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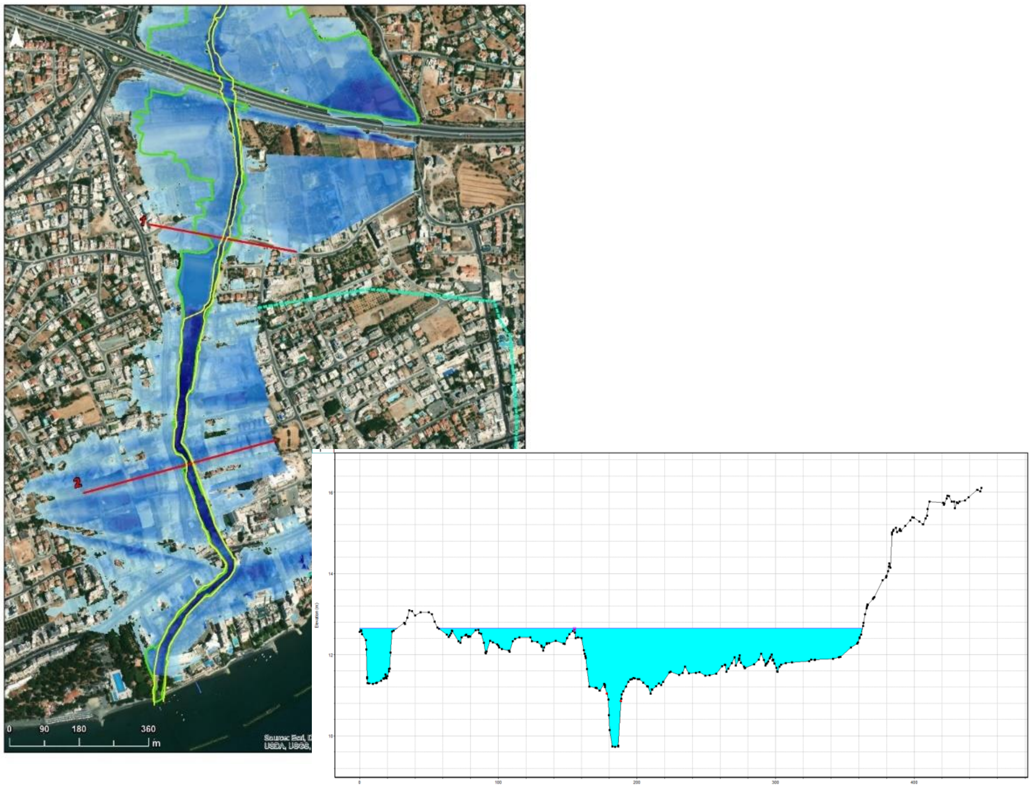

JULY
2020

IMPLEMENTATION OF FLOOD MAPS FOR FUTURE MODELLED EXTREME RAINFALL EVENTS FOR THE GERMASOGEIA RIVER

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TABLE OF CONTENTS

1. INTRODUCTION

I.A.CO Environmental and Water Consultants Ltd has been commissioned by The Cyprus Institute (CYI) to implement flood maps for future modelled extreme rainfall events for the Germasogeia river in Limassol.

The scope of this study is to support the **ERMIS-F**loods Project[1]. The ERMIS-F (Environmental Risk Management and Information Service – Floods) is supported by the European Commission, and intends to create a model of an Integrated Public Service, a Digital System and an Online Information Platform regarding floods and other natural and environmental risks. The "ERMIS-F" is part of the INTERREG V-A Program "Greece – Cyprus 2014-2020" extending from January 2018 to June 2020.

ERMIS-Floods ambition is to function as a unique source of information on different kinds of natural hazards (starting with floods) through**:**

- a GIS web-portal (ERMIS-F portal)
- a Knowledge Data Base
- a Social Network application
- a Crowdsourcing application
- An Early Warning System

The aim is to make available to the public useful scientific information, which can be incorporated into the decision-making tools handled by each interested target group: namely, the local government, professional groups, environmental organizations, civil society, scientific community, etc.

The project is piloted in Larnaka, Lesvos and Chania regions, and is being implemented by a specialized team from the Cyprus Institute (coordinator), the University of the Aegean and North Aegean Water Directorate, the Technical University of Crete and the Municipality of Chania.

[1] https://ermis-f.eu/ermis-f/

2. WATER DEVELOPMENT DEPARTMENT STUDY[2] - GERMASOGEIA WATERSHED

2.1 BRIEF DESCRIPTION OF METHODOLOGY AND DATA USED FOR THE WDD STUDY

In June 2014, the Water Development Department (WDD)[2] conducted a study on the assessment and management of flood risks for the Germasogeia River basin, within the framework of the implementation of the EU Directive 2007/60/EU.

The watershed of the Germasogeia river covers an area of 178km^2 with the catchment elevation ranging between 1.553m to 0m over a 37km of river length. For the hydrological analysis the watershed was divided into 39 sub-catchments as it is shown on Map 1. Germasogeia and Arakapas dams were constructed to provide water supply to the residential and agricultural areas. Germasogeia dam was constructed in 1968 and has a capacity of 13.5Mm^3 while Arakapas dam was constructed in 1975 and has a capacity of 129.000m^3. The flows of the river tributaries are monitored by four gauging stations. The segment of the river downstream the Germasogeia dam is designated as one of the nineteen areas of Potential Significant Flood Risk in Cyprus according to the Flood Directive implementation (WDD 2011)[3].

The hydrological model calibration was carried out with the following methodology:

i. Using historical floods → Runoff data from two flow gauging stations were used for the calibration of the model. Both stations are located upstream the Germasogeia dam as it can be seen on Map 1. Historical records of rainfall and flood events that occurred on 9th of January 1989 and 21st of November 1994 were used for the model calibration. The hydrological parameters of each sub-catchment (Curve Number and Initial Losses), after the calibration procedure, are shown in Table 1.

ii. Using statistical analysis of recorded annual peak → Annual recorded peak flows frequency analysis was performed using the Hydrognomon software[4] (ver. 4.1.0) in order to calculate the flood event at various return periods. Based on this analysis, the duration of the design storm events for 1 in 20, 100 and 500-yrs was determined, as well as the Antecedent Moisture Conditions (AMC).

[2] *WDD (Water Development Department), 2014. Areas of potentially significant flood risk (in Greek)*

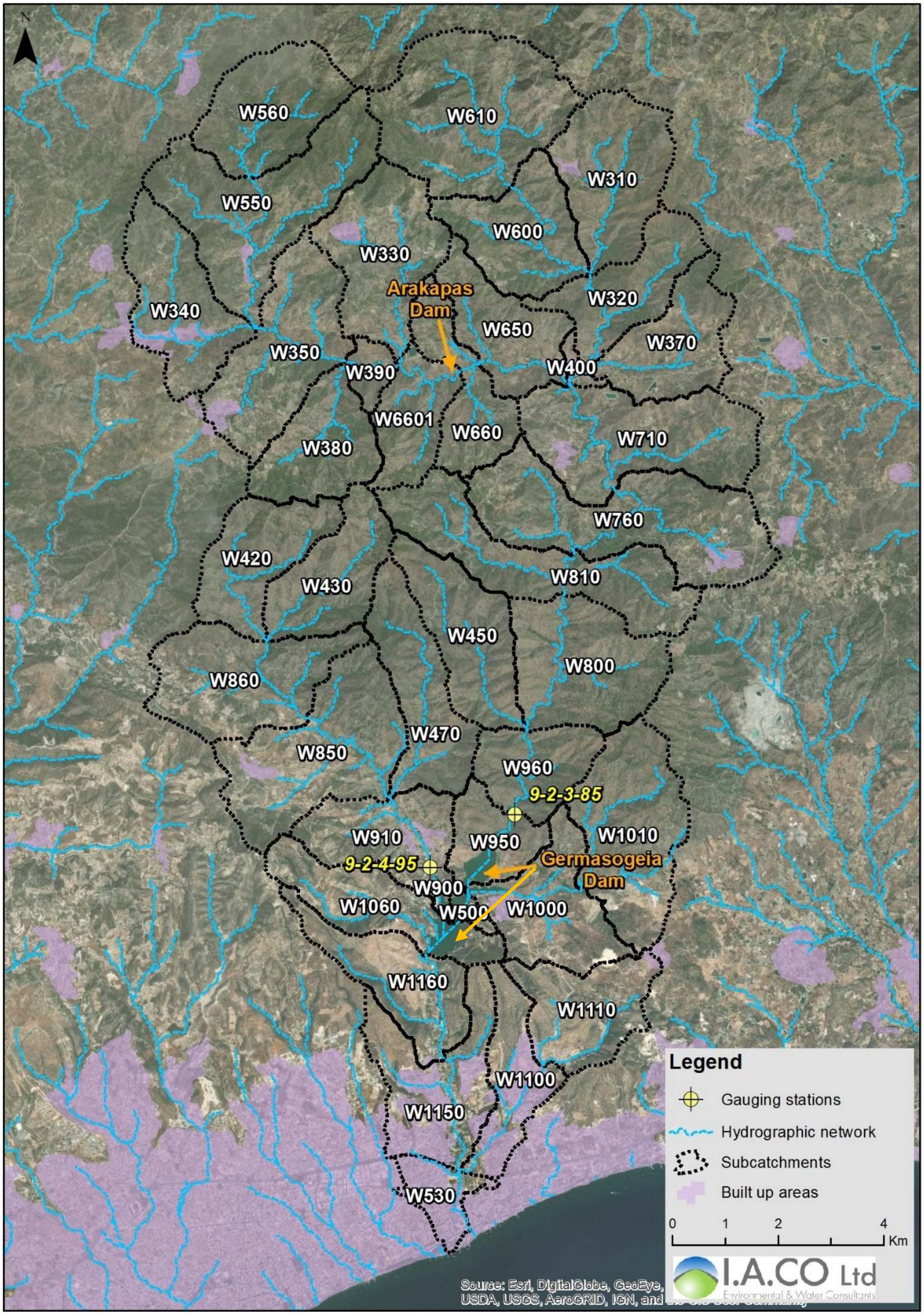
[3] *I.A.CO Ltd, 2011. Identification of potentially serious flooding risk areas. Water Development Department, Ministry of Agriculture, Natural Resources and Environment, Nicosia. (in Greek)*

[4] http://www.hydrognomon.org/

Table 1: Hydrological parameters for each sub-catchment

Sub-catchment	AMC_I		AMC_{II}		AMC_{III}		Lag Time (min)
	CN_I	Ia (mm)	CN_{II}	Ia (mm)	CN_{III}	Ia (mm)	
W1000	35	48,04	56	31,36	74	17,55	59,55
W1010	40	38,09	61	23,35	79	13,91	69,58
W1060	30	59,52	50	40,59	70	21,74	73,65
W1100	51	24,81	71	12,68	85	9,06	61,0
W1110	34	48,79	55	31,96	74	17,82	75,41
W1150	41	36,02	63	21,69	79	13,15	72,44
W1160	24	78,55	44	55,8	64	28,69	75,5
W310	27	68,5	47	47,8	67	25,02	48,24
W320	32	53,49	53	35,73	72	19,54	60,73
W330	38	40,79	60	25,53	77	14,90	59,61
W340	35	47,29	56	30,75	75	17,27	61,4
W350	40	38,2	61	23,44	78	13,95	66,36
W370	37	42,84	59	27,18	76	15,65	71,02
W380	32	53,63	53	35,85	72	19,59	43,23
W390	33	50,52	54	33,34	73	18,45	21,9
W400	47	29,13	67	16,15	83	10,64	16,92
W420	31	57,14	51	38,67	71	20,87	62,59
W430	31	57,14	51	38,67	71	20,87	56,18
W450	33	51,02	54	33,75	73	18,63	61,41
W470	37	42,89	59	27,21	76	15,67	64,19
W500	48	27,9	68	15,17	83	10,19	24, 68
W530	57	18,96	76	7,98	88	6,93	50,13
W550	33	50,48	55	33,32	73	18,44	68,94
W560	29	61,17	50	41,91	69	22,34	39,26
W600	34	98,88	55	32,5	74	18,06	50,16
W610	25	112,33	45	52,9	65	27,35	50,52
W650	38	81,71	60	25,6	77	14,92	58,99
W660	37	84,97	59	26,9	77	15,52	39,24
W6601	33	103,02	54	34,1	73	18,81	51,08
W710	28	95,76	49	44,0	69	23,31	74,36
W760	30	88,59	51	40,2	70	21,57	72,25
W800	35	95,08	56	30,9	75	17,36	67,39
W810	31	114,27	51	38,7	71	20,87	65,64
W850	37	86,96	58	27,7	76	15,88	52,36
W860	34	97,41	55	31,9	74	17,79	50,87
W900	49	51,93	70	13,6	84	9,48	21,69
W910	36	90,72	57	29,2	75	16,57	42,25
W950	45	61,93	66	17,6	82	11,31	41,76
W960	44	64,91	65	18,8	81	11,85	47,67

"AMC" = Antecedent Moisture Conditions (i, ii, iii refer to dry, average and wet condition), "CN" = Curve Number, and "Ia" is for Initial Losses



Map 1: Sub-catchments, flow gauging stations, river network, dams and built up areas

2.2 KEY RESULTS

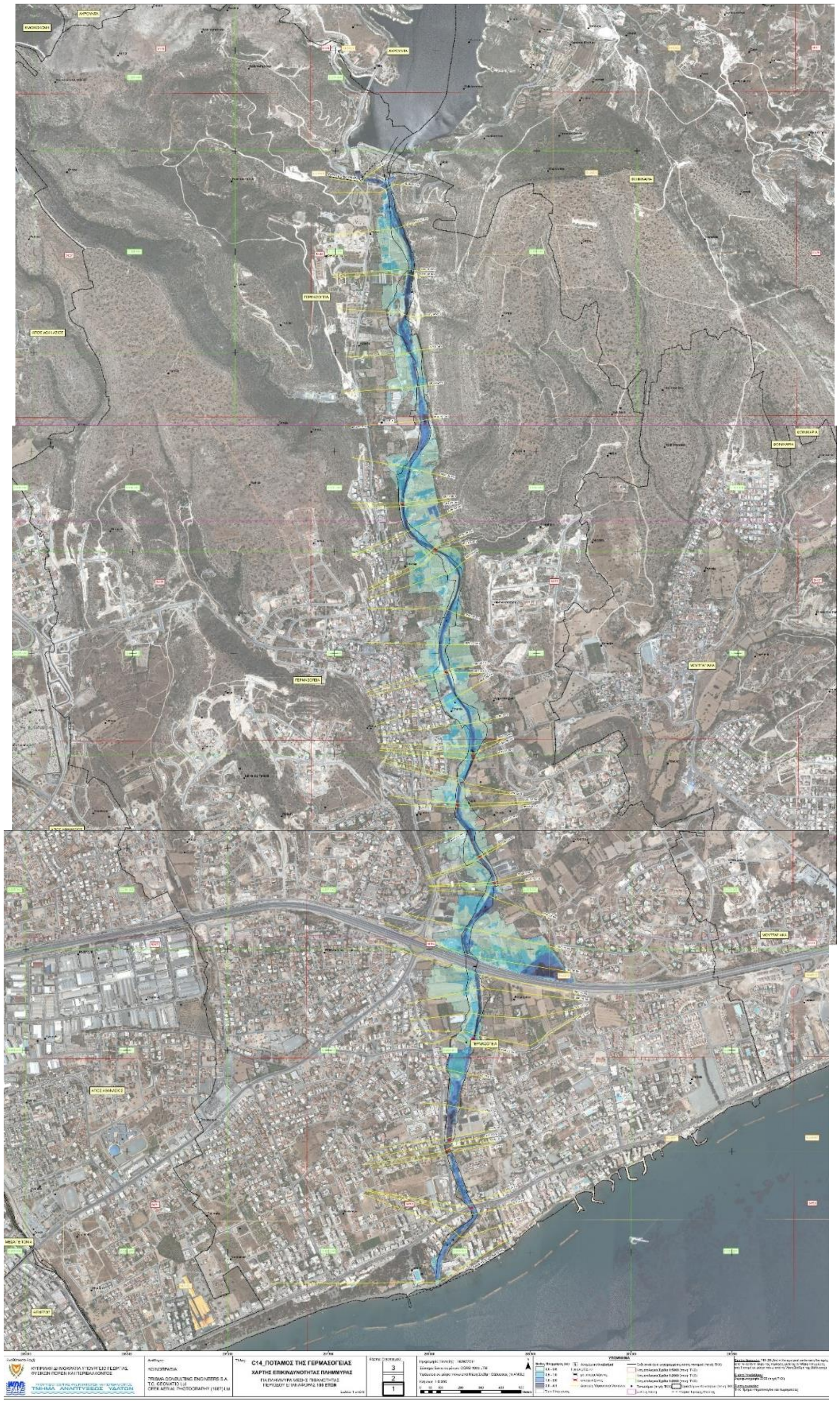
The hydrological analysis was performed considering average Antecedent Moisture Conditions (AMC_{ii}).

The results of the hydrological analysis for the 1 in 100-year flood event are shown in Table 2. The peak flow at the outlet of the model at the sea coast, was estimated at 150,4 m^3/s.

Table 2: Estimated peak flows of the WDD Study

Study area	Model peak flow (m^3/s)
Germasogeia basin outlet	150,4
9-2-4-95	32,9
9-2-3-85	174,7

The hydraulic analysis concerned the segment of Germasogeia River downstream the Germasogeia dam. The flood map, as derived by the WDD hydraulic analysis, for the 1 in 100-year flood event of the study area is shown on the Map 2 below.



Map 2: Flood map of the Germasogeia river for the 1 in 100-year flood event (WDD Study)

3. ERMIS – FLOOD PROJECT – GERMASOGEIA WATERSHED

3.1 MODEL OBJECTIVES

Germasogeia River is one of the case studies of the ERMIS-F Project with the research being focused on the impacts of climate and land use change to the floods. The overall goal is the utilization of the WDD calibrated hydrological model, in order to enable the assessment and management of single flood events in coping with future climate and land use changes.

The modelling of the future climate change scenarios has been carried out by the CYI and resulted to an ensemble set with five precipitation configurations in year 2054. The climate change scenarios were coupled with the Germasogeia dam initial storage conditions, as well as land use change scenarios. Further details about the examined scenarios are described further below.

3.2 MODEL APPLICATION

The model used for the hydrological analysis is the HEC-HMS and for the hydraulic simulation and generation of the flood maps the HEC-RAS and the HEC-GeoRAS models have been employed. The future extreme rainfall events, as derived and provided by the Cyprus Institute have been used to simulate and calculate the flood flows and for the generation of the relevant flood maps for various climate and land-use change scenarios.

→ **Hydrological Model**

The five future rainfall configurations (2054) have been simulated and output hydrographs were produced by the hydrological model.

All the five climate change scenarios were simulated assuming that the initial storage conditions of Germasogeia dam are at full level and 70% full (Dam capacity 13.5Mm^3). Based on the results of the hydrological simulations the most extreme scenario and the median scenario have been determined. In addition to this, the most extreme scenario was simulated assuming that the initial storage conditions of the dam were at 50%. Therefore, in total 11 hydrological simulations have been performed regarding the climate change scenarios.

Furthermore, the most extreme and the median scenarios were simulated in combination with land use scenarios (burnt forest areas) and two initial storage conditions of the dam, 100% and 50%. Thus, four hydrological simulations have been performed under both climate and land use change scenarios (see Table 3).

→ **Hydraulic Model**

The hydraulic model concerns the segment of the river downstream the Germasogeia dam which constitutes part of the urban area of the Germasogeia Municipality. Flood maps were produced as follows:

a) Two flood maps for the most extreme and the median scenarios with the assumption of the dam being full.

b) Two floods maps for the most extreme and the median scenarios with the assumption of the dam being 70% full.

c) One map for the most extreme scenario with the assumption of the dam being 50% full.

d) Two maps for the most extreme and the median scenarios with the assumption of the dam being full under land use change scenario (Burnt coniferous forest areas).

e) Two maps for the most extreme and the median scenarios with the assumption of the dam being 50% full under land use change scenario (Burnt coniferous forest areas).

In total, nine flood maps were produced under the various examined scenarios taking into account the climate change, the land use change and the attenuation effectiveness of Germasogeia dam initial storage conditions.

The following Table summarizes the performed simulations for the hydrological and hydraulic analysis.

Table 3: Performed simulations for the hydrological and hydraulic analysis

Precipitation member	Hydrological analysis					Hydraulic analysis/Flood maps
	Climate change scenarios			Land use change + Climate change scenarios		
	Dam full	Dam 70%	Dam 50%	Dam full	Dam 50%	
mp01*	✓	✓	✓	✓	✓	✓
mp02	✓	✓				
mp05	✓	✓				
mp06**	✓	✓		✓	✓	✓
mp16	✓	✓				

**Most Extreme scenario*
***Median Scenario*

3.3 Model Input Data

The main input parameters of the hydrologic model are the following:

→ Sub-catchment input parameters:
- Sub-catchment geometric properties (Area, Mean slope etc.)
- Losses – “SCS CN” method[5]
- Transformation method – “SCS” unit hydrograph

→ Stream input parameters
- Routing method – “Muskingum-Cunge”

→ Rainfall input data
- Modelled future extreme events as derived by Cyprus Institute (Five future rainfall configurations as an ensemble set of 2054).

Map 3 shows the sub-catchments and the Curve Number (see Table 1) used for the climate change scenarios for average Antecedent Moisture Conditions (AMCii) as derived by the WDD Study.

Regarding the land use change scenario, one future land use change scenario was developed considering that the forest areas are burnt (Arakapas Forest). For each sub-catchment, a new Curve Number was estimated, taking into account the Corine Land Cover (CLC) of 2018 and the soils, according to the methodology followed by the Water Development Department (WDD 2015) for the preparation of the Flood Hazard and Risk Maps for the implementation of the Article 6 of the Floods Directive 70(I)2010.

Specifically, the sub-catchments of which the forest cover (“coniferous forest”) exceeded the percentage of 50%, considered as burnt area. The new land use according to the CLC (2018)[6] was set to be the one of the “Burnt areas – 334”. Considering that the Hydrologic Soil Group (HSG) type is “D”, the new CN was estimated to be equal to “86” and the Initial Losses were also estimated using the new CN.

Map 4 shows the sub-catchments in which the “burnt scenario” was applied.

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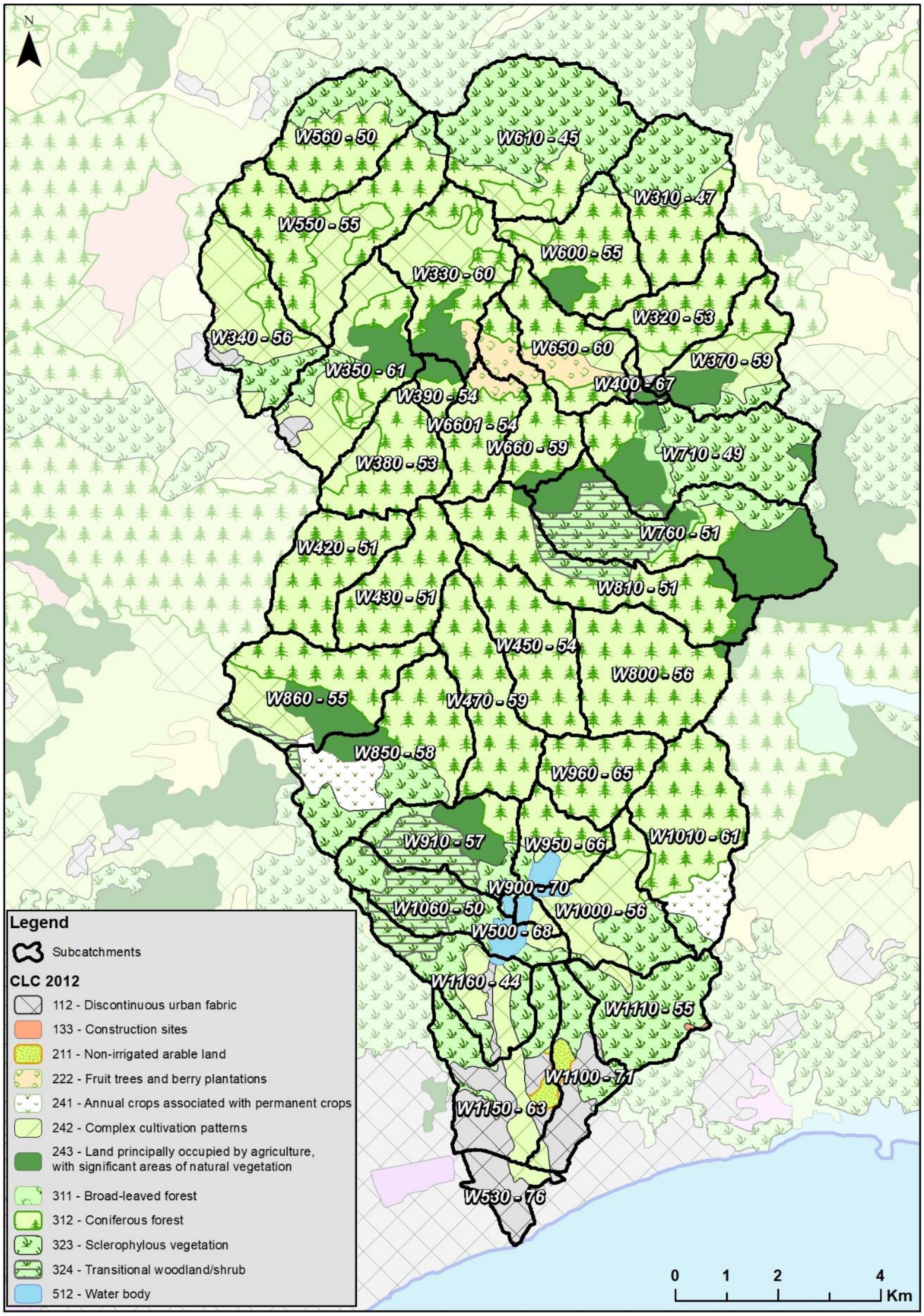
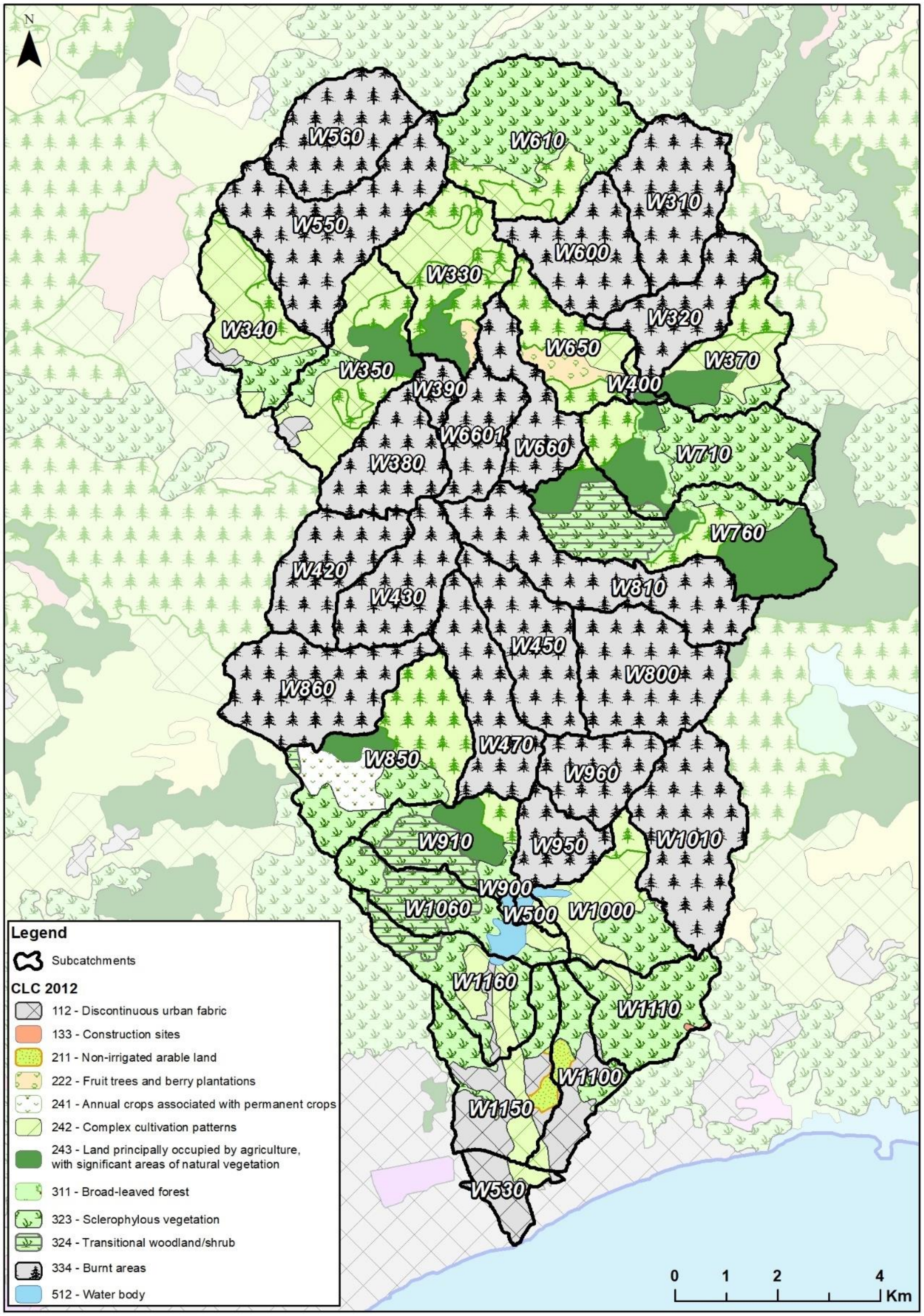
[5] https://www.hec.usace.army.mil/confluence/hmsdocs/hmstrm/infiltration-and-runoff-volume/scs-curve-number-loss-model

[6] https://land.copernicus.eu/pan-european/corine-land-cover/clc2018?tab=mapview



Map 3: Germasogeia river sub-catchments and Curve Number



Map 4: Land uses after the application of the "Burnt scenario"

3.4 RESULTS

➔ **Hydrological Model Results**

i) <u>Climate change scenarios</u>

The simulations were performed for five scenarios as mentioned above (see Table 3). The following Table summarizes the results of the simulations at the outlet of the model, while Figures 1 – 3 present the derived hydrographs at the outlet of the model for all the eleven scenarios. As it can be seen the most extreme precipitation member is the "mp01" where the peak discharge, for the dam being full, is 712,0m^3/s.

Table 4: Peak flows (m^3/s) and volume (m^3) at the outlet of the model for the climate change scenarios

Precipitation member	Average Rainfall within the watershed over 24 hour (mm)*	Climate change scenarios					
		Dam full		Dam 70% full		Dam 50% full	
		Peak Discharge (m^3/s)	Volume (m^3) x1000	Peak Discharge (m^3/s)	Volume (m^3) x1000	Peak Discharge (m^3/s)	Volume (m^3) x1000
mp01	141,1	711,8	7.445	472,2	3.389	212,6	944
mp02	101,4	395,5	3.455	9,1	87		
mp05	102,4	564,2	4.401	62,2	353		
mp06	121,6	525,2	5.427	241,1	1.375		
mp16	42,8	53,9	516	0,3	0,8		

** Average of all the grid points in the watershed*

- Dam full -

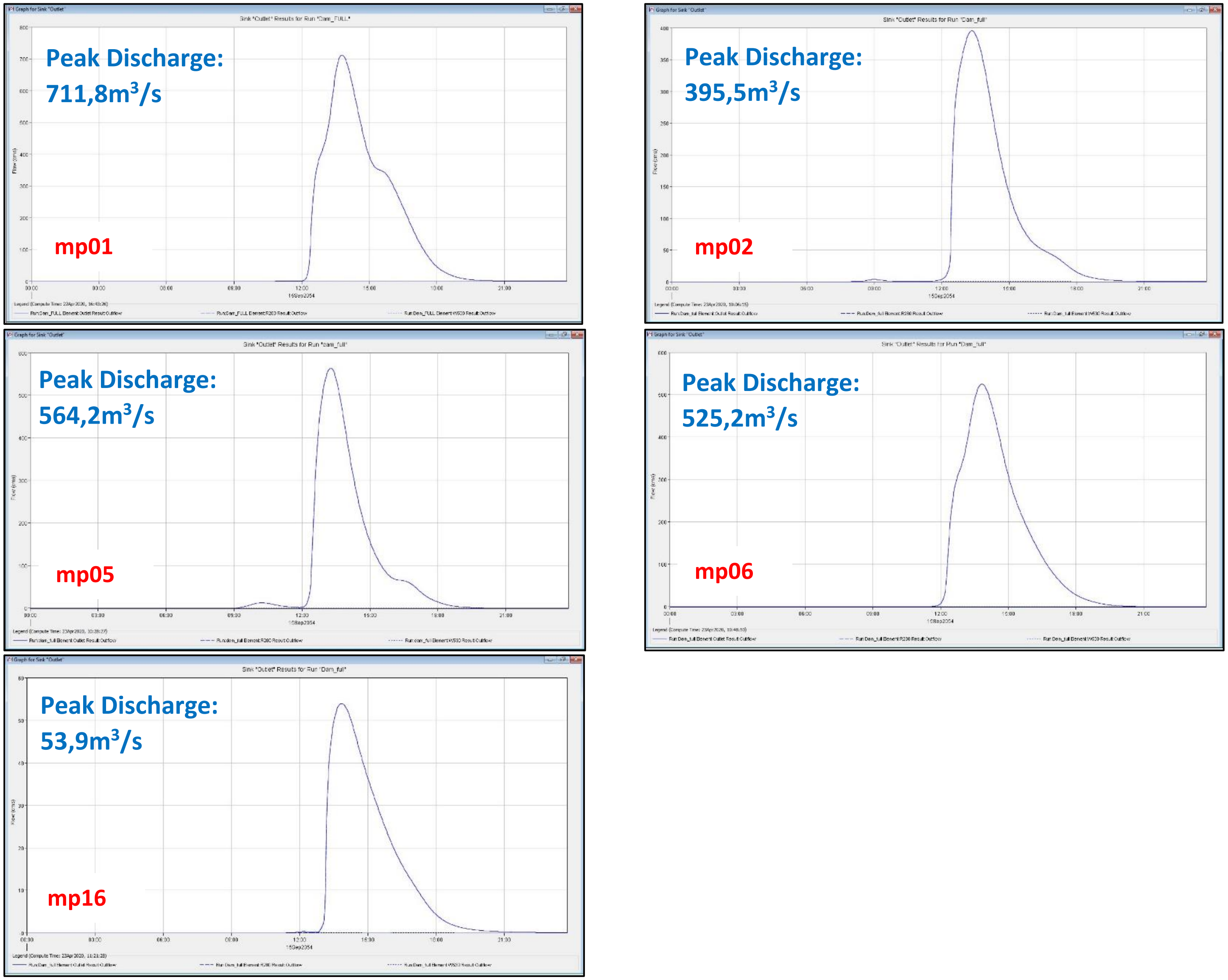


Figure 1: Hydrological analysis results of all scenarios, with the dam being full, at the outlet of the model

- Dam 70% full -

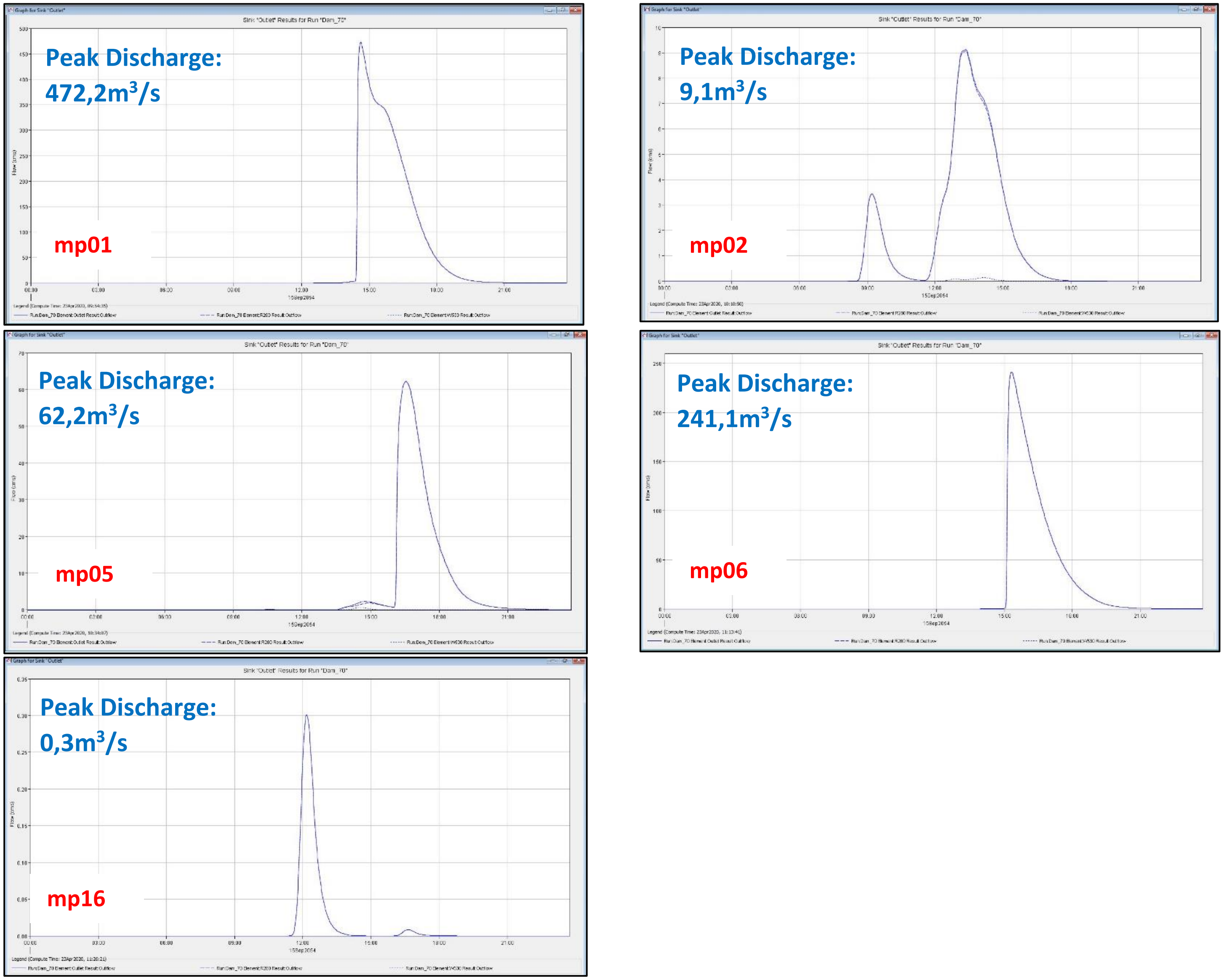


Figure 2: Hydrological analysis results of all scenarios, with the dam being 70% full, at the outlet of the model

- Dam 50% full -

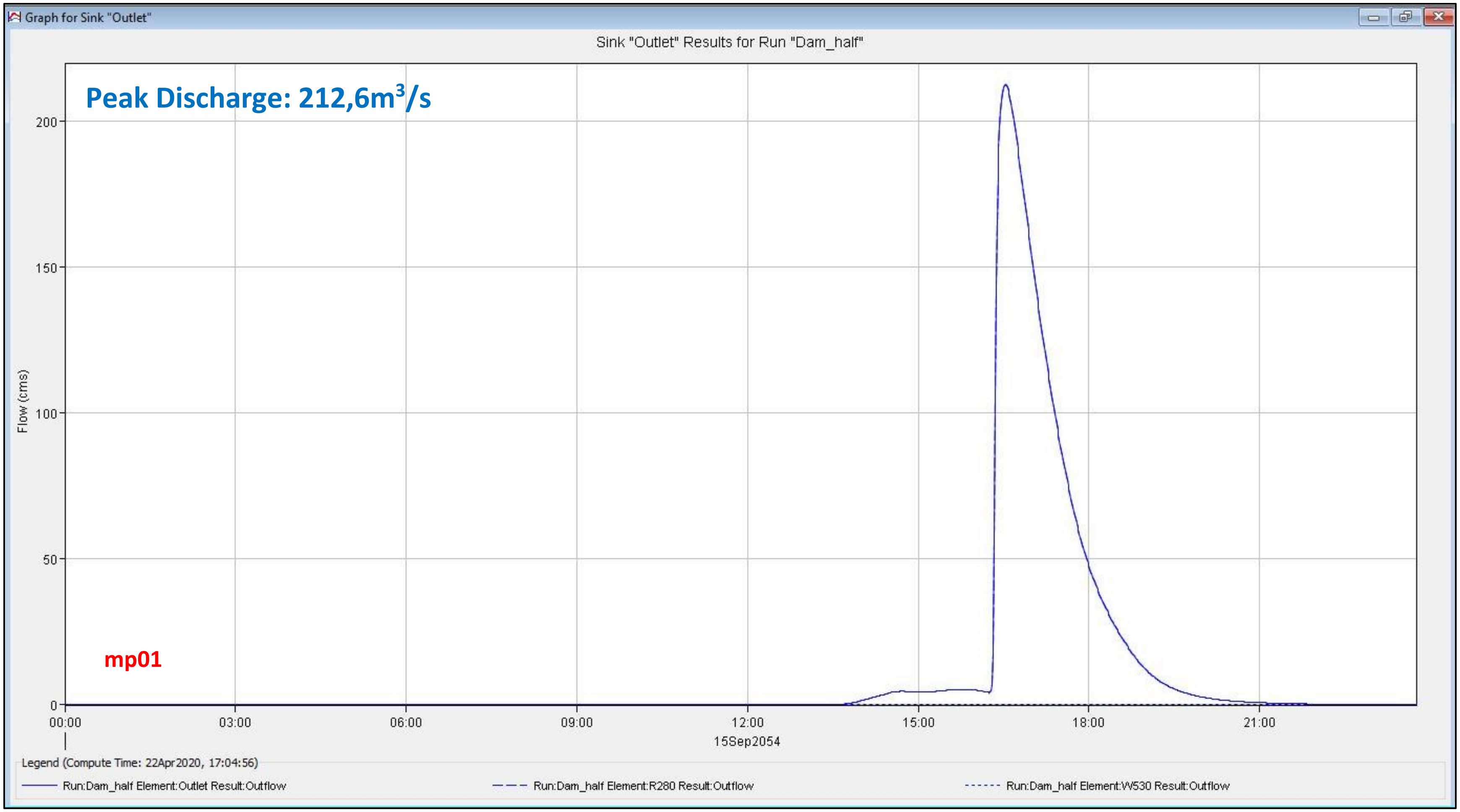


Figure 3: Hydrological analysis results of the mp01 precipitation member, with the dam being half (50%) full at the outlet of the model

Figures 4 and 5 present the hydrological results at the location of the flow gauging stations for the most extreme scenario (mp01). The results of the other scenarios can be found on the Appendix I.

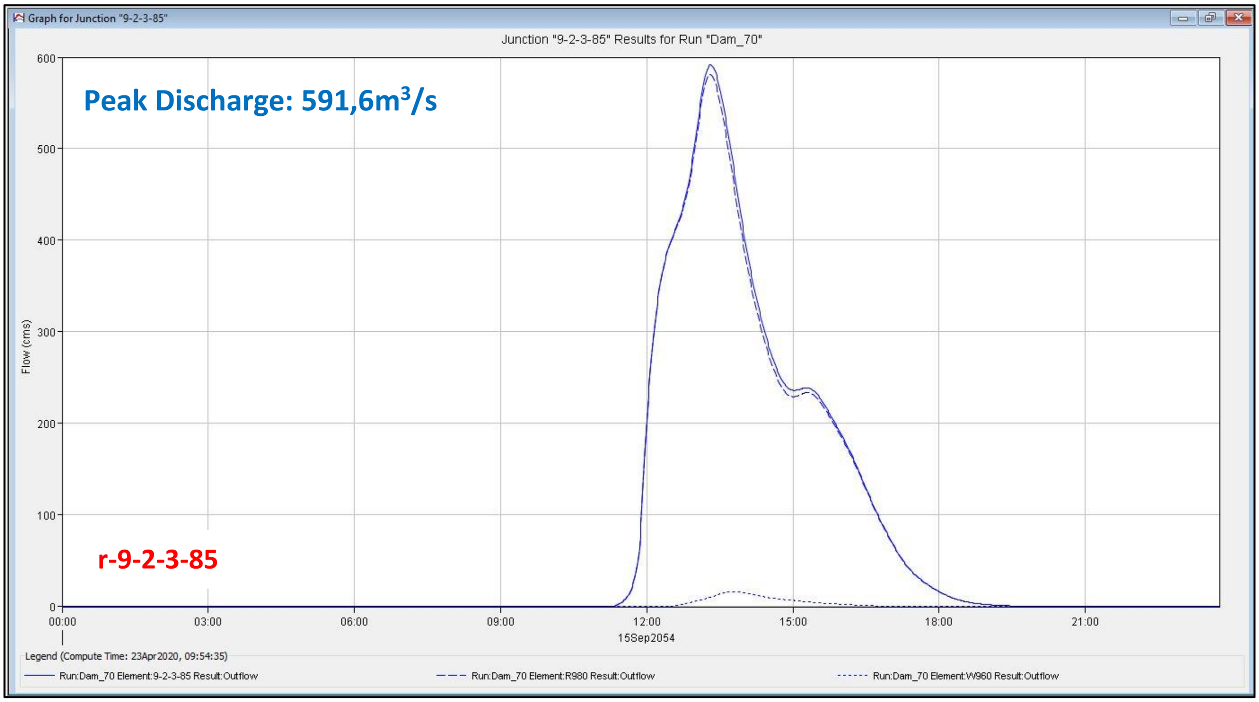


Figure 4: Hydrological analysis results at the flow gauging station r-9-2-3-85

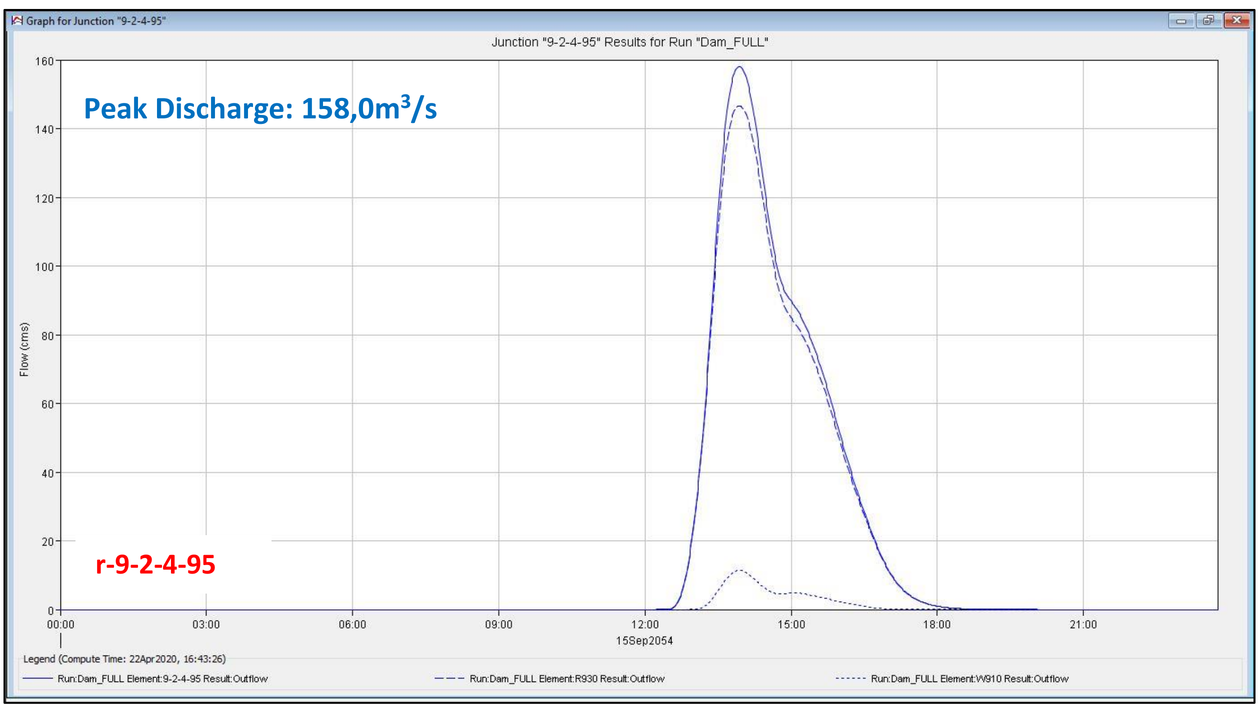


Figure 5: Hydrological analysis results at the flow gauging station r-9-2-4-95

As it is mentioned above, for better understanding of the attenuation effectiveness of Germasogeia dam, all of the scenarios were hydrologically simulated under two different initial storage dam conditions, while the most extreme member was simulated for an additional initial condition (see Table 3).

The three initial storage conditions for the dam are as follow:

a) Dam is full (Initial Storage = 13.5 Mm^3)

b) Dam is 70% full (Initial Storage = 9.45 Mm^3)

c) Dam is half full (Initial Storage = 6.75 Mm^3)

Figures 6-8 present the results (developing storage curves and inflow/outflow hydrographs) of the various dam scenarios at the dam spillway for the most extreme scenario (mp01), while the results of the other scenarios are presented in the Appendix II.

As it can be seen here-below with the dam full, the inflow is equal to outflow, while with the dam being 70% full, a considerable attenuation can be observed. When the dam is half full, the achieved attenuation is even much greater.

This analysis implies that the flood protection effectiveness of the dam could be significant and the initial storage dam conditions, when a flood event occurs, determine the flood protection level to the downstream residential areas.

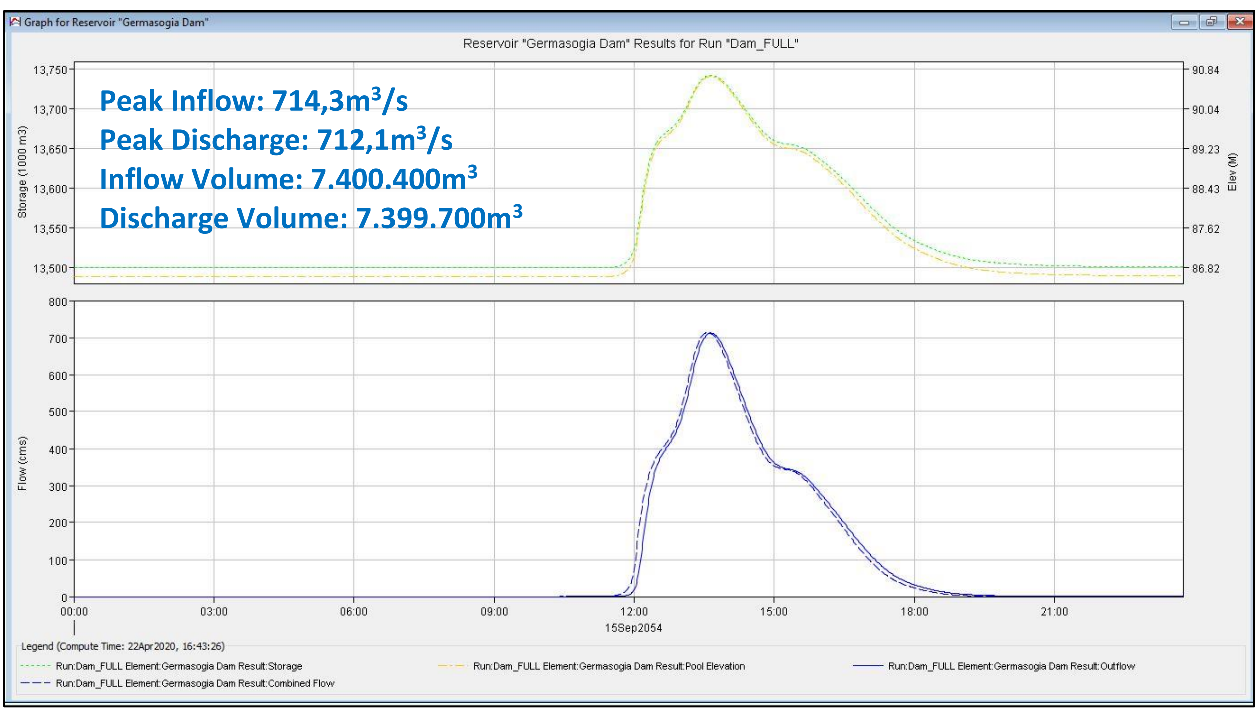


Figure 6: Hydrological analysis results for the "mp01" rainfall event considering the Germasogeia dam as full

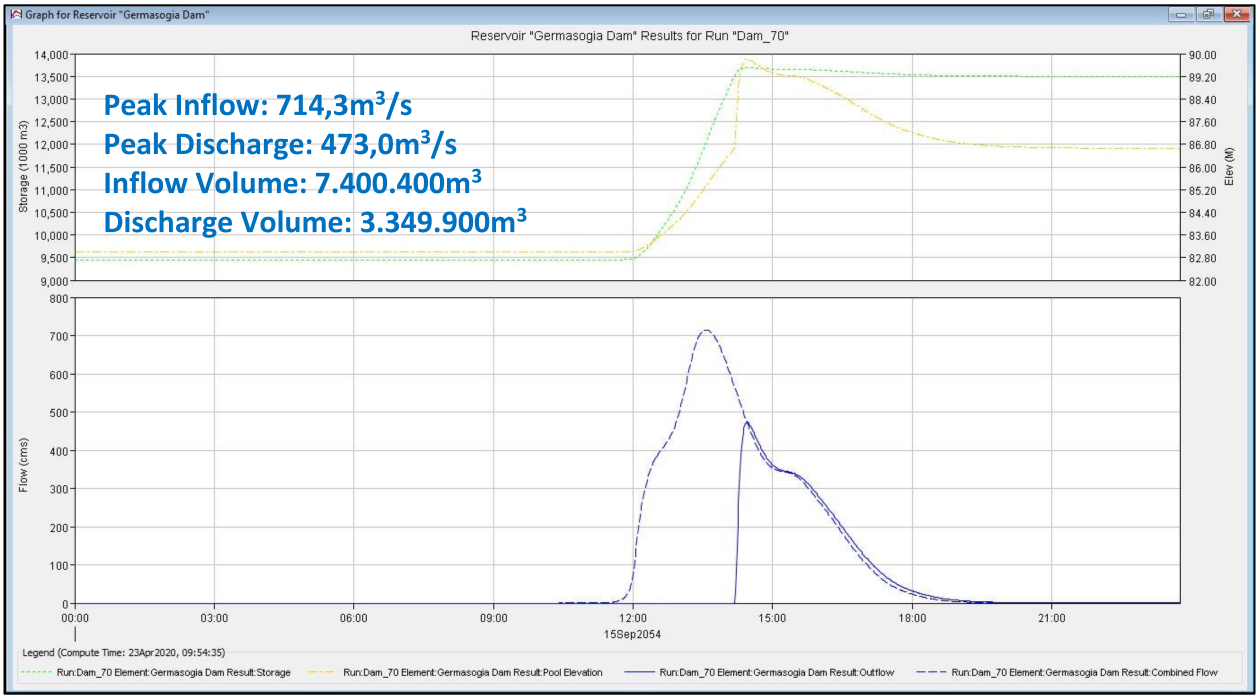


Figure 7: Hydrological analysis results for the "mp01" rainfall event considering the Germasogeia dam as 70% full

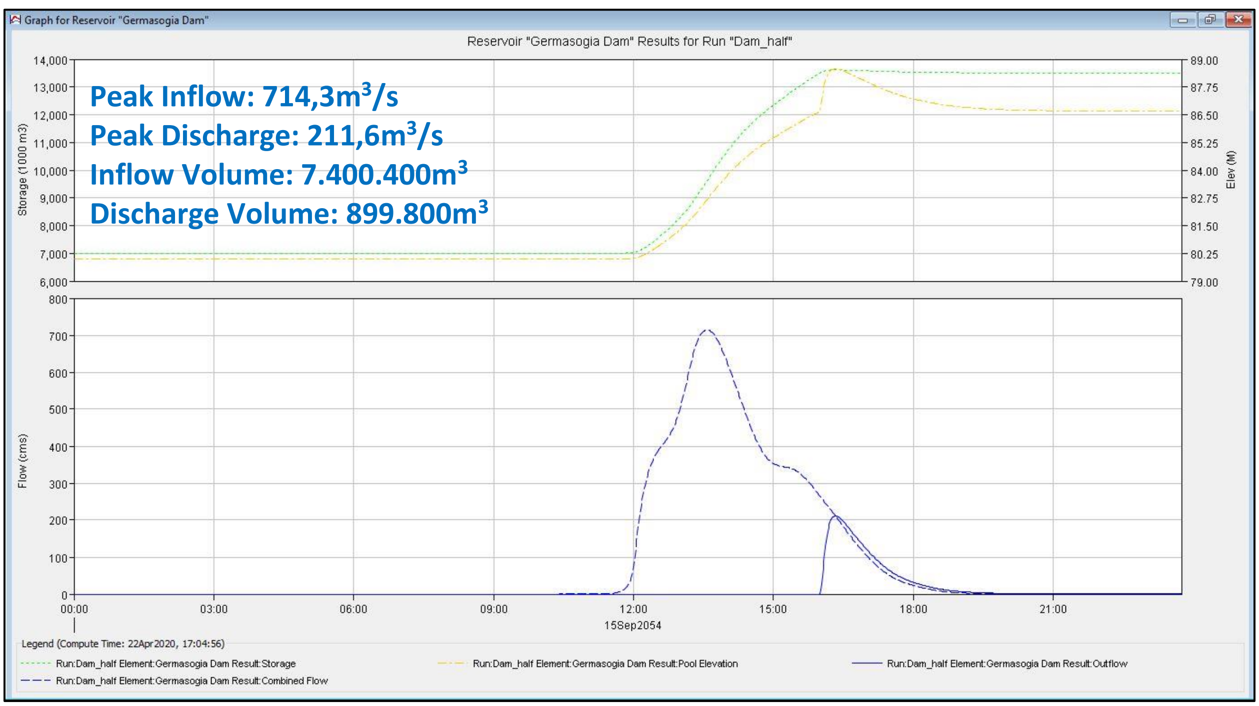


Figure 8: Hydrological analysis results for the "mp01" rainfall event considering the Germasogeia dam as 50% full

ii) Climate and land use change scenarios

The hydrological analysis for the climate and land use change scenarios, was performed for the most extreme and the median scenarios; "mp01" and "mp06" (see Table 3).

Figure 9 and 10 show the derived hydrographs at the outlet of the model for the "mp01" with the dam being full and half full respectively.

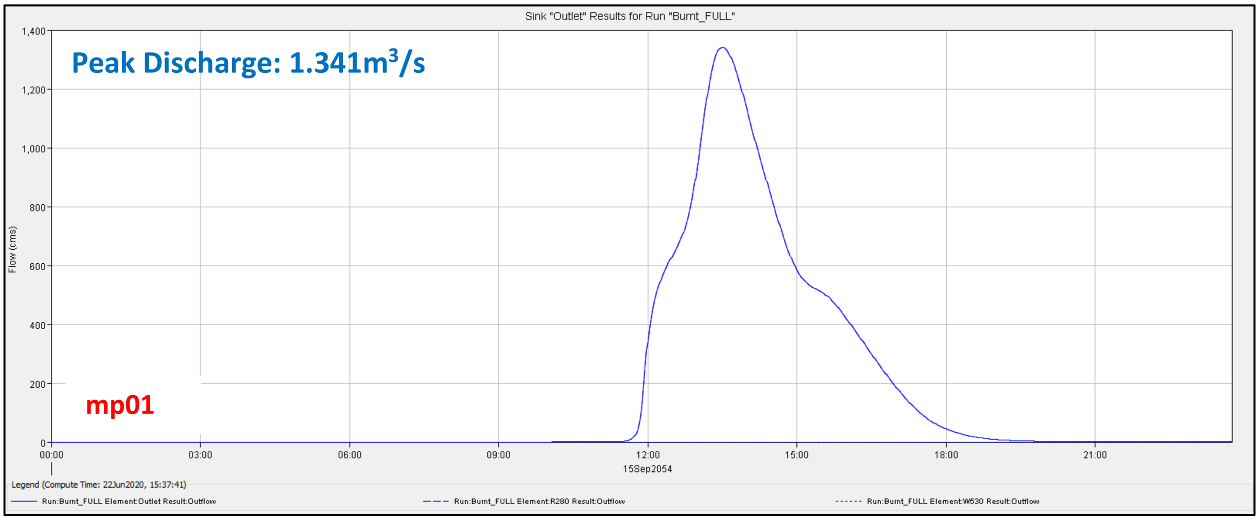


Figure 9: Hydrological analysis results for the "mp01" rainfall event considering the Germasogeia dam full for the "Burnt scenario" at the model outlet

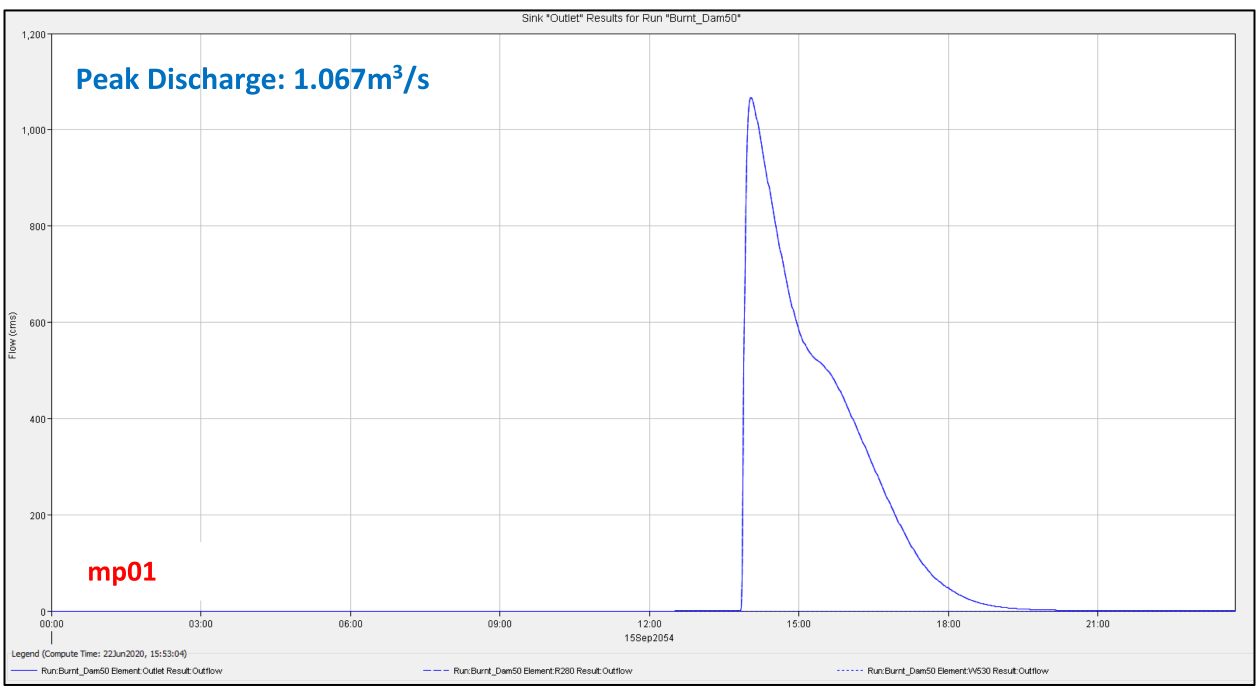


Figure 10: Hydrological analysis results for the "mp01" rainfall event considering the Germasogeia dam half full for the "Burnt scenario" at the model outlet

Figure 11 and 12 show the derived hydrographs at the outlet of the model for the “mp06” rainfall event with the dam being full and half full respectively.

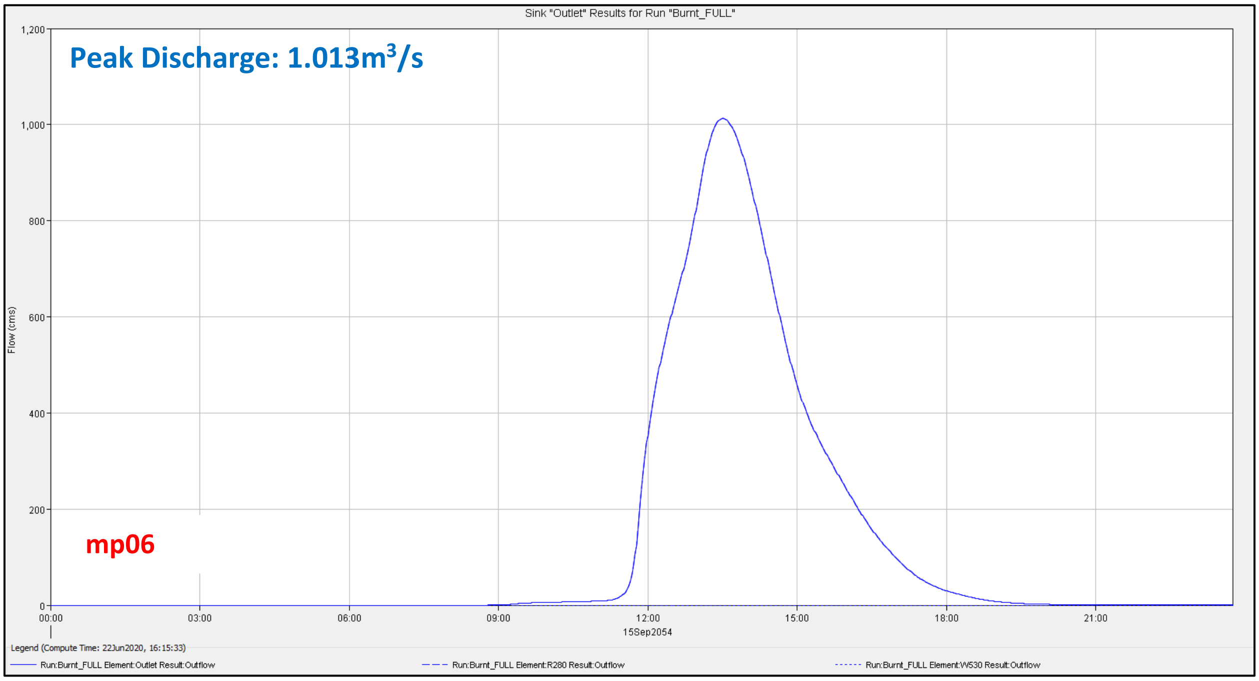


Figure 11: Hydrological analysis results for the “mp06” rainfall event considering the Germasogeia dam full for the “Burnt scenario” at the model outlet

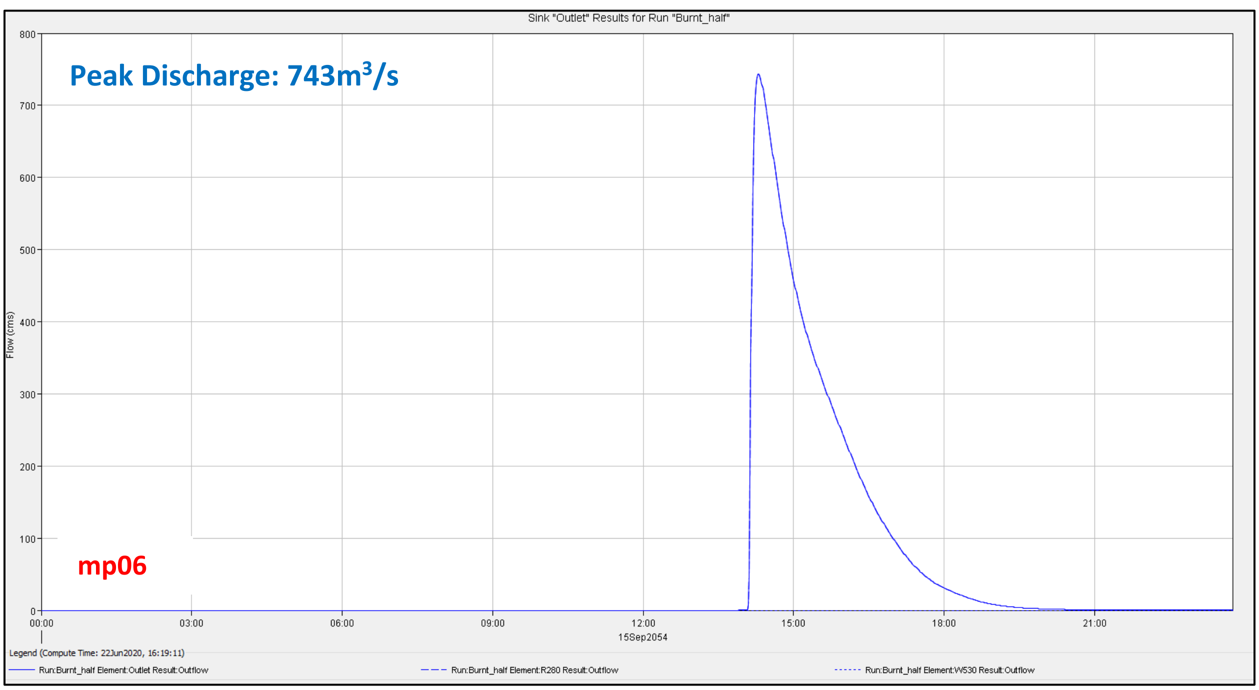


Figure 12: Hydrological analysis results for the “mp06” rainfall event considering the Germasogeia dam half full for the “Burnt scenario” at the model outlet

Table 5 shows the peak (m^3/s) and the total (m^3) inflow and outflow at the dam spillway for both scenarios, while the relevant hydrographs are shown in the Appendix II.

Table 5: Peak and total inflow and outflow at the dam spillway for the most extreme and median rainfall event

Rainfall Event	Dam spillway – Initial Dam conditions: Full capacity			
	Peak inflow (m^3/s)	Peak outflow (m^3/s)	Total inflow ($x1000m^3$)	Total outflow ($x1000m^3$)
mp01	1.347	1.344	13.184	13.172
mp06	1.016	1.014	10.492	10.481
Dam spillway – 50% capacity				
mp01	1.347	1.080	13.184	6.684
mp06	1.016	753	10.493	3.992

The following Table 6 summarizes the calculated peak flow at the outlet of the model for the most extreme and the median scenario in combination with the land use change scenario. The maximum flow appears to be at the event "mp01" at the land-use change scenario (1.341m^3/s).

It is worth mentioning that the increase of the peak flow due to the burnt areas is about 90%, something that indicates the significant role of the forest (among others) to the flood protection.

Table 6: Summary of the peak flow at the outlet for the most extreme and median rainfall event

Rainfall Event	Peak flow at the outlet of the model in m^3/s				
	Climate change scenario + Current Land use			Climate + Land use change Scenario	
	Dam full	Dam 70% full	Dam 50% full	Dam full	Dam 50% full
mp01	712	472	213	1.341	1.067
mp06	525	241	-	1.013	743

➔ **Hydraulic Model Results**

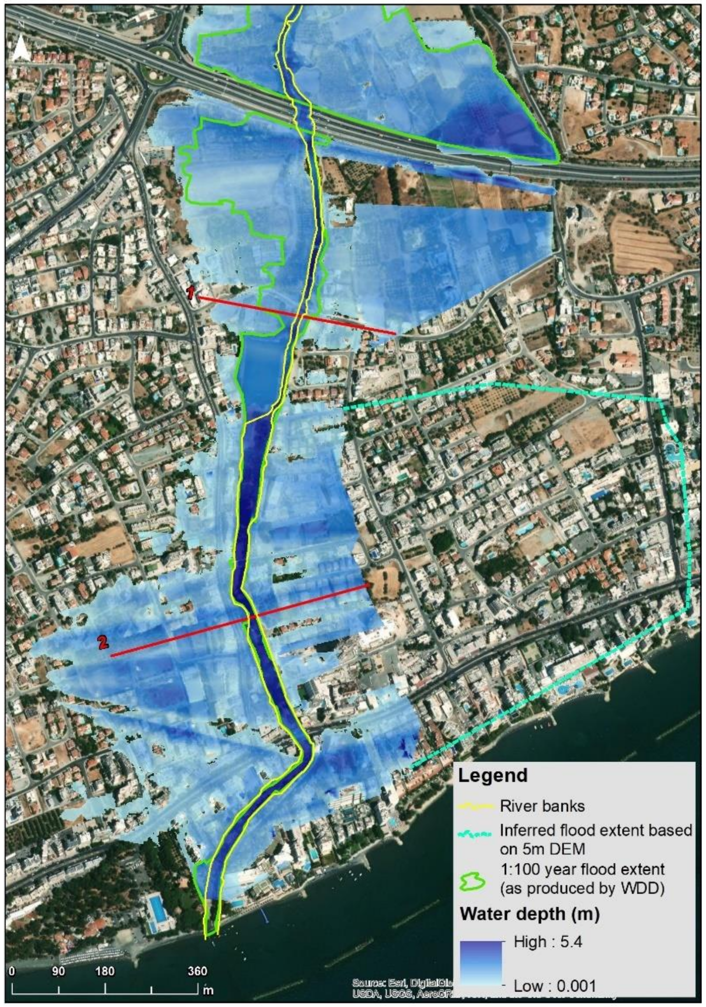
The output hydrographs of the hydrological analysis have been used as input flow data for the hydraulic analysis. As mentioned above the HEC-RAS software has been employed for the hydraulic simulations and the HEC-GeoRAS for the spatial analysis of the results and for the production of the pertinent flood maps. The flood maps have been produced for the extreme and the median scenarios.

The following figures show on a satellite image the flood maps as generated by HEC-GeoRAS for the examined future rainfall events for a selected indicative residential area as an example, located at the lower part of the Germasogeia River. Furthermore, two selected hydraulic cross sections, as produced by the HEC-RAS, are shown as an example as well. It is noted that the cross-section direction is looking downstream.

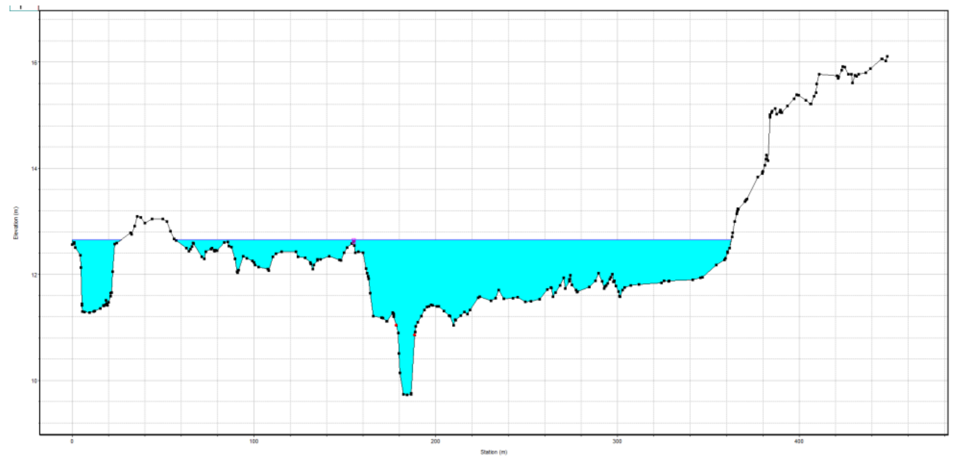
It is stressed that the available TIN file (file as derived by LiDAR task) does not cover the whole extent of the floods, and as result the generated flood extent edge in some maps looks irregular and not so natural (e.g. Figure 13), as it is limited by the extent of the TIN file.

Thus, in the following maps the inundated area has been extended using the available DEM (Digital Elevation Model), in order to show an indication of the flood extent in the study area. It is also noted that the flood extent is indicative and does not take into account the surface elements e.g. buildings, trees etc.

mp01 – Climate change with the dam being full



Cross Section 1



Cross Section 2

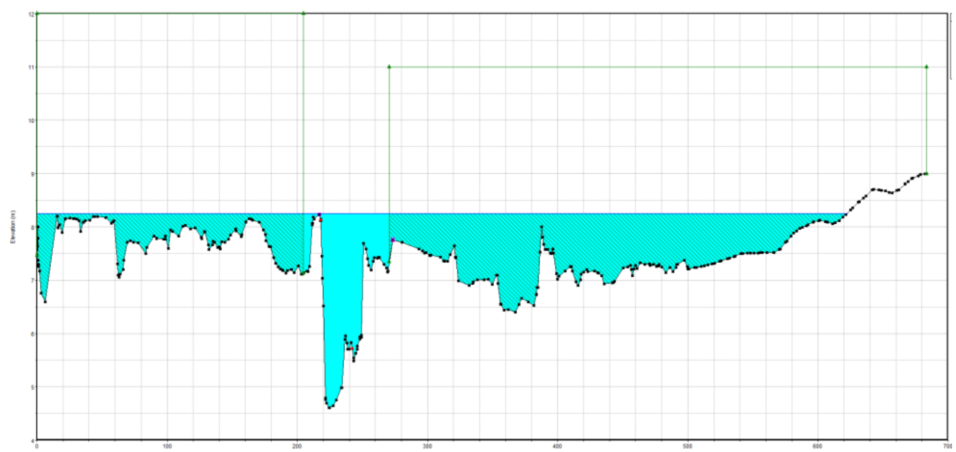


Figure 13: Flood map with water depth at a selected residential area (left) and two indicative hydraulic cross sections for the mp01 rainfall event for the climate change scenario with the dam being full

mp01 – Climate change with the dam being 70% full

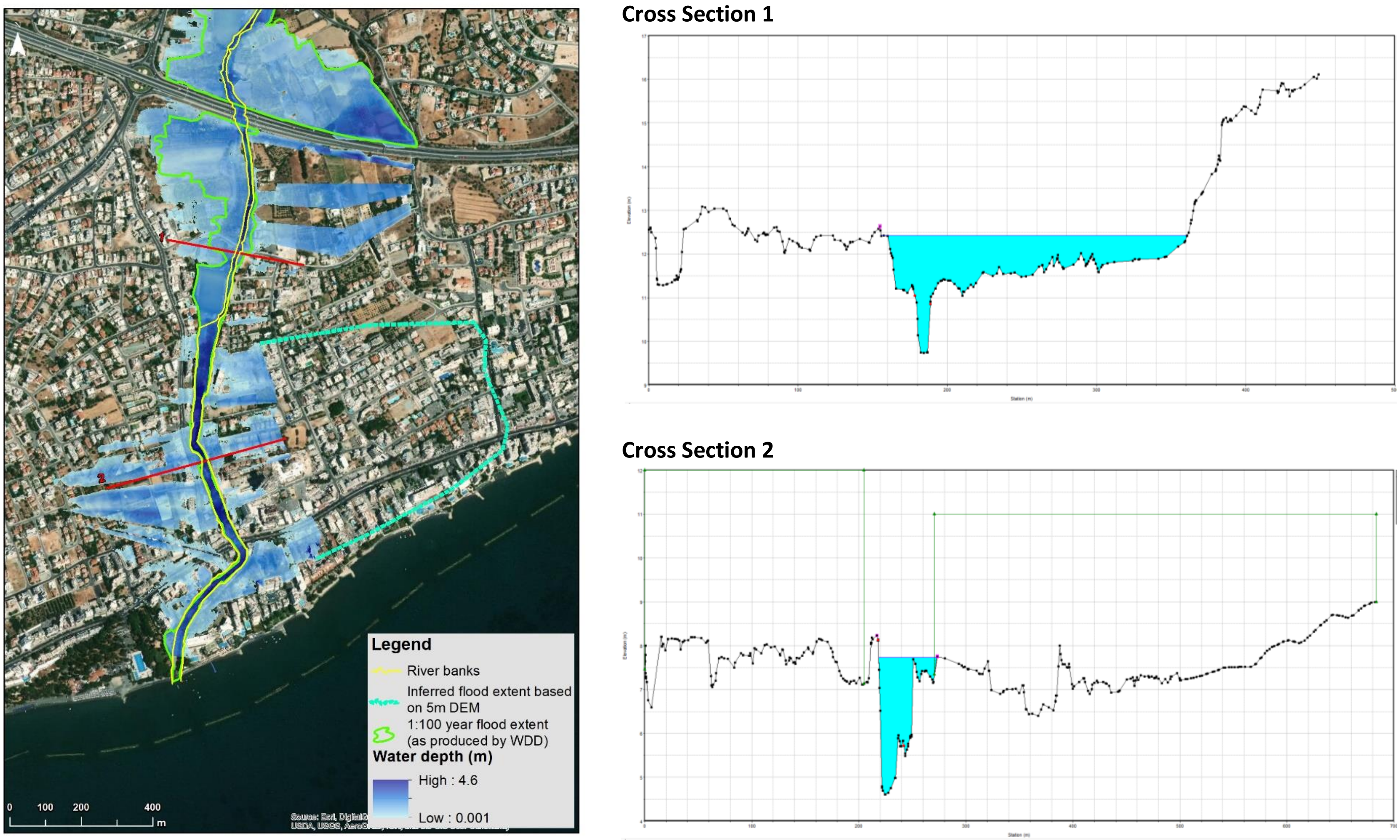
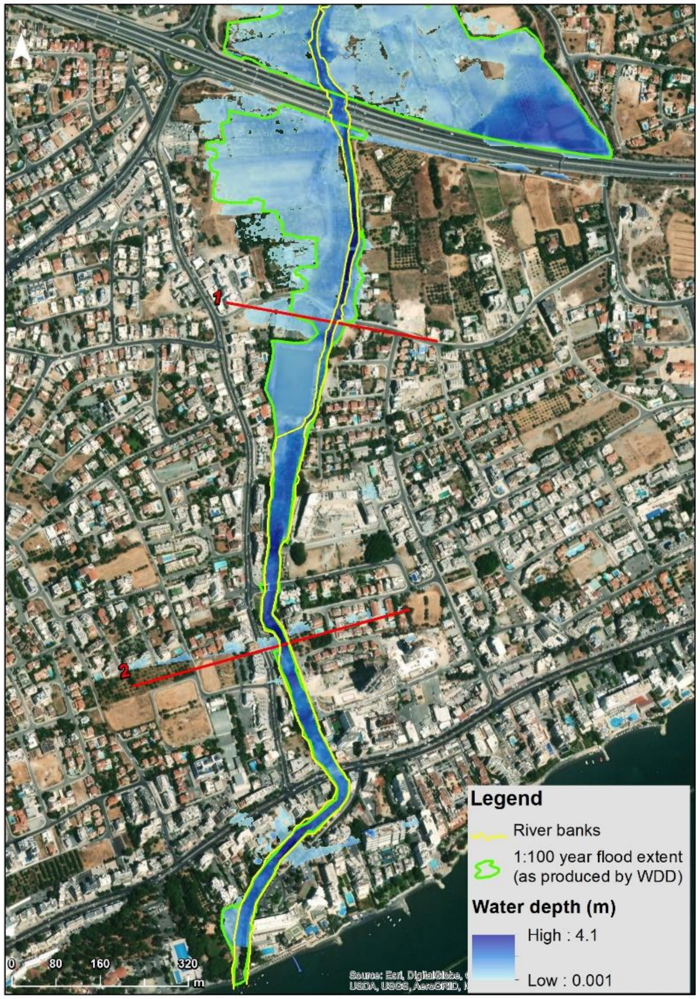
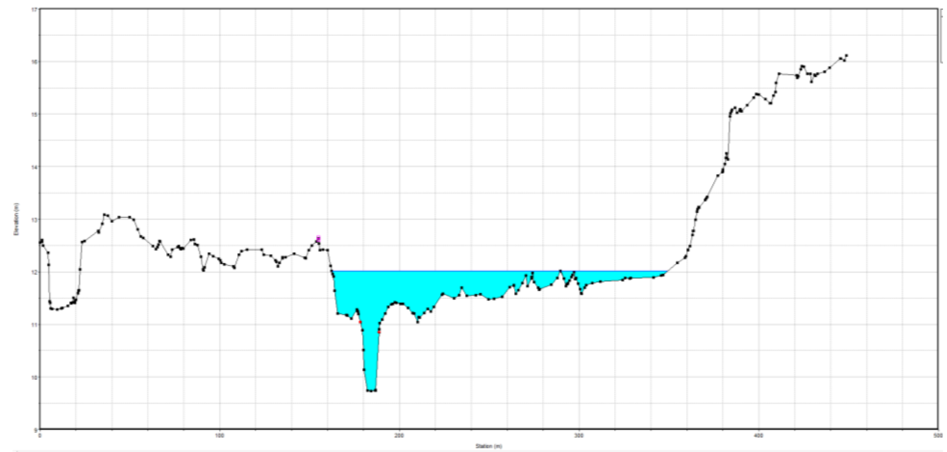


Figure 14: Flood map with water depth at a selected residential area (left) and two indicative hydraulic cross sections for the mp01 rainfall event for the climate change scenario with the dam being 70% full

mp01 – Climate change with the dam being 50% full



Cross Section 1



Cross Section 2

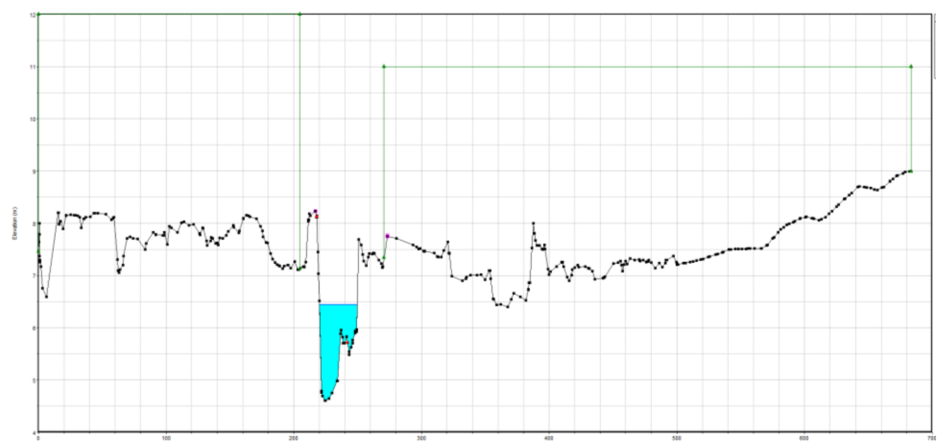


Figure 15: Flood map with water depth at a selected residential area (left) and two indicative hydraulic cross sections for the mp01 rainfall event for the climate change scenario with the dam being 50% full

mp06 – Climate change with the dam being full

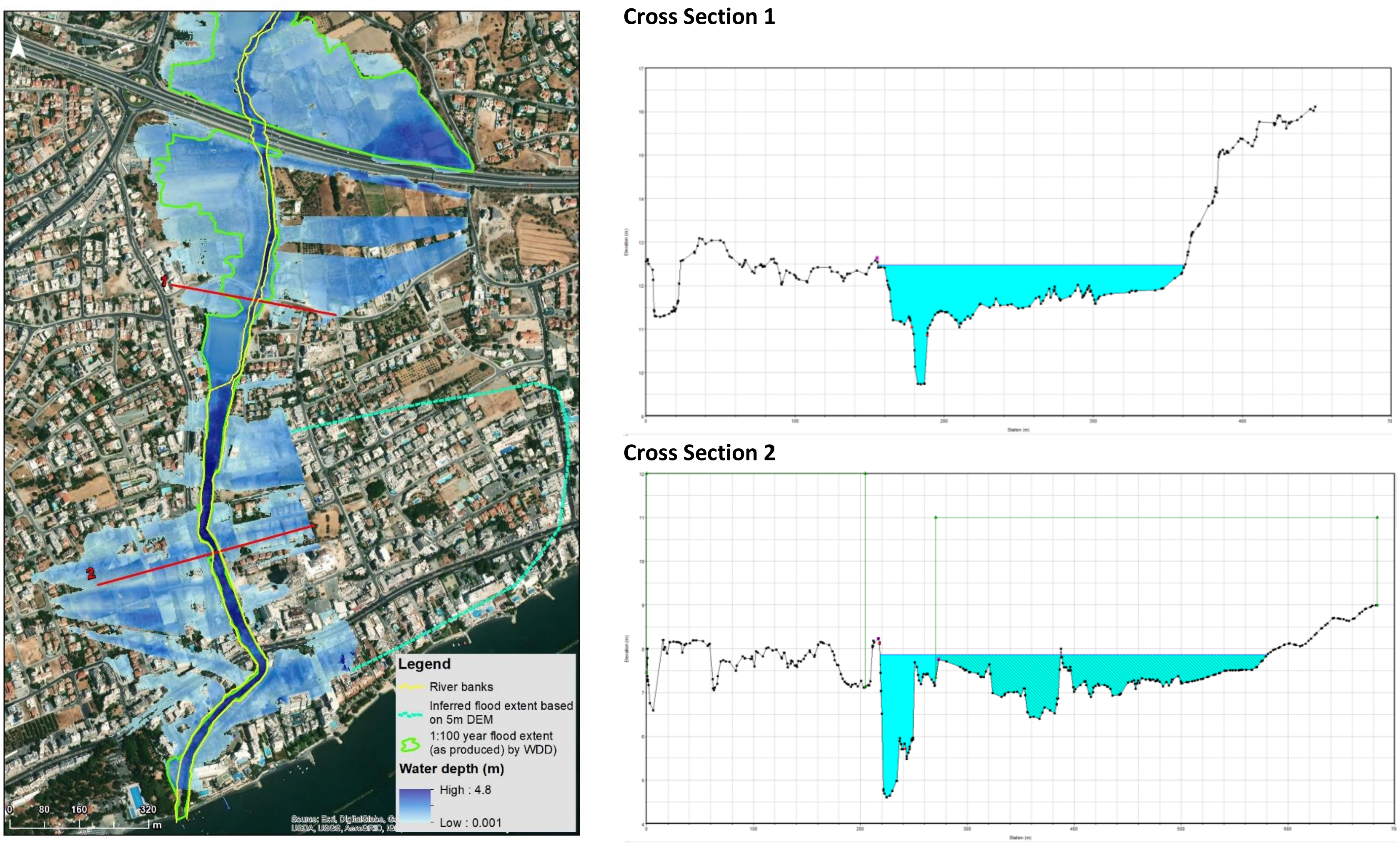


Figure 16: Flood map with water depth at a selected residential area (left) and two indicative hydraulic cross sections for the mp06 rainfall event for the climate change scenario with the dam being full

mp06 – Climate change with the dam being 70% full

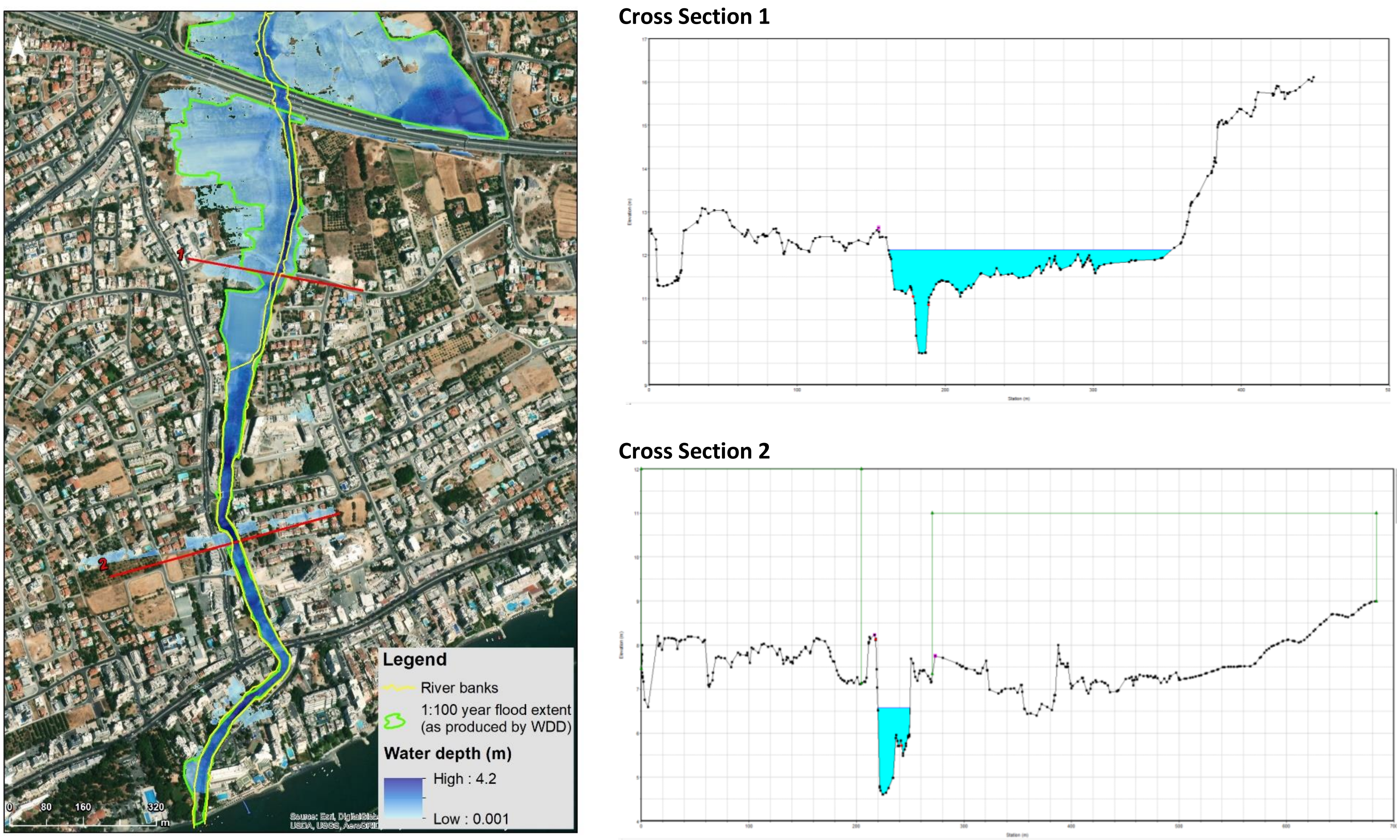
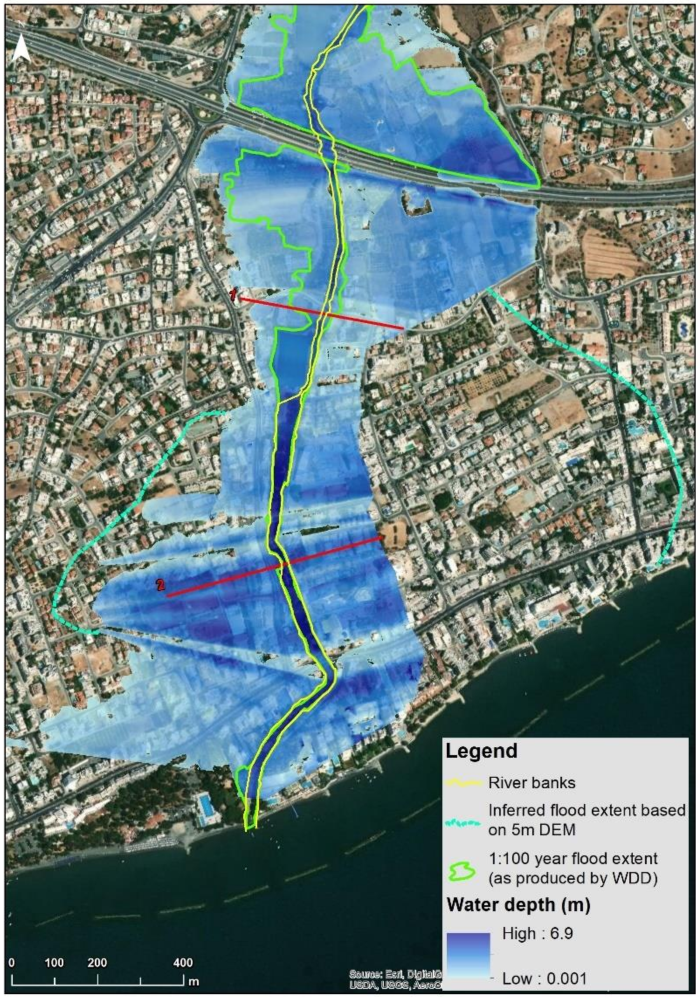
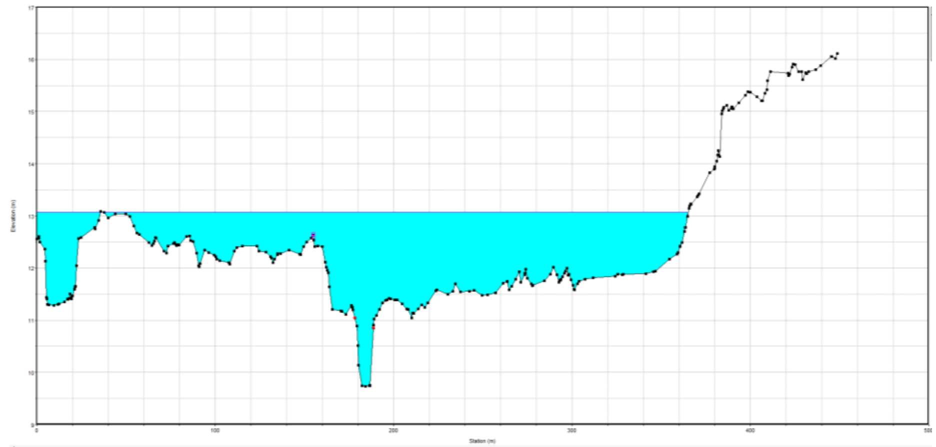


Figure 17: Flood map with water depth at a selected residential area (left) and two indicative hydraulic cross sections for the mp06 rainfall event for the climate change scenario with the dam being 70% full

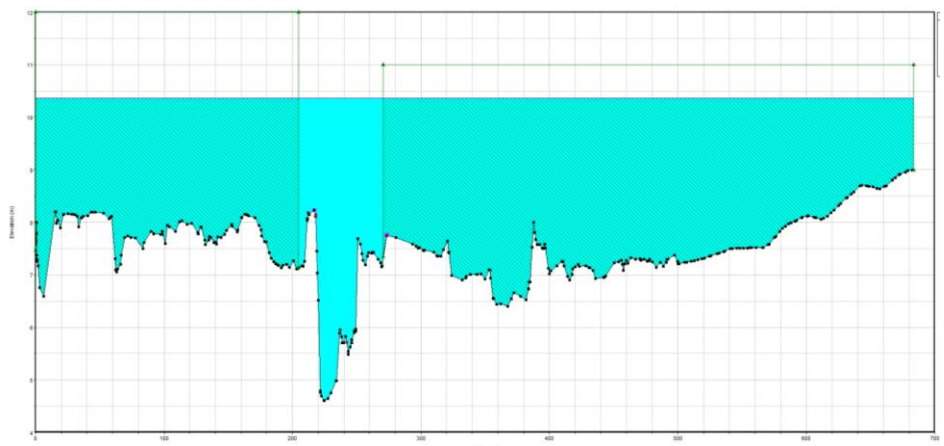
mp01 – Climate change + land use change scenario with the dam being full



Cross Section 1

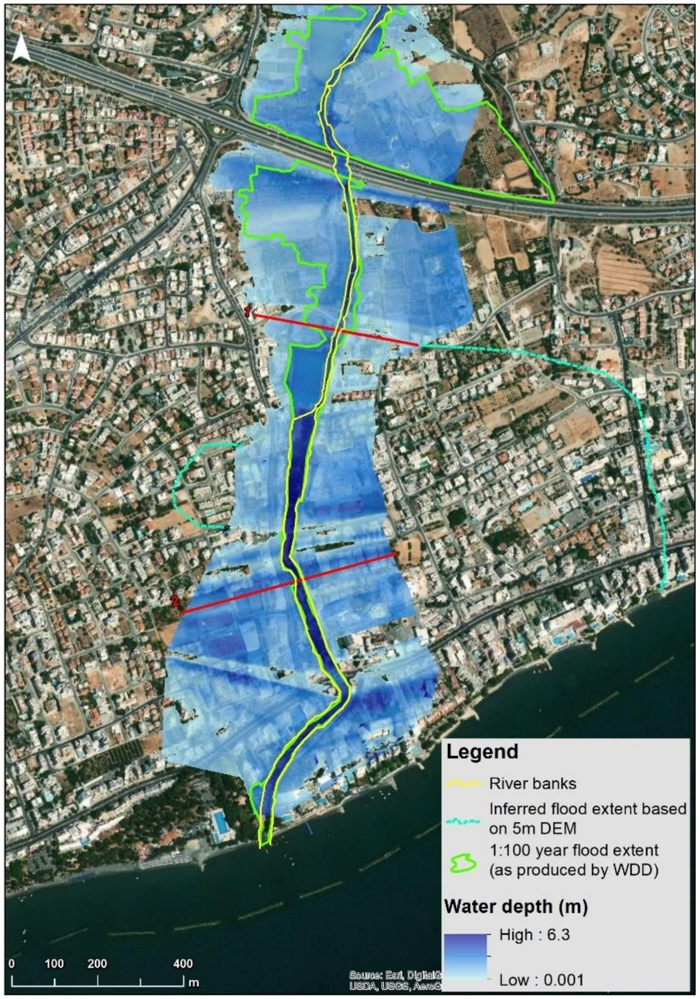


Cross Section 2

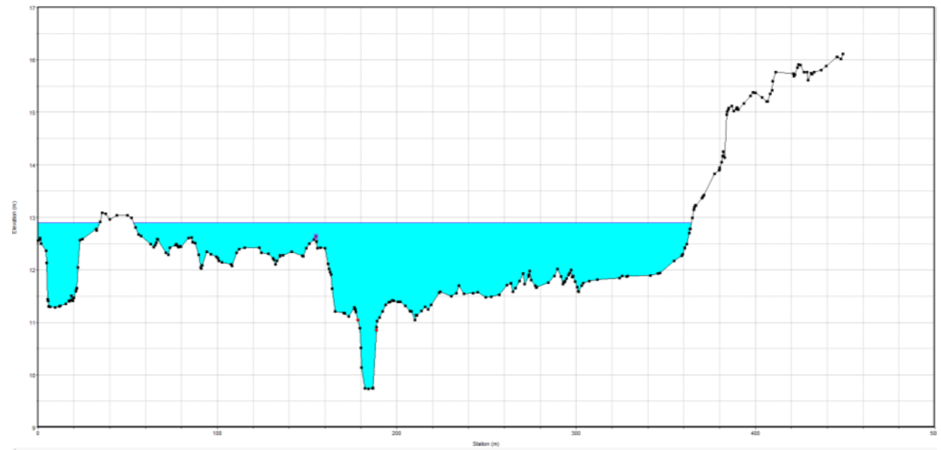


<u>Figure 18: Flood map with water depth at a selected residential area (left) and two indicative hydraulic cross sections for the mp01 rainfall event for the climate and land use change scenario with the dam being full</u>

mp01 – Climate change + land use change scenario with the dam being 50% full



Cross Section 1



Cross Section 2

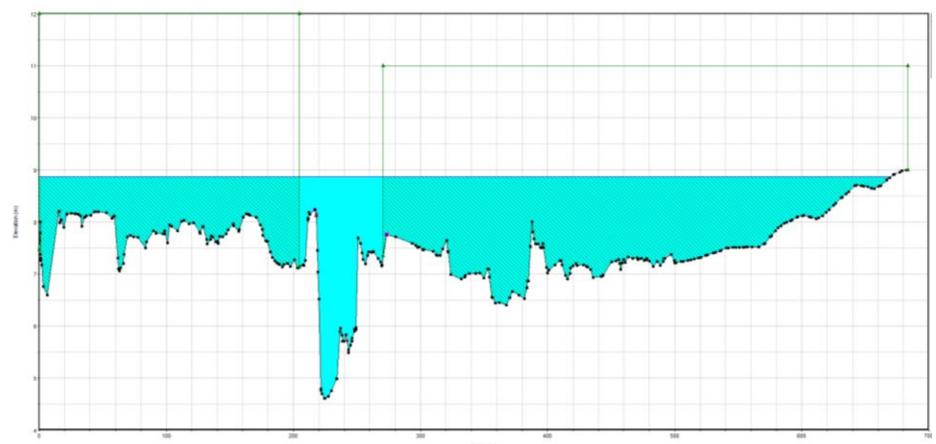


Figure 19: Flood map with water depth at a selected residential area (left) and two indicative hydraulic cross sections for the mp01 rainfall event for the climate and land use change scenario with the dam being 50% full

mp06 – Climate change + land use change scenario with the dam being full

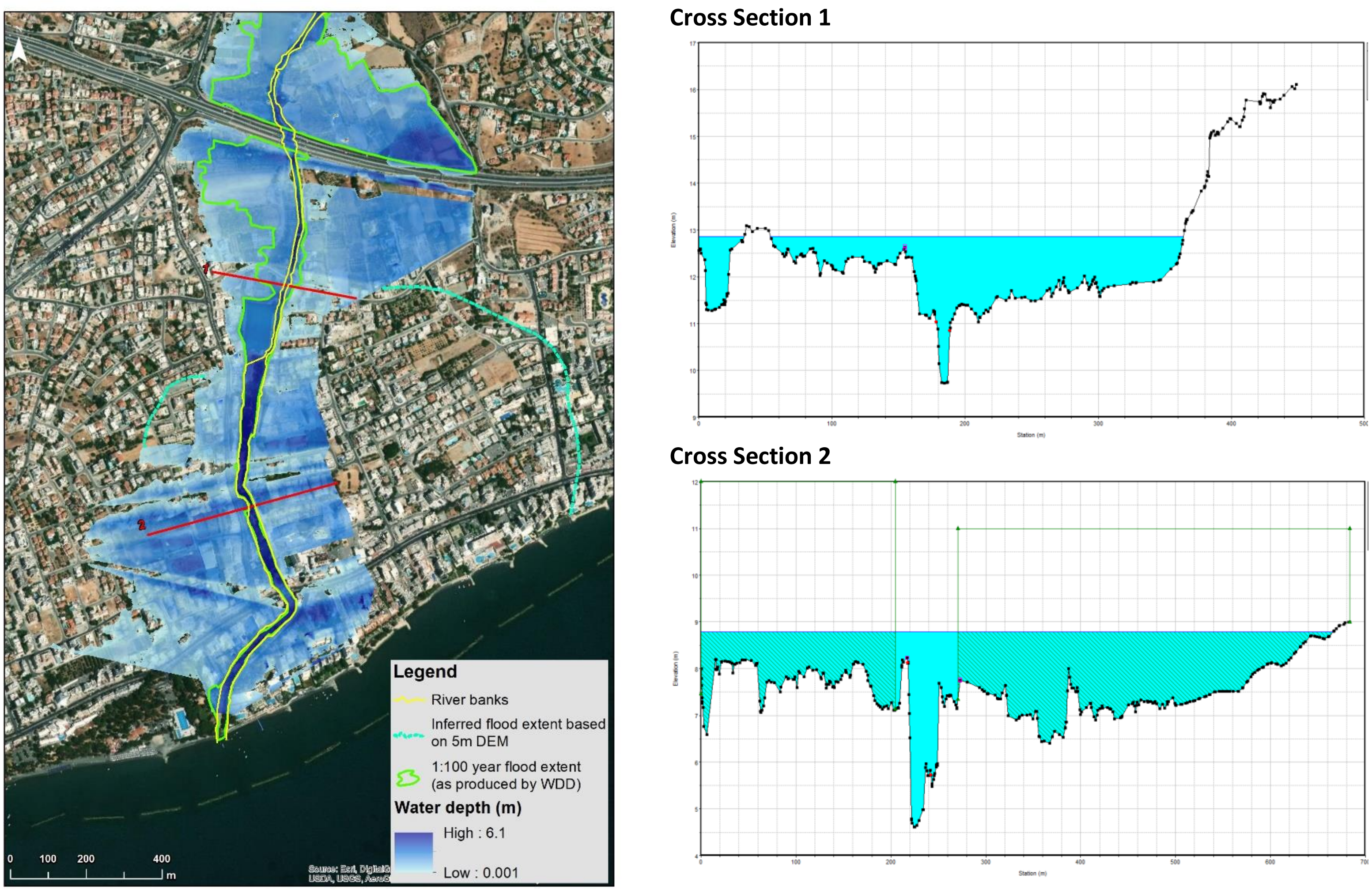
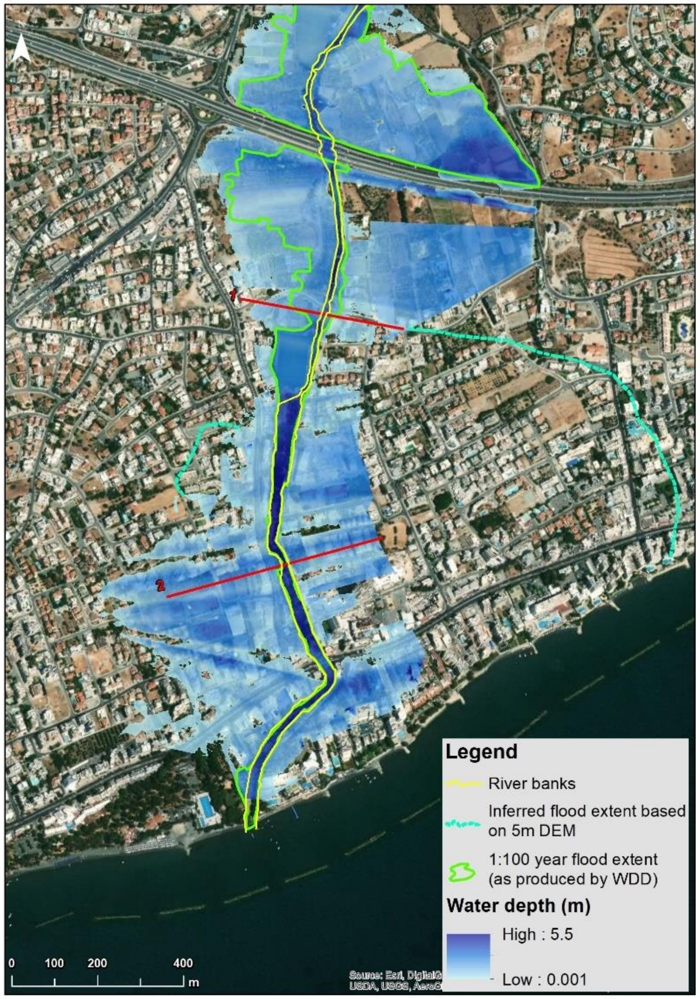
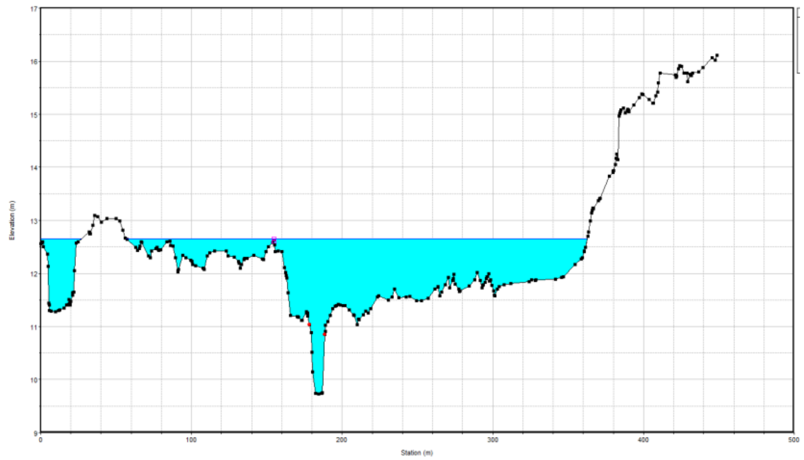


Figure 20: Flood map with water depth at a selected residential area (left) and two indicative hydraulic cross sections for the mp06 rainfall event for the climate and land use change scenario with the dam being full

mp06 – Climate change + land use change scenario with the dam being 50% full



Cross Section 1



Cross Section 2

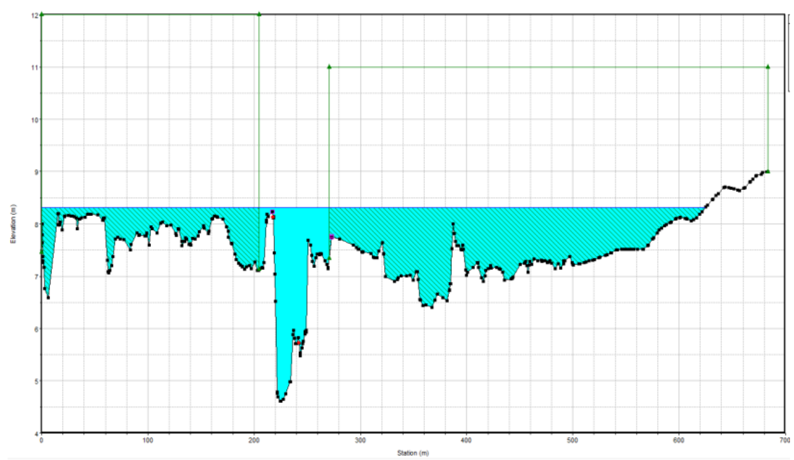


Figure 21: Flood map with water depth at a selected residential area (left) and two indicative hydraulic cross sections for the mp06 rainfall event for the climate and land use change scenario with the dam being 50% full

3.5 SYNOPSIS AND EXTENT OF THE FLOODS

The following Table summarizes the results of the hydrological and hydraulic analyses for the examined future events under climate and land use change scenarios.

The most extreme rainfall event is the “mp01” where the peak flow is at its maximum value (1.341m^3/s) in the climate and land use change scenario with the Germasogeia dam initial condition being full. The inundated area in this vast extreme event covers an area of approximately 2,0 km^2 where 0,9 km^2 cover Residential Town Planning Zones (including Commercial and Tourist Town Planning Zones).

Table 7: Summary of the hydrological and hydraulic analysis results for the examined future rainfall event under climate and land use change scenarios

Various scenarios		Future Extreme Event	Peak Flow at outlet of the model (m^3/s)	Extent of the flood (km^2) *	Extent of the flood within the Residential Town Planning Zones (km^2) **
Climate change/Land use	**Dam Initial Condition**				
Climate change	Full	mp01	712	1,7	0,7
		mp06	525	1,5	0,5
	70% full	mp01	472	1,4	0,5
		mp06	24	1,0	0,2
Climate + Land use change	Full	mp01	1.341	2,0	0,9
		mp06	1.013	1,8	0,8
	50% full	mp01	1.067	1,7	0,7
		mp06	743	1,7	0,7

** Based on the available TIN file*
***Including Commercial and Tourist Town Planning Zones (source: Town Planning and Housing Department)*

4. COMPARISON BETWEEN WDD AND ERMIS-F STUDIES

Table 8 summarizes the key results of the WDD Study and the ERMIS-Floods Study. The WDD Study resulted to a peak flow of 150,4m^3/s at the model outlet for the 1 in 100-year flood event, while the ERMIS Study resulted to peak flows ranging from 54,0m^3/s to 712,0m^3/s with the assumption that the Germasogeia dam is at full capacity.

Table 8: Summary of the key results of the WDD Study and the ERMIS-Flood Study at the model outlet

Study		Peak Flow at the model outlet (m^3/s)	Peak flow at the flow gauging stations (m^3/s)	
		Dam full	r-9-2-4-95	r9-2-3-85
ERMIS	mp01	711,8	158,0	591,6
	mp02	395,5	69,4	298,0
	mp05	564,2	5,8	529,9
	mp06	525,2	76,1	469,8
	mp16	53,9	5,8	52,0
WDD		150,4	32,9	174,7

Table 9 shows the peak inflow and outflow in m^3/s and the total inflow and outflow in m^3 at the dam spillway for both studies. The ERMIS-Flood Study results are also with the assumption that the dam is full.

Table 9: Peak (m^3/s) and total (m^3) inflow and outflow at the dam spillway of the WDD and ERMIS-Flood Study

Study		Dam spillway			
		Peak inflow (m^3/s)	Peak outflow (m^3/s)	Total inflow (x1000m^3)	Total outflow (x1000m^3)
ERMIS	mp01	714,3	712,1	7.400.4	7.399.7
	mp02	388,6	387,2	3.370.8	3.370.3
	mp05	567,0	565,1	4.389.3	4.388.8
	mp06	527,3	525,9	5.421.4	5.420.8
	mp16	54,9	54,0	515.8	515.4
WDD		385,4	143,7	3.577.0	3.526.6

As it can be seen from the above Tables, the rainfall events examined within the framework of the ERMIS project seem to be quite extreme in relation to the WDD Study.

5. APPENDICES

APPENDIX I: HYDROLOGICAL RESULTS AT THE LOCATION OF THE FLOW GAUGING STATIONS

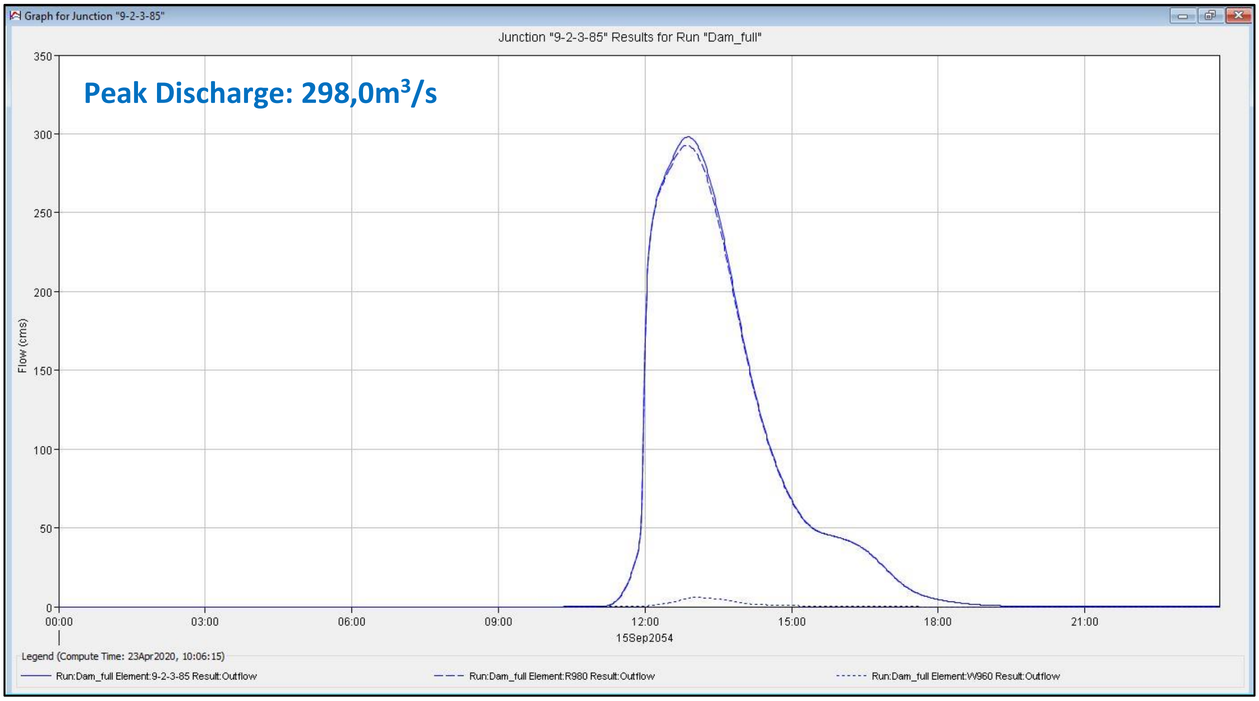
APPENDIX II: HYDROLOGICAL RESULTS AT THE DAM SPILLWAY

APPENDIX I:

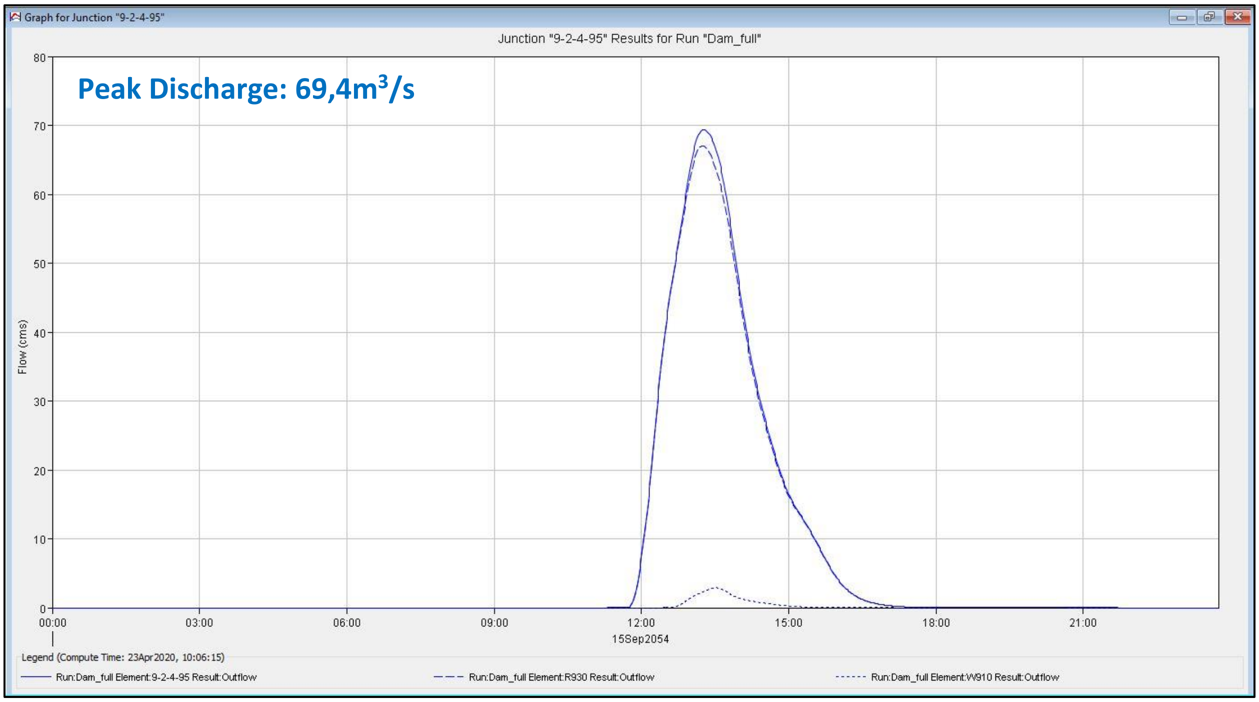
HYDROLOGICAL RESULTS AT THE LOCATION OF THE FLOW GAUGING STATIONS

Precipitation member mp02

➔ r-9-2-3-85

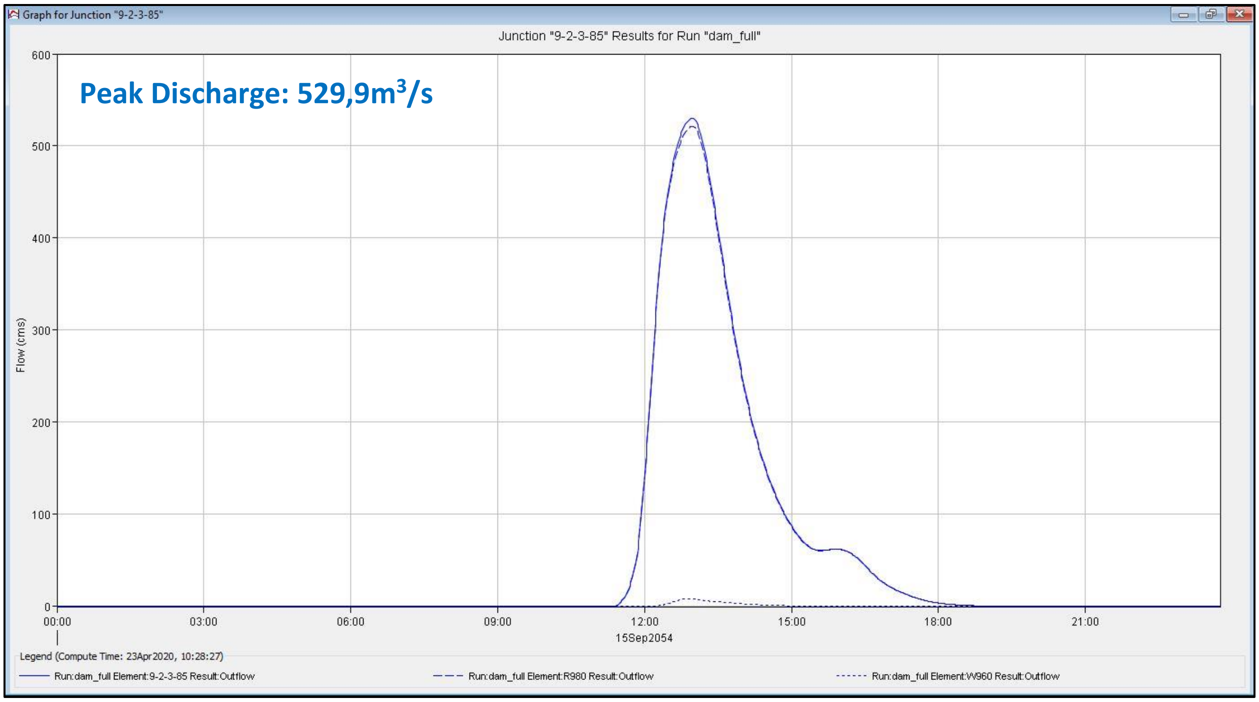


➔ r-9-2-4-95

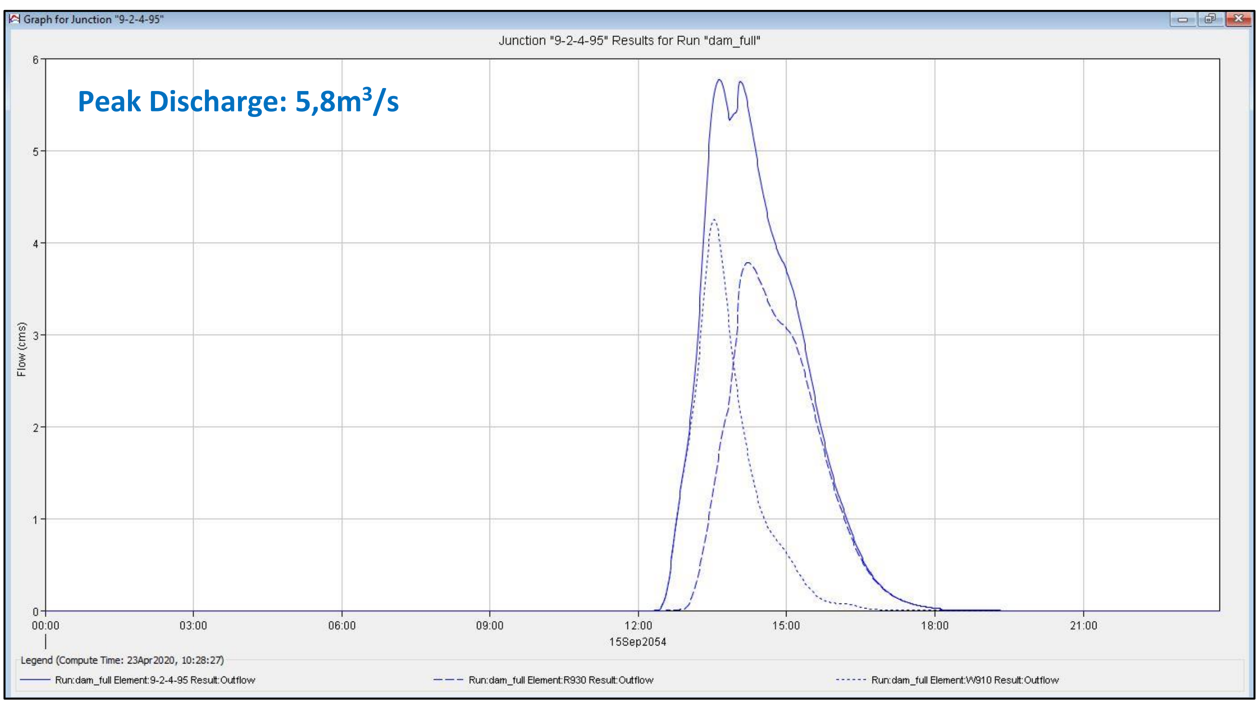


Precipitation member mp05

➔ r-9-2-3-85

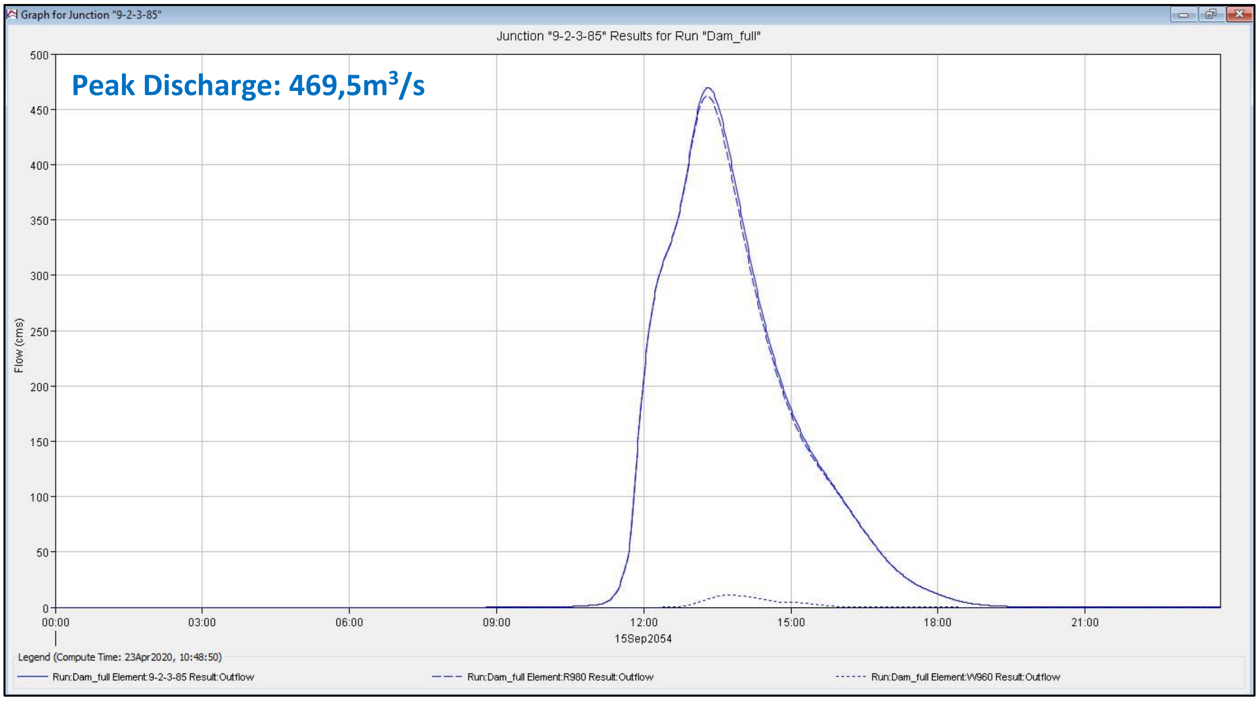


➔ r-9-2-4-95

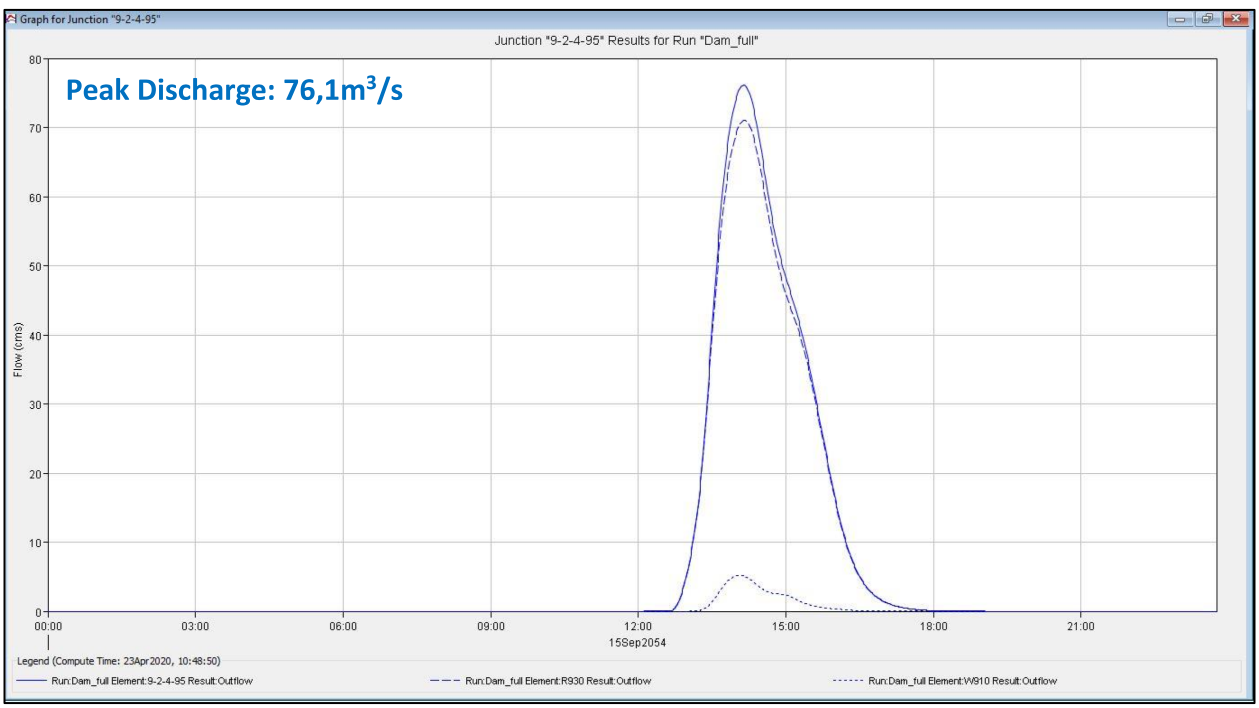


Precipitation member mp06

➔ r-9-2-3-85

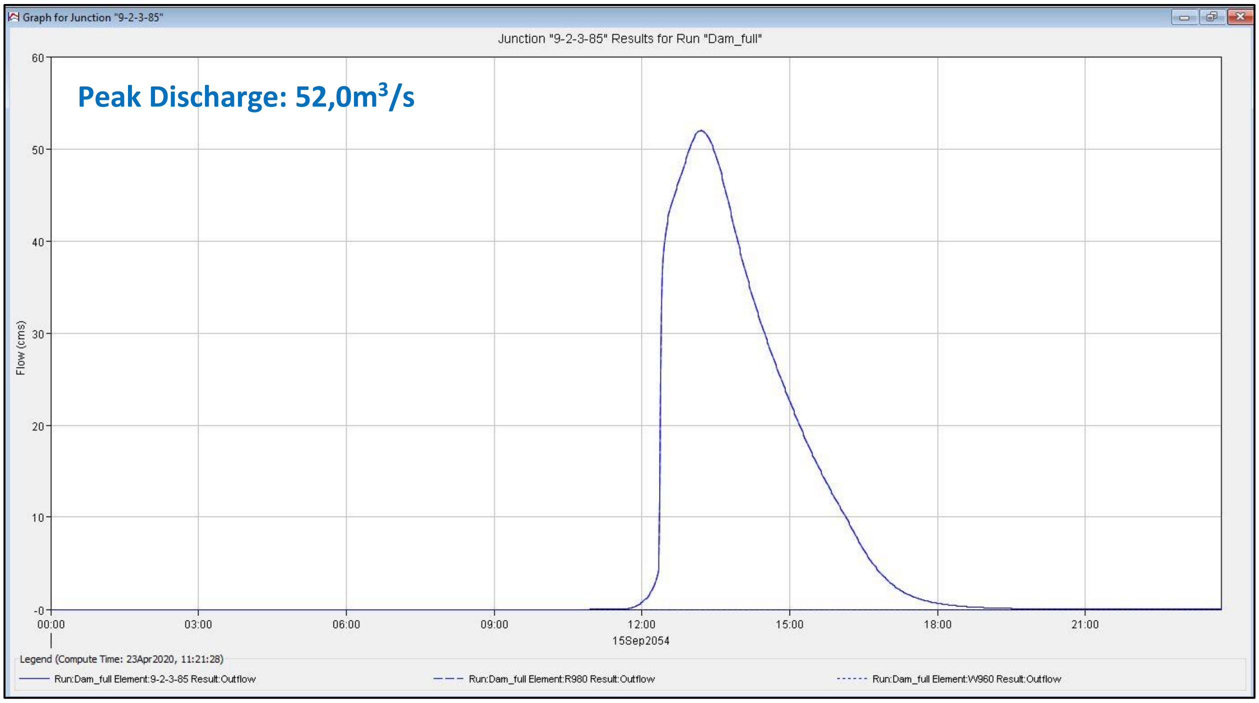


➔ r-9-2-4-95

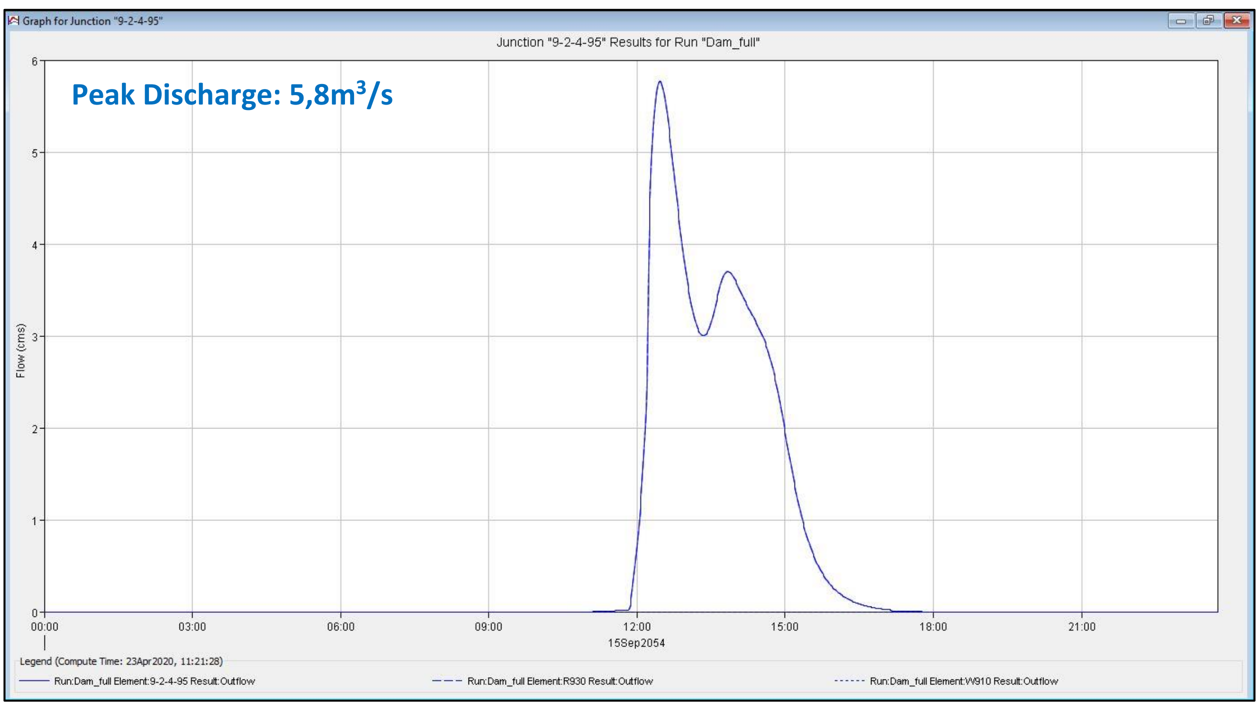


Precipitation member mp16

➔ r-9-2-3-85



➔ r-9-2-4-95



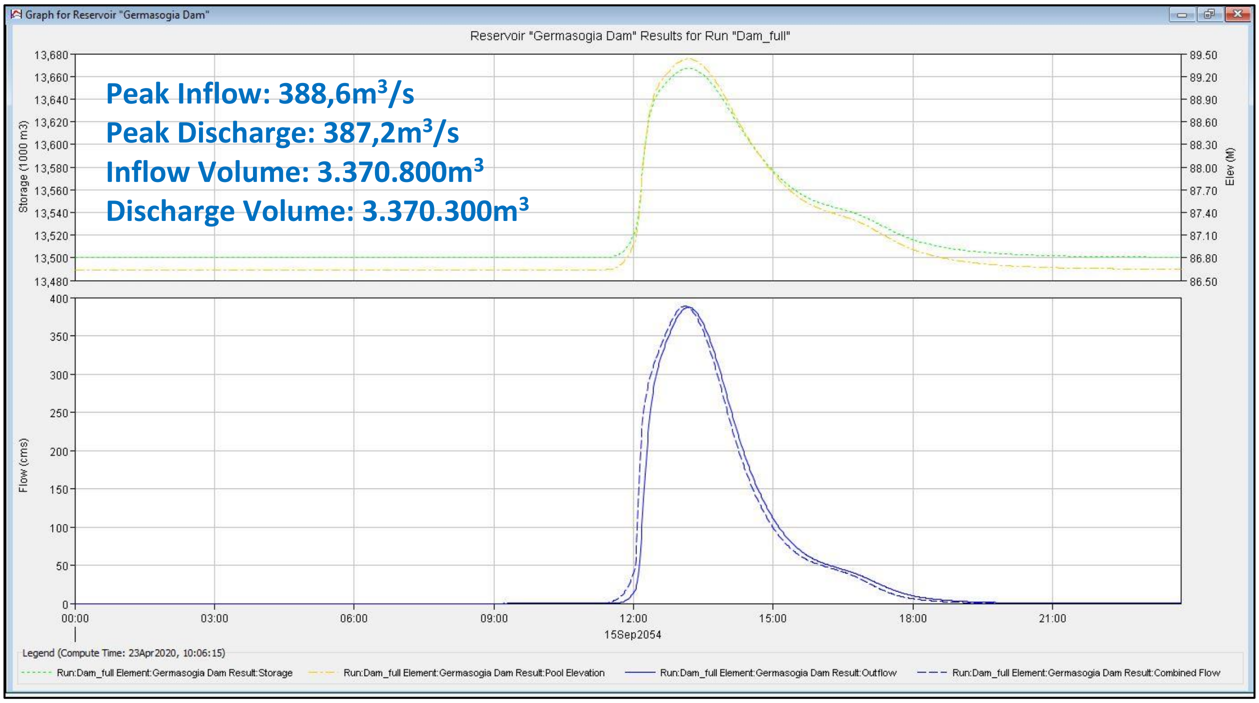
APPENDIX II:

HYDROLOGICAL RESULTS AT THE DAM SPILLWAY

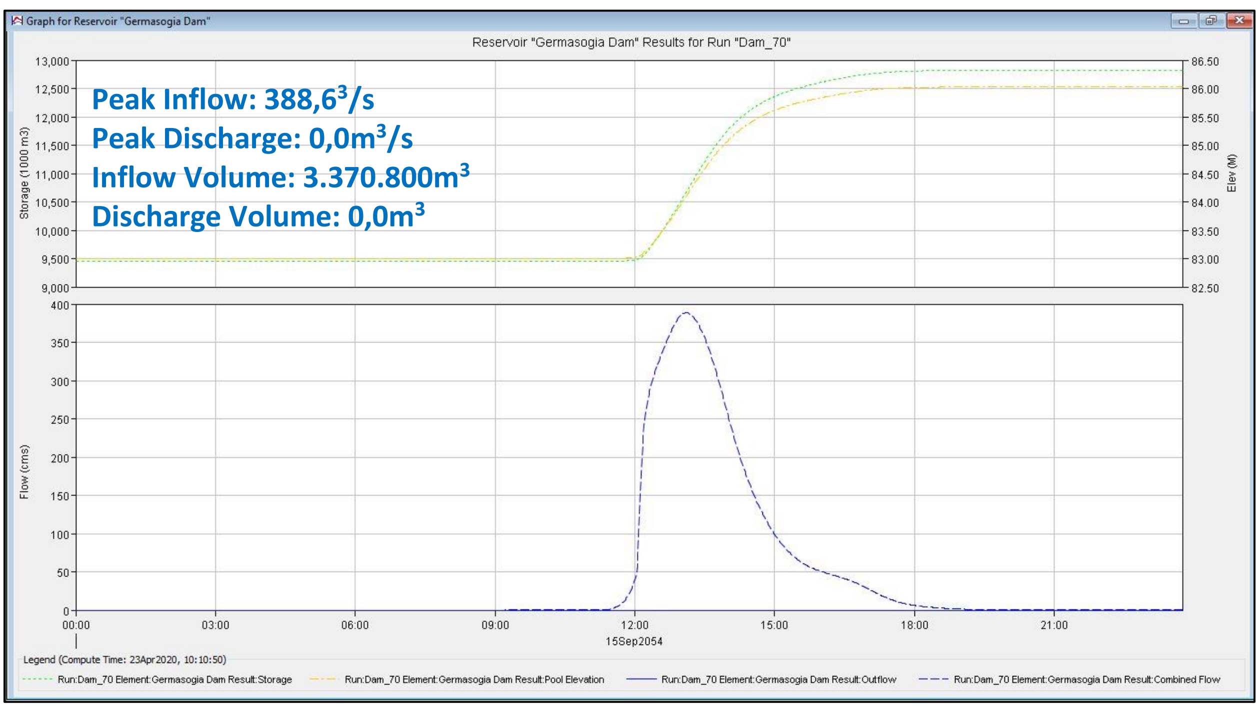
A) Climate change scenarios

Precipitation member mp02

➔ Dam Full

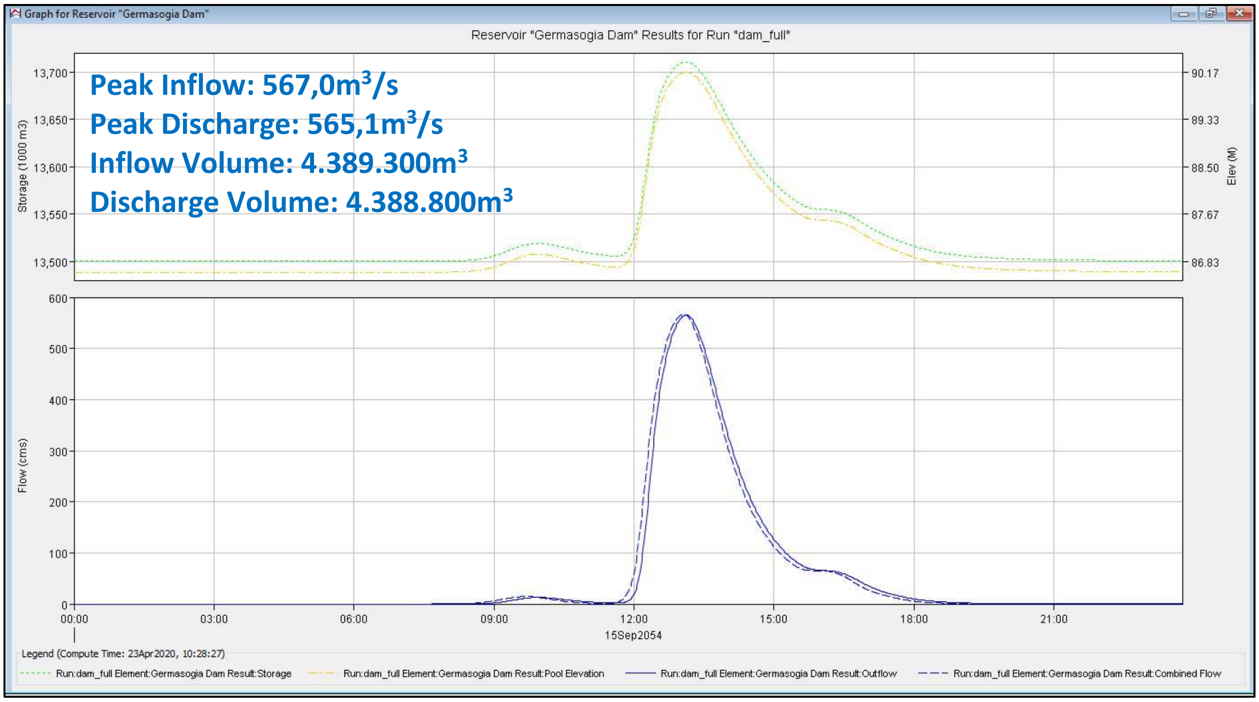


➔ Dam 70% full

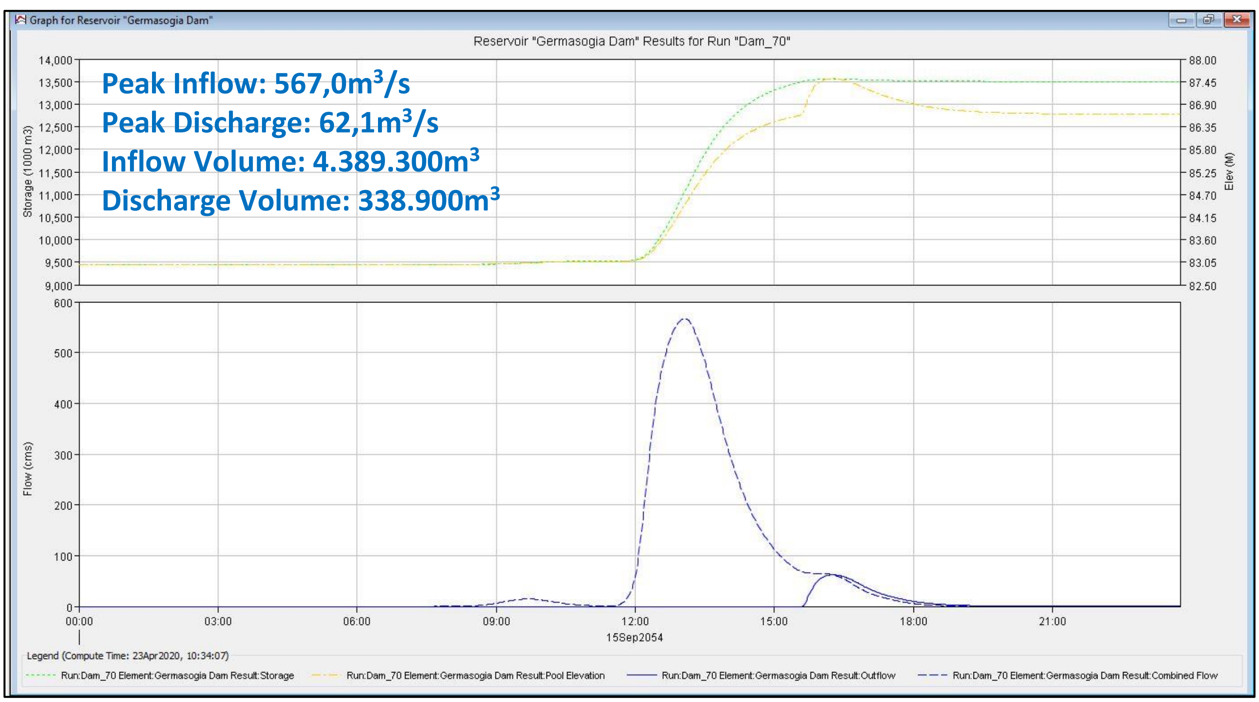


Precipitation member mp05

➔ Dam Full

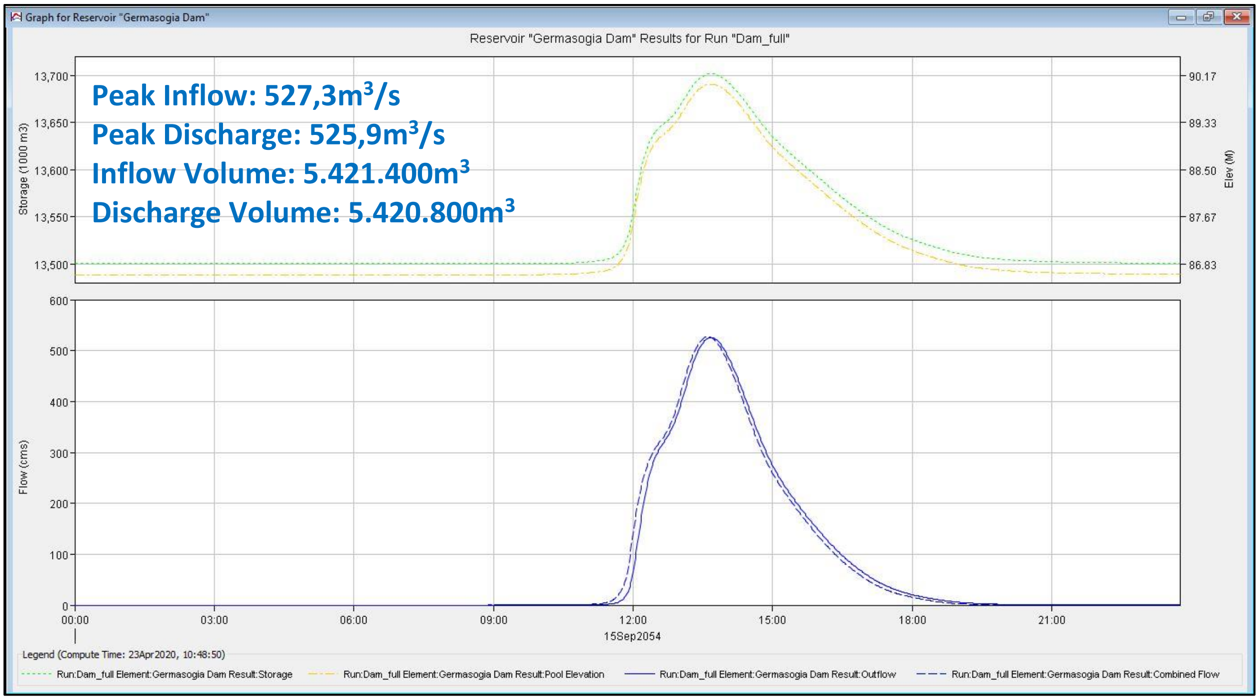


➔ Dam 70% full

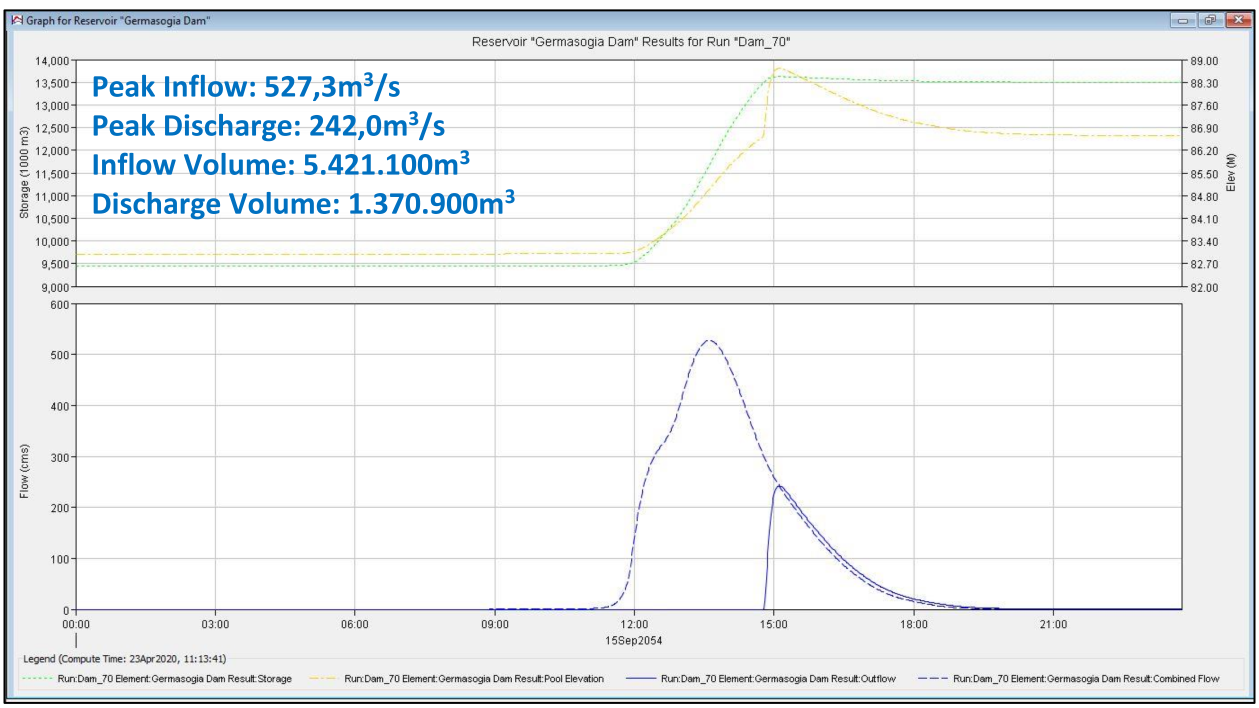


Precipitation member mp06

➔ Dam Full

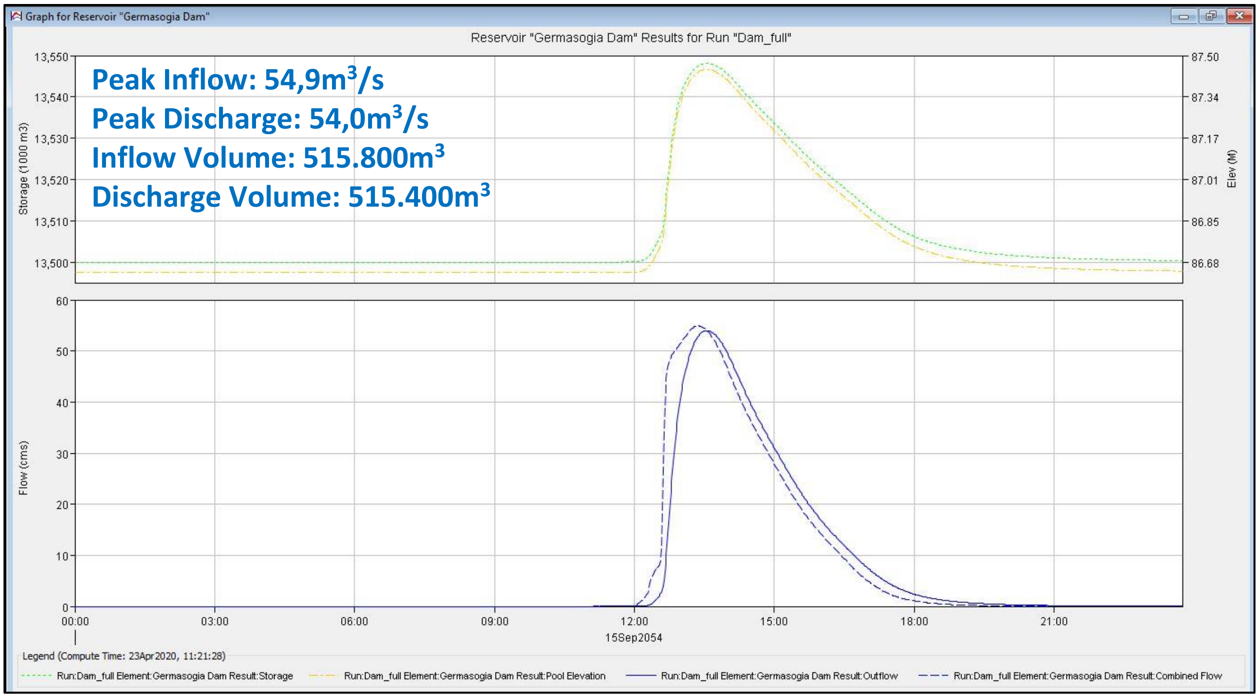


➔ Dam 70% full

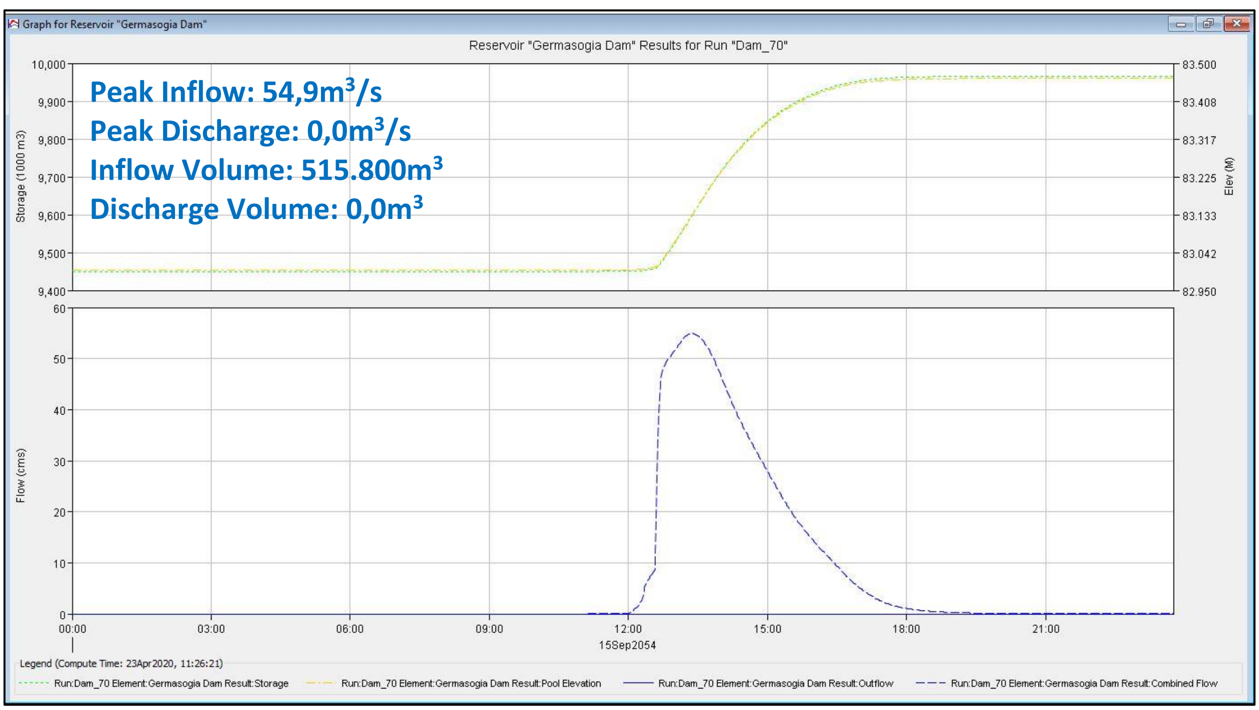


Precipitation member mp16

➔ Dam Full



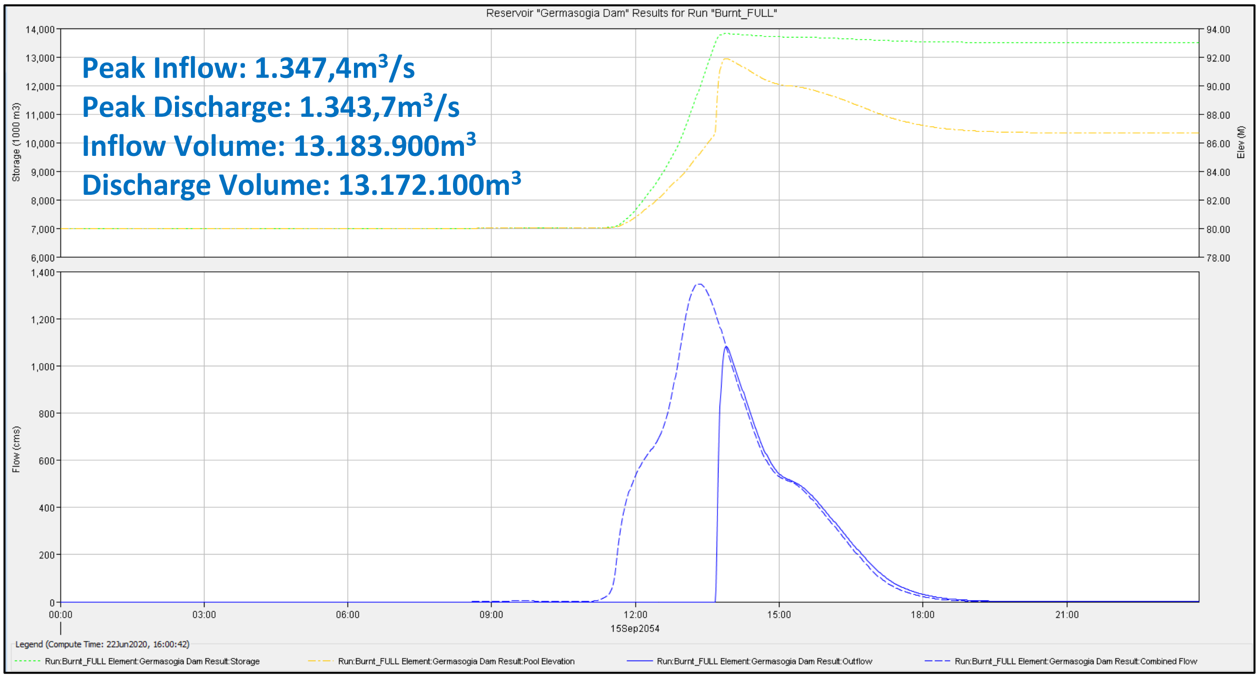
➔ Dam 70% full



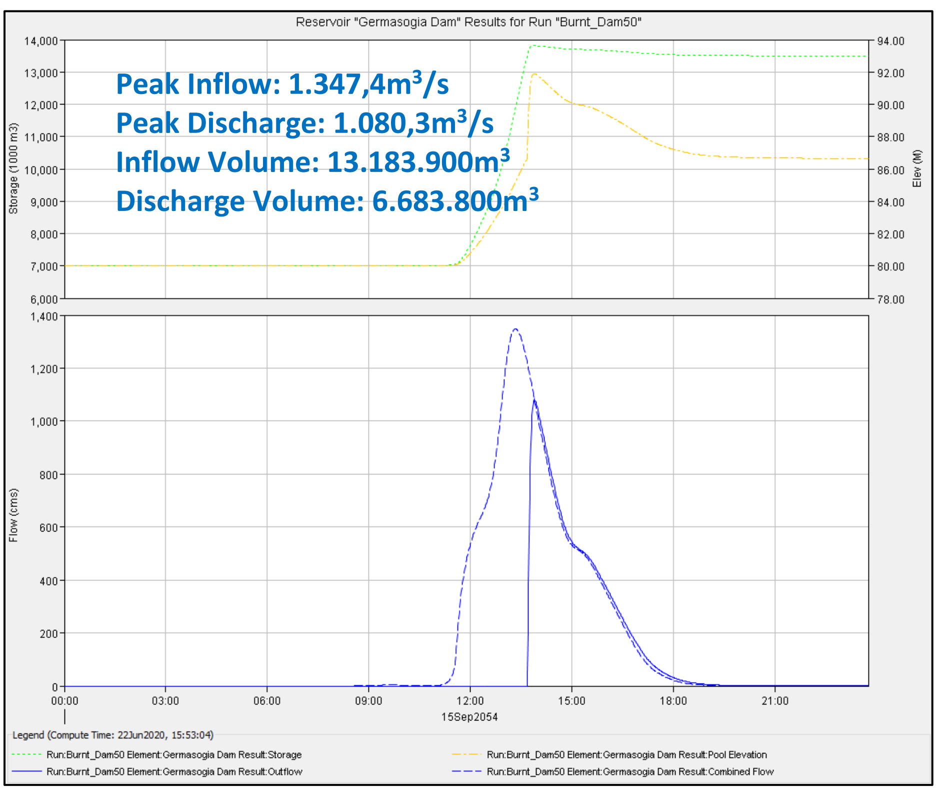
B) Climate change and land use scenarios

Precipitation member mp01

➔ Dam Full

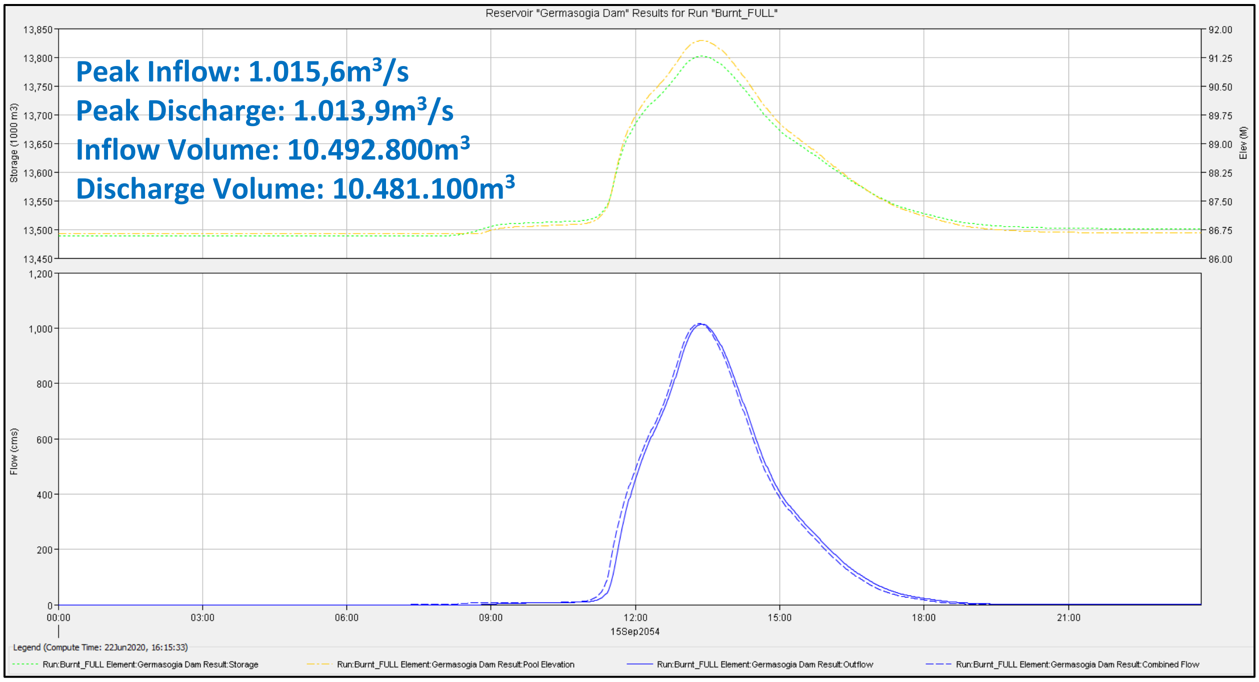


➔ Dam 50% full



Precipitation member mp06

➔ Dam Full



➔ Dam 50% full