flow. This type of flow cannot be represented adequately with one dimensional flow models. A combination of 1D, 2D routing models can give a more realistic result regarding the capacity of the system. However, in order to get high resolution results, detailed topographical data are needed.

Redesigning the training works of a main watercourse is usually realized by increased cross section with widening and/or deeper excavation. Small diversions to the main watercourse can be easily accommodated, alleviating some city networks, that would be difficult to upgrade.

3.2 Road crossings

Road bridges over watercourses have to be designed with adequate freeboard, higher return period, and account for sediment transport leading to increased discharge.

3.3 Effects of climate change

Evaluation of climate change effect is often required for project financing. To achieve the required level of flood protection and resilience, main issues of sea level rise, increase of precipitation extremes and associated landslide risk have to be accounted for. Current predictions of involve high uncertainty. Precipitation trends investigated reveal no evidence of climate change effect, due to limited records. It is suggested that idf upper confidence limits are used for the increased discharge and rainfall intensities estimation.

Sea level rise has to be taken into account in the specification of materials used for training works to assure durability to saline exposure.

Urban networks designed for low return periods is difficult to be upgraded. Main watercourses flood protection design has to account for the anticipated worsening of runoff.

4 Case studies

4.1 Nedon river, Kalamata, Peloponnese

Nedon river flows through the city of Kalamata. The most recent storm event in the area occurred on 06-07/09/2016, causing flooding and sediment flows mainly north of the city and around the road circumventing the city (Perimetriki Odos).

By comparison to the new idf relations a critical return period of 500~1000 yrs was estimated for the area of Kalamata city.

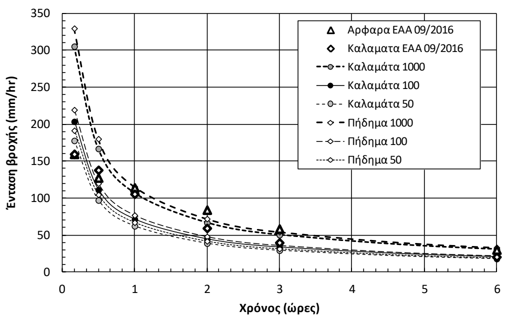

Figure 1. IDF comparison with 06-07/09/2016 Kalamata rainfall event data

Table 1. Estimated return period of 06-07/09/2016 storm event near Kalamata (IDF: Kalamata, EGY)

d (hr)	0.167	0.50	1	2	3	6	12	24
Kalamata	**30**	**326**	**928**	**500**	**257**	**101**	**50**	**55**
Arfara	30	210	1500	4300	2583	885	480	793
Kopanaki	2	8	9	10	11	9	11	14

Comparing land uses of 2000, 2018 it was noted that forests were restricted by the development of agricultural areas and the increase of shrub vegetation, resulting in small CN increase.

Table 2. Nedon river catchment area - land use

	Agriculture (%)	Forests (%)	Shrubs etc (%)	Urban areas (%)
2018	14.87	43.48	35.75	5.90
2000	8.76	56.17	30.00	5.07
2018-2000	+6.11	-12.69	+5.75	+0.83

CN_2018=59.0, CN_2000=58.5

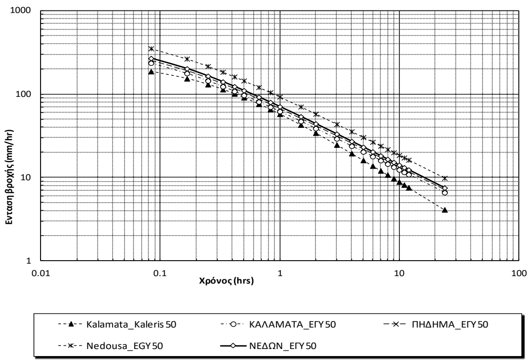

Figure 2. IDF comparison for T=50yrs for Nedon

Existing training works were designed for 300m^3/s. Use of a complete hydrologic model and the new idf curve results in Q50~450m^3/s, indicating the need for additional flood protection.

Table 1. Nedon river discharge (m^3/s) estimation

Location	Study	idf	A (km^2)	Q10	Q50	Q100
Sparti bridge	(2000)				259.7	316.7
Sparti bridge	(1999)		121.5	299.8	389.1	427.5
Perimetriki	(2020)		121.4	242.2	451.7	568.0
OSE	(2014)	KK	128.4		292.5	
OSE	(2014)	KY	128.4		488.0	
OSE	(2014)	KS	128.4		440.2	
OSE	(2020)	KE	135.2	248.9	462.9	581.6

Different timing of peaks due to the short travel time through diversion works and long time of concentration of the upstream catchment area can be used for a more economical design.

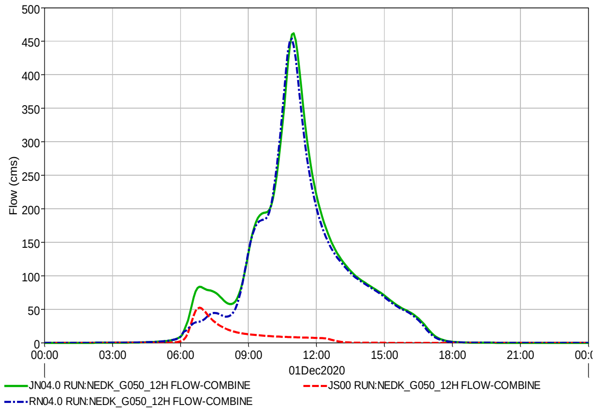

Figure 3. Hydrographs at confluence of diversion tunnel to Nedon, T=50yrs

The study of the redesign of training works with the less possible interference with public uses is underway.

4.2 Lilas river, Evia

Lilas river basin in Evia is located south of Chalkis, does not flow though a city and does not have any major training works. There are, however, establishments around its outflow in Evoikos gulf that are in the flood hazard area.

Major storm events occured on 11-12/09/2009 and 08/09/2020. Road crossing (bridges) have been damaged to various extents, requiring actions from scour countermeasures to the building of new structures.

By comparison to the new idf relations a critical return period of ~1500 yrs was estimated for the 2020 event.

Table 3. Estimated return period (yrs) of storm events

	h (mm)	d (hr)	i (mm/hr)	T_est St_E	T_est L_211
Steni_NOA 2020-08-09, 03:30-07:30	200	4.00	50.00	**684**	4287
2020-08-09, 23:20-07:30	299	8.17	36.61	**1534**	10230
2020-08-09*	338.5	24	14.11	**242**	1389
2009-09-11 *	195.9	24	8.16	13	56
2009-09-12 *	229.8	24	9.58	28	131
2009-09-(11+12)*	425.8	48	8.87	**197**	1110
Psachna_NOA 2020-08-09 *	255.4	24	10.64	49	**241**

* daily values adjusted to max24h

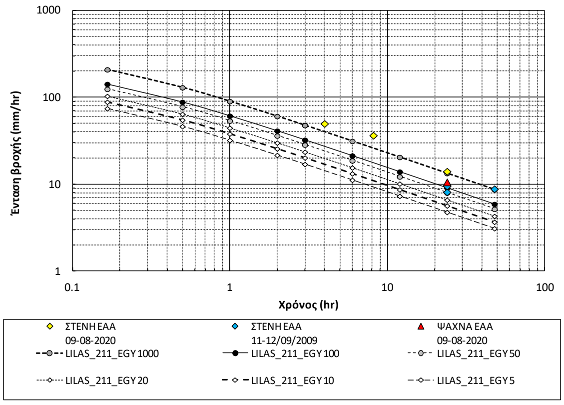

Figure 4. IDF comparison with 2009, 2020 rainfall event data in Evia

Comparing land uses of 2000, 2018 it was noted that agricultural areas were taken over by forest. Urban areas almost doubled but still they cover a very small percent of the catchment area, mostly downstream, not affecting peak flow.

Table 4. Lilas river catchment area - land uses

	Agricultu re (%)	Forests (%)	Shrubs etc (%)	Urban areas (%)
2018	38.94	17.00	42.48	1.58
2000	40.92	14.95	43.39	0.74
2018-2000	-1.98	+2.05	-0.91	+0.84

CN_2018=69.5, CN_2000=69.6

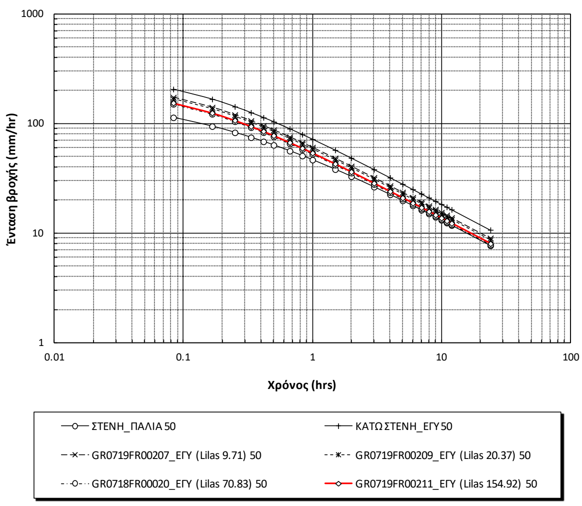

Figure 5. IDF comparison for T=50yrs for Lilas

Table 1. Lilas river discharge (m3/s) estimation, A=257 km^2, CN=69.5, D=24 hrs

Study	Method	Q10	Q50	Q100	Q500	Q1000
(2017)	Rational	380	532			
FRMP	Hydro-graphs		609	790		1938
(2020)	Hydro-graphs		635	795	1242	

The new bridges are designed with freeboard to accommodate the 100-yr flood, accounting also for the augmentation due to sediment transport, and appropriate scour measures. The design does not interfere with the ongoing study for training works.

5 Conclusions

Updated hydrologic study conforming with recent developments (new idfs, land use changes, FRMPs methods and guidelines) often leads to increased design discharges, augmented even more if climate change or sediment transport is accounted for. Use of the CN method for hydrologic losses gives more than proportional increases in the resulting discharge predictions. Comparing past and future conditions (2000-2018) has been facilitated by available landcover data through the Copernicus program, while designer's judgment is still needed to predict further trends in land practices/ urban development. Evaluation of climate change effect is often required for project financing. Main issues are sea level rise, increase of precipitation extremes, associated landslide risk. Current predictions involve high uncertainty. Precipitation trends investigated reveal no evidence of climate change effect, due to limited records. It is suggested that confidence limits are used instead.

Urban networks designed for low return periods is difficult to be upgraded. Main watercourses' flood protection design has to account for the anticipated worsening of runoff to achieve the required level of flood protection and resilience. Case studies for two major streams in Greece are presented: Nedon river flowing through the city of Kalamata and Lilas river in Evia, where main road crossings damaged by the flood are to be repaired and/or reconstructed.

6 References

FRMPs, Greece, http://floods.ypeka.gr

EGY (2016), Special Secretariat for Water, Development of IDF curves for Greece.

Papanicolaou, D and M. Diakakis (2011), Changes in the intensity and distribution of natural disasters, Committee on Climate Change Impact.

Daniil E., Michas S., and Aerakis G. (2017), "Hydrologic issues in demarcation studies of watercourses in Greece", 15th International Conference on Environmental Science and Technology (CEST 2017), Rhodes, Greece, 31 August to 2 September 2017.

Daniil E.I. and Michas S.N. (2019), "Trends in hydrologic prediction for the design of hydraulic projects", 16th International Conference on Environmental Science and Technology (CEST 2019), Rhodes, Greece, 4 to 7 September 2019.