FIRST REPORT
REGARDING
POST-DISASTER REMEDIATION
OF
2023 THESSALY FLOODING

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SUMMARY

Key findings

- There is a need to revise all flood defense infrastructures and other infrastructures that are directly or indirectly related to flood management and to *"build back better"*.
- Stronger water governance is needed.
- An Early Warning System and protocols for crisis management are needed, which clearly stipulate roles, responsibilities and courses of action that are to be undertaken, and under what circumstances.
- Storm Daniel created a momentum to review the fundamental problems of water supply as water shortages are as problematic, if not more so, as flash floods. There is a clear momentum and need for fundamental change.

Background

On 5-7 September 2023 Thessaly was battered by a once-in-a-1000-year weather event (Storm Daniel) where extreme rainfall caused extensive floods and loss of human life, livestock, harvests, land, and assets. The medicane was likely the most severe storm that has ever hit Europe and an estimated 3.7 billion m3 of rain inundated Thessaly. This caused at least 15 deaths and damages of more than €2 billion. By comparison, the catastrophic European floods of July 2021 where 242 lives were lost and where damages were well over €10 billion, the water volumes were far less (only 100-270 mm of rain fell whereas Thessaly was hit by 700 mm in 48 hours). That the casualties were not in the many hundreds or thousands was extremely fortunate.

HVA International was tasked with assessing the cause and impact of the flooding and to develop a *"Master Plan of Irrigation and Anti-flooding projects"*, which is expected to be ready in end of February 2024. In September and October 2023 fact finding missions were organized, with teams comprised of experts in water management, flood protection and mitigation, irrigation, agronomy and livestock dispatched throughout Thessaly, backed by agricultural economists and GIS experts, amongst others. This first *"Fact Finding Report*" outlines the initial findings and how a 3-layer safety model will form the basis for the Master Plan.

Due to global warming, extreme weather events such as Storm Daniel are likely to occur with both greater frequency and severity. The Thessaly Plain is unfortunately one of the most flood-prone regions of Greece and it will be impossible to completely prevent inundations if a medicane as devastating as Storm Daniel once again batters the region. With proper and timely measures, the impacts can, however, be reduced significantly.

Strategy for Flood Management

The existing Flood Management Plans (Flood Risk Management Plan 2014-2020) are not operational/actionable in the sense that they could not play a role in the prevention of the floods caused by Storm Daniel (measures that could not be implemented). The new Flood Management Plan for Thessaly should provide directions for the development of protective infrastructures as well as measures and procedures for crisis management based on agreed-upon safety levels. Safety levels need to be differentiated according to the social, economic and environmental functions of the area to where they apply. The development of the safety levels and the plan is a complex technical and political exercise, and will require novel technical expertise, financial expertise and policy dialogues.

The Master Plan for Thessaly will require integrated flood management that builds on three "safety" layers and provides protection against floods and the minimalization of impacts.

Safety-level 1: Prevention

All flood defense infrastructures need to be revised and a program to "build back better" be developed. Infrastructures for flood protection will be a combination of creating retention capacity, increased drainage capacity and improved dyke systems.

Rivers and streams are frequently confined to narrow passages, wedged in-between dykes to maximize the area of adjacent farmlands. Numerous industries and residential areas have also been built over previous decades in the floodplain of streams and rivers, which exacerbated the flooding. Bridges, roads and railways were damaged because their original designs had not properly taken into consideration the requirements for water management. These then became obstructions, causing damage and inundation. There is also no coordinated maintenance of hydraulic infrastructure.

Many dykes were not well constructed originally with poor maintenance and monitoring mechanisms of blocking debris. The heights of dykes are also often not uniform or insufficient with a lack of a well-integrated holistic operations management and monitoring system of dams and dykes.

The Lake Karla area is a closed basin, where water from the dyke breaches near Gyrtoni accumulated. Approximately 30% of the total inundations in that area (450-500 million m3) originated from the Pineios River. It may take 1,5 to 2 years before the water from the Lake Karla area is discharged.

There was hardly any attenuation of the surface runoff. This means that river discharges are "flash floods". The capacity of the existing networks of drains, rivers and streams can by no means discharge the volumes of water from these floods.

There are 2 strategies that can be used (in combination) to deal with flash floods:

1. Attenuation of the floods, which lowers the peak discharges (and water levels) while increasing the duration of the discharge;

2. Creation of greater drainage capacity (*"Give the river room"*).

The prospects of retention by reservoirs and large dams are limited. Large dams are expensive, require specific conditions, and often serve multiple purposes (energy production, irrigation), which will likely conflict with flood management.

Safety-level 2: Governance

The flooding evidenced that water resources management and flood management are fragmented between numerous organizations that have responsibilities over administrative units that do not coincide with hydrological boundaries. There is insufficient coordination between- and supervision of these organizations, which operate only in accordance with the interests of their constituents. There are for example no official, centrally endorsed protocols for the operation of pumps and gates.

Water management should be based on the hydrological boundaries (i.e., river basins). It is therefore strongly recommended that a River Basin Authority (RBA) with executive powers be established. The set-up and governance model of the RBA will be further elaborated in the Master Plan.

Safety-level 3: Crisis management

There is an urgent need to establish a 24/7 Early Warning Center that continuously receives, analyzes and processes relevant, real-time flooding information and data. The Early Warning Center should have the expertise and the tools to make accurate flood forecasts and assessments as well as communicate effectively with local stakeholders.

The preparedness for future flooding disasters can be further increased by creating repositories with the equipment and machinery for emergency repairs and debris removal, boats for rescue operations, and sandbags that can be distributed to protect vulnerable spots in dykes, as well as to protect houses and vital infrastructure.

Response and remediation efforts

Given the severity and sudden onset of the flooding and with almost 700,000 people residing in Thessaly, the number of casualties was astonishingly low. Thanks to the strong cohesion in communities, locals collaborated long into the night bringing elderly and infirm individuals to safety. They had almost no requisite tools, equipment or means to stem the flooding, such as sandbags. Emergency / survival kits with flashlights, batteries, inflatable rafts, flares, whistles, bags of drinking water and shelf-stable food supplies were also lacking.

Numerous SMS warning messages were sent out. Despite warnings being sent out, many populated areas were taken by surprise by the floods and more than 100,000 livestock and 130,000 poultry birds drowned before they could be saved. Some farmers asserted that they could have saved their livestock if they had had enough time or comprehended the seriousness of the flooding. They were forced to give up their efforts to save the livestock in order to save their own lives.

However, even if warnings had been issued earlier and more forcefully, the farmers would have needed enough time and somewhere safe to transport their livestock and means by which to feed them. In the event of severe storms, evacuations should likely be undertaken before rains even begin to fall, which requires having an adequate planning and preparedness culture.

Disaster response is a complicated matter. Preparedness is often viewed as the responsibility of emergency services, but these units can and will often become overwhelmed in a large-scale disaster and inhabitants must be prepared to handle disaster on their own, which is exactly what the people of Thessaly did.

Although the electricity network manager (ΔΕΔΔΗΕ) provided power generators for flooded critical infrastructure (such as a hospital in Volos) to restore electricity, it was not possible to connect the external generator to the electrical circuit of the facility. That the emergency generators of the hospital were located in the basement indicates that flooding had not been taken into account when designing the hospital.

Unlike previous storms and medicanes, where landslides started at lower altitudes, the landslides caused by Storm Daniel started at the top of the hills, displacing rocks. Rock piles in some rivers were observed to be several meters high, completely blocking the passage beneath a bridge. The damaged infrastructure needs to be rebuilt as soon as possible as the area has become very vulnerable to landslides.

Boulders that are up to 3 meters in diameter were observed that pose a serious risk of smashing into communities during the next storm.

Agriculture

The collection and incineration of livestock carcasses so as to prevent the contamination of water and spreading of water-borne zoonotic diseases such as cholera, typhoid and leptospirosis was exceptionally well-handled. In addition to the devastation on farms, the floods had a profound impact on the processing sector, extensive damage has rendered many of them inoperative. When compensations are paid to farmers, the entire value chain must be taken into consideration: if the processing factories are not repaired, the farmers will have a difficult time selling their products.

Many farmers were encountered who did not have insurance. Livestock farmers expressed discontent in regard to compensations as these did not take into account that it takes years to build up a herd from scratch. HVA will examine potential measures during the drafting of the master plan.

Drainage and irrigation

The drainage infrastructure in several residential areas was inadequately maintained and had also altered by residents, factors that contributed to speeding up the entering of water into many homes. Residents frequently pave over the rain gutters of the streets outside their homes so as to enlarge their properties, which impedes water run-off. Drainage canals alongside roads were overgrown with vegetation which obstructed drainage.

Some farmers had constructed illicit dams in canals in order to collect and divert water to their fields for irrigation. Drainage canals were also found to be operating as irrigation canals. These were factors that contributed to the faster spreading of floodwaters.

Crop selection is an issue that needs to be addressed. There are currently water-intensive crops being cultivated extensively in Thessaly that are highly unsustainable for water-scarce areas, especially if they require consistent irrigation throughout a long growing season. Given the lack of water in Thessaly and its hot, dry summers, the practice of cultivating such crops depletes groundwater and forces farmers to undertake measures such as building the aforementioned illicit dams, thereby exacerbating the flood risk, or pumping groundwater from depths of 300 meters.

Conclusions

Infrastructures will principally entail a combination of creating retention capacity, increased drainage capacity and improved dyke systems. Flood protection infrastructures have to be aligned with political decisions on safety levels, spatial planning and the socio-economic development of Thessaly.

The results of the Master Plan should be well integrated with the Greek National Flood Management Plans, combining:

- A series of post-disaster no-regret activities that are immediately needed
- Short-term interventions (on governance and the development of the Flood Management Plan)
- Medium-term interventions (on the development of investment plans, bankable projects and financial architecture).

The Master Plan will provide the terms of reference for the short and medium term interventions, and the roadmap towards efficient irrigation usage and a flood-resilient Thessaly.

1. INTRODUCTION

1.1 Storm Daniel

In September 2023 large areas in the Mediterranean were affected by Storm Daniel. On 5-7 September 2023 Thessaly experienced extreme rainfall followed by extensive floods, resulting in the loss of human lives, livestock, harvests, land and assets. The flooding was a sudden-onset event as the floods occurred very fast[1]. The first delineation of the affected area showed that on 6 September at 04:40 UTC, already 18,393 hectares had succumbed to flooding. By 7 September at 16:25 UTC, less than 60 hours after the rains started, 72,951 hectares were inundated by flooding.

Further monitoring via satellite imagery showed severe inundations in the Palamas region (almost 17,000 ha inundated by 10 September) and in the Larissa region (more than 15,000 ha), affecting an estimated 22,500 people. On 12 September the floods had receded slightly, with a total area of 26,000 ha still being inundated in these regions. The estimated number of affected people had increased to 28,000. By 15 September more than 7,000 ha were still flooded in the Larissa region and more than 7,000 ha in the Palamas region. By 17 September the inundations in these areas had reduced to 4,500 and 5,000 ha respectively. By 19 September the inundation had gone down to 3,000 and 1,000 ha, and traces of the previous areas could readily be observed and documented.

In Stefanovikeio, in the Lake Karla area, approximately 15,000 hectares were inundated, with 1,000 inhabitants being affected. The water levels in the inundated areas decreased much more slowly than elsewhere, seeing as the area has no natural outlet. By 19 September the inundated area was still around 10,000 ha and after storm Elias on 25 September the inundated area increased once again.

In the Karditsa region on 12 September almost 19,000 ha were flooded, with 13,000 inhabitants affected. By 18 September the flooded areas had decreased to approx. 2,000 ha.

The response of the authorities was to execute emergency repairs and measures. Drinking water and supplies were distributed to affected people and livestock farmers were supplied with fodder for their animals. The Ministry for Climate Crisis and Civil Protection also commenced releasing compensations to affected farmers.

1.2 Method

Estimates of the extent of the floods and the damage caused by the floods to infrastructure, homes and assets were made with the aid of satellite images and geographical data. As the data can be accessed through the website of the Copernicus Emergency Management Service (https://rapidmapping.emergency.copernicus.eu/EMSR692/) they have not been recapitulated in this report.

[1] A further assessment and explanation is presented in Paragraph 5.3.

1.3 Fact Finding and Master Plan

The Fact Finding is the first phase of a comprehensive process that will result in advice to be implemented. The current report is based on observations during field visits, interviews with officials and experts, the review of technical and official documents, the analysis of thematic geographical information, the analysis of drone video footage, an aerial flyover and the use of low-flying drones at specific locations.

The results of the Fact Finding phase will be elaborated into strategies that will be laid out in a Master Plan for Flood Management. On the basis of the Master Plan, necessary institutional and legal reforms can be implemented and an investment plan for infrastructural works can be drafted. Based on the investment plan, bankable projects can subsequently be developed.

1.4 Structure of the report

This report starts with a description of the paradigms and best practices in flood management, which will serve as benchmarks for the situation in Thessaly (Chapter 2). In Chapter 3 the current practices in Thessaly have been assessed against these benchmarks on the basis of field observations and interviews.

A general strategy for future flood management is provided in Chapter 4.

2. BASIC CONCEPTS OF FLOOD MANAGEMENT

2.1 Integrated approach

Flood risk management and mitigation (further referred to as ***"Flood management"***) can be considered as an integral part of overall water management, which aims at assuring the availability of the right quantity and the right quality of water at the right time and at the right place (***water security***). Flood management focusses on ***water safety*** (protection against floods).

An integrated approach is key for both water management and flood management. Integration refers to good coordination between water uses from all social and economic sectors (and within those sectors) in any intervention that may have repercussions on the water resources. This particularly refers to the integration of spatial planning and water management, which should result in all stakeholders (including nature) having a fair share in the use of water resources, and that they do not infringe on the share of other uses, either by using too much water or by polluting the water.

The planning, development and management of (irrigated) agriculture, residential areas, industrial zones, nature, roads, railways, etc. thus require the full incorporation of water management (and flood management) issues. An effective and efficient water governance structure that considers and integrates the demands of all social and economic sectors is imperative.

2.2 Best practice in flood management: Multiple-layer safety

It is good practice to build (integrated) flood management on three “safety”-layers, which together provide protection against floods and the minimization of flooding impacts:

- Safety-layer 1: Prevention: Protective measures and infrastructure that prevent floods.
- Safety-layer 2: Integration of water management and spatial planning and -development.
- Safety-layer 3: Emergency measures / crisis management to minimize and mitigate the impacts of floods.

Figure 1 illustrates the principle of the 3-layer safety model.

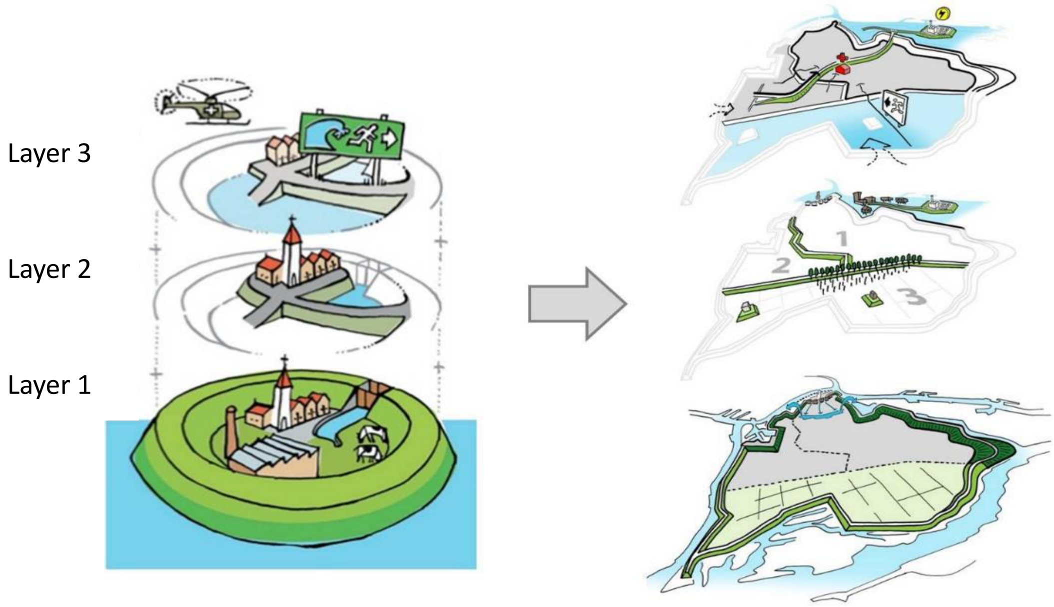


Figure 1: The 3-layer safety model

(Source: National Water Plan of the Netherlands, 2009)

Safety-layer 1 encompasses flood defense (infra)structures. This may include dykes, drainage systems, flood-resilient bridges (with large hydraulic perimeters), culverts, retention areas (areas for controlled inundations), dams, all kind of nature-based solutions, and flood bypass systems.

Safety layer 2 basically refers to water governance and the harmonization of water and flood management with all activities that may impact it. It also encompasses adaptive building of premises to become more flood-resilient, specific strategies for vital infrastructure (e.g., hospitals and other critical services), and the governance issues related to Safety-layer 3, such as the planning and development of evacuation routes, safe havens and shelters for people, livestock and machinery. The governance component also includes the operation and maintenance of water infrastructure and the enforcement of laws and regulations.

Safety-layer 3 refers to an effective crisis management structure for the proper coordination of all actions to be taken during emergencies, such as the evacuation of people, livestock and machinery; the controlled inundations in the case of risk of dyke breaks; protection against looting, etc. Safety-layer 3 also encompasses a system for early warning, which should allow for anticipating expected events and good and timely communication to inhabitants who are at risk.

The 3-layer safety concept will be used as benchmark in this Fact-Finding report, and for recommendations for the future.

3 CURRENT PRACTICES IN THESSALY

3.1 General outline

Following the benchmarks outlined in Chapter 2, the current practices in Thessaly were analyzed on the basis of field visits, interviews with regional and local actors and experts, existing documents and maps, and the collection of additional information.

The main findings with respect to the Safety-levels 1, 2 and 3 are presented, respectively, in Paragraphs 3.2, 3.3 and 3.4.

3.2 Safety-layer 1: Prevention

At many places dykes were breached, resulting in villages, industrial areas and vast agricultural lands becoming inundated. Bridges and roads collapsed or were damaged, and irrigation systems (primary, secondary and tertiary canals, gates and drainage canals) suffered heavy damage.

The field visits showed that the heights of dykes are often not uniform within an area. The dyke south of Karditsa, which protects the irrigation infrastructures of the Local Organization for Land Improvements (TOEB) Tavropou, was damaged and almost flooded again after the rains of Storm Elias (25 September). This occurred only a few weeks after the repairs. After Storm Ianos in 2020. Their total irrigated area amounts to 11,500 ha. The teams assessed dykes in many locations in the Thessaly area and the conclusion is that there is definitely a need to assess all dyke systems in Thessaly on their present state and performance.

Various bridges have collapsed or are heavily damaged. There are mainly 2 causes for this. Occasionally old bridges have been replaced by new ones, while the old (historical) bridge still remained in place, without having taken additional measures to allow the water to pass through, for example the bridge near Mirina in the Karditsa area.

Another cause of damage to bridges and inundations of the surrounding areas is the accumulation of debris from the catchment that blocked the passage of water. This occurred at several locations. A typical example could be observed in the village Megalo Efidrio, where the bridge over the Enipeas River was severely damaged. Enormous amounts of debris had accumulated there.

It can be concluded that there is a need to revise all flood defense infrastructures and other infrastructures that are directly or indirectly related to flood management (Safety-layer 1) and to ***"build back better"***.

While great improvements are possible and necessary, it will be impossible to prevent inundations in the event of extreme weather events such as Medicanes once again battering Thessaly. With proper and timely measures, the impacts can be largely reduced but not eliminated entirely.

3.3 Safety layer 2: Governance

Central and decentral administrations

The 1st revision report for the Preliminary Flood Risk Assessment for Greece[2] presents an overview of the responsible authorities for flood management. The Secretariat for Natural Environment and Water of the Ministry of Environment is responsible for the development, processing, monitoring, evaluation and control of the national flood management program. The flood management program is part of the national programs for the protection and management of the Greek water resources.

The Secretariat also has a coordinating role with state agencies, such as the General Secretariat of Civil Protection of the Ministry of Citizen Protection, and other relevant ministries.

The Water Departments of the decentralized administrations are responsible for the implementation of the national flood management program. In collaboration with the Departments of Civil Protection they are to prepare flood risk maps and flood risk management plans. The Water Departments have a coordinating task and must ensure the active participation of the interested parties in the preparation, review and updating of the flood management plans. They have to report (annually) to the Water Environment Protection and Management Directorate of the General Secretariat of the Natural Environment and Waters.

The above responsibilities are endorsed by law. It was, however, reported by the Ministry of Environment and Energy that part of the tasks of the decentralized Water Departments are being executed at a central level, because of a lack of capacity at the decentral level.

The development of flood management plans is delayed, and there is also uncertainty as to whether the current scope of work for the development of these plans is adequate (see Paragraph 4.2).

Fragmentation of water management

The floods that were caused by Storm Daniel showed that the current institutional setting and performance are not effective. Water resources management and flood management are largely fragmentated over numerous organizations, such as municipalities, the approximately 50 local organization for land improvements, dam operators, and the 4 regional authorities (the Prefectures of Karditsa, Larissa, Trikala and Magnesia), with no overarching coordinating organization. They have the mandates over, sometimes, relatively small areas that are mostly determined by administrative boundaries and that do not coincide with hydrological boundaries.

[2] The document is prepared within the framework of the Directive 2007/60/EC for the assessment and management of flood risks.

Water planning and development

The result has been a very excessive overexploitation of groundwater resources, mostly by the agricultural sector, which uses more than 90% of the total water in Thessaly. The total volume of consumed water is approximately 1.5 billion m^3, of which 70% is groundwater.

The number of boreholes has increased from less than 7,000 in 1975 to approximately 33,000 wells today. A recent inventory showed that approximately 22,000 of these boreholes have now been registered. It will require an enormous tour de force to develop and implement a strategy for sustainable groundwater exploitation.

The annual overexploitation of groundwater is estimated at 300 million m^3 per year[3]. The groundwater consumption will need to be reduced substantially to recover the depleted and degraded aquifers, which - according to existing studies - would require a total volume in the order of 3 billion m^3.

It is obvious that the water deficit in Thessaly cannot be solved by water demand management alone. Either more water (from the upper Achelous river basin) needs to be transferred to the Thessaly Region or the area of irrigated lands must be reduced drastically. The devastation caused by Storm Daniel could be an opportunity to reform the agricultural sector and to redesign the land. In either case, tough decisions must be taken and implemented in the short term. This requires strong water governance.

Daily water management

The distribution of water over the irrigated lands is managed by the approximately 50 local organizations for land improvements in the region, with no mutual coordination. Official protocols for the operation of pumps and gates do not currently exist.

Intersectoral coordination and spatial planning

Numerous homes and industries have been built in the floodplain of streams and rivers. These suffered immense damage, which could have been avoided. What is worse is that these structures exacerbated the floods. Along the bridge between Larissa and Giannouli a built-up area was developed in the flood plain of the Pineios River. This area caused a bottleneck for the discharge of the Pineios River. Residential and industrial areas have also been developed on the northern bank of the Pineios River, at locations where, from a flood management perspective, should not have been permitted. These bottlenecks contributed to the flooding of vast areas south-west of Giannouli, causing inundations of more than 4 meters.

[3] A larger deficit would be expected on the basis of groundwater recharge assessments in areas with a similar climate.

Enforcement of laws

It was reported that many illicit dams and other structures had been erected by individual farmers. Some farmers have even applied for compensation for damage to their (illegally erected) dams.

Maintenance of water infrastructure

As in daily water management there are no coordinated actions for maintenance of hydraulic infrastructure. The local organization for land improvements maintain and repair their own assets. Responsibilities of municipalities are sometime not clear.

A similar case was observed north of Larissa where the ruptured river dyke was being repaired by order of the governor, whereas the repairs near the pumping station and bridge were being negotiated between the Municipality of Larissa and the Prefecture. There are also different rules for rivers that flow within one prefecture, and rivers that flow through more prefectures.

There is a pressing need for stronger water governance (Safety-layer 2). A strong, overarching, coordinating body, with expertise in water and flood management, and executive powers regarding water issues, is imperative.

3.4 Safety layer 3: Crisis management

The fragmented water governance was evident during the emergency situation caused by Storm Daniel.

The existing warning system and communication with inhabitants was ineffective. Even though Storm Daniel was anticipated to be severe, many populated areas were taken by surprise by the floods.

There is a very pressing need for an early warning system and protocols for crisis management, which clearly stipulate roles, responsibilities and courses of action that are to be undertaken, and under what circumstances. The new Flood Management Plans should include crisis management (Safety-layer 3).

4. GENERAL STRATEGY FOR FLOOD MANAGEMENT

4.1 General outline

The conclusion from the findings outlined in Chapter 3 is that all 3 safety layers for flood risk management and mitigation in Thessaly need to be improved.

The Master Plan will stipulate a roadmap for activities for the short- and medium term, and elaborate the required actions to address both the water governance issues and measures for flood prevention and crisis management.

A revised Flood Management Plan is currently being elaborated by the Greek government. It is, therefore, of utmost importance that the results of the Fact Finding Mission and the Master Plan be incorporated in this new plan. It is also of utmost importance that the new plan be implemented and become a genuine operational tool.

The revised Flood Management Plan for Thessaly and other flood-prone regions in Greece will need to be incorporated into the EU Floods Directive (2007/60/EC).

Paragraph 4.2 presents observations with respect to the existing flood management plans for Greece and Thessaly.

4.2 Flood Risk Management Plan 2014-2020

In 2019 the "1st revision of the Preliminary Flood Risk Assessment" for Greece was approved. The document includes an overview of flood risk areas in Thessaly. These areas actually correspond well with the areas that were inundated by Storm Daniel.

In the same period, a risk management plan for Thessaly was issued by the Water Department of Thessaly, also covering the period 2014-2020. The plan shows comprehensive background data and calculations of the risk zones for extreme rainfall events. Figure 2 presents the predicted inundation depths for a return period of 1,000 years. Figure 3 presents the recorded inundation depths on 7 September 2023.

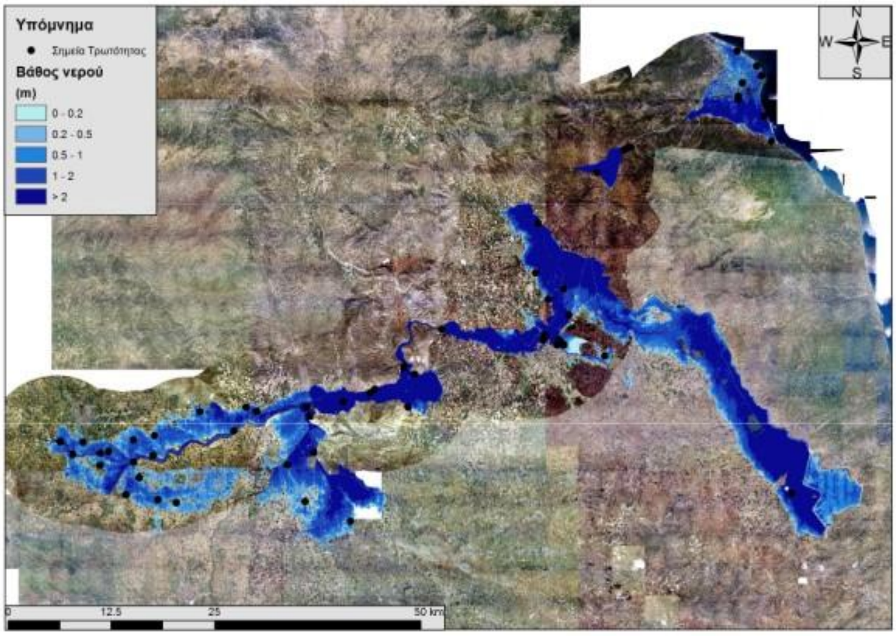


Figure 2: Predicted inundation depths for a return period of 1000 years.

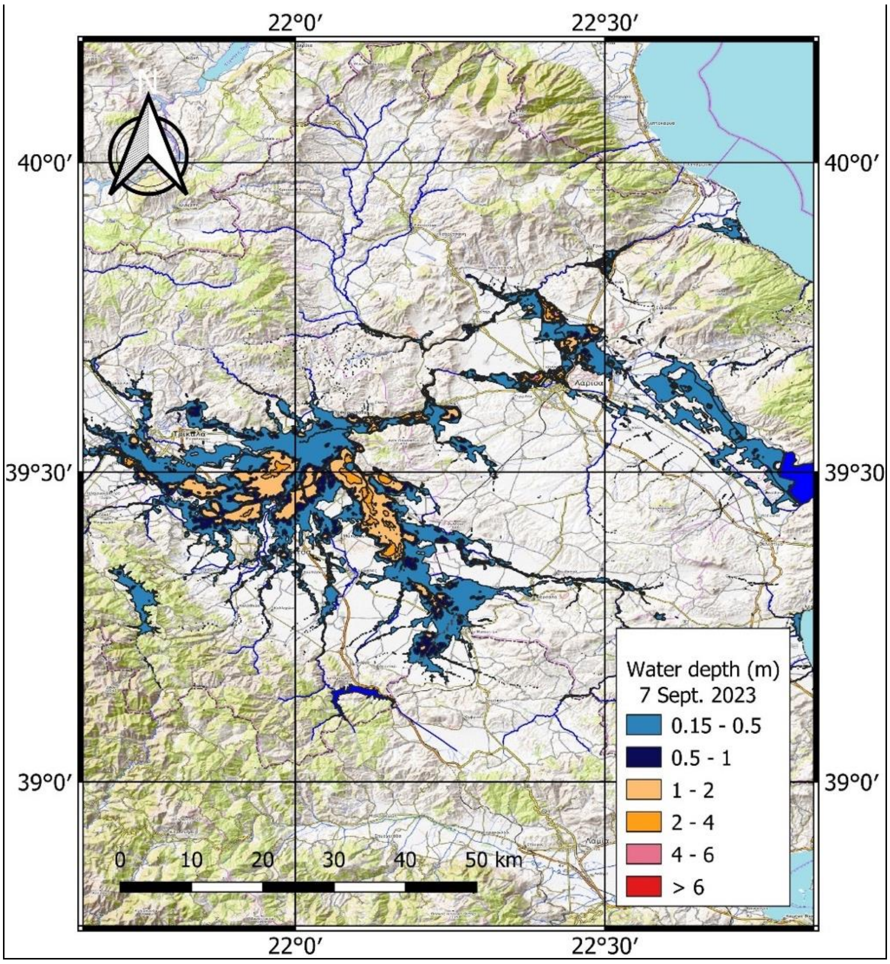


Figure 3: Inundation depths on 7 September 2023

The discrepancy is likely the result of the applied schematization and parametrization of the applied HEC-RAS models. Rainfall-runoff relationships were apparently calculated with the use of the "Curve Number Method", which is a tentative method if input data is not accurate or not available. At the time of the development of the model more accurate input data was probably not available. An updated model should thus be more accurate, especially if the model also has to be applied for the planning and development of flood prevention infrastructure and as operational tool for forecasting floods as a key component of an early warning system.

The existing Flood Management Plans are not operational in the sense that they did not play a role in the prevention of the floods caused by Storm Daniel.

4.3 Revision of Flood Risk Management Plan

The new Flood Management Plan for Thessaly should address all 3 safety layers that were discussed and assessed in Chapters 2 and 3. Moreover, the plan should be implemented and become a genuine operational tool in flood management.

Safety levels

The Flood Management Plan should devote due attention to strategic and operational water management. For the design of flood prevention measures (Safety-layer 1) safety levels need to be elaborated. These safety levels should be specific, acceptable and executable, in terms of required investments within budget frameworks.

Safety levels have to be differentiated according to the social, economic and environmental functions of the area to where they apply. The safety levels will thus be based on costs and benefits of interventions in relation to the risks of the loss of human life, livestock, assets and livelihoods, as well as the social impacts of flooding.

Realizing safety levels

To achieve the required safety levels substantial infrastructural works will need to be designed and constructed. A novel, detailed hydrological/flood model is imperative for this purpose.

As will be made evident, it must be acknowledged that not all areas in Thessaly can be protected to the desired safety levels. This means that priorities in spatial planning and socio-economic development need to be set ("*not everything is possible anywhere*")[4].

[4] It will likely not be feasible, either technically or financially, to redesign all areas so that they can cope with storms like Storm Daniel. One may have to be accept that certain areas will have to continue suffering from flood events, and that the only feasible option is to develop safe havens for people and animals and evacuate them in time, in combination with compensatory payments. For this reason, policy discussions should be held alongside the technical analyses.

It may be necessary to relocate economic functions and people. This means that the Flood Management Plan also needs to place specific attention on compensations (e.g., for agricultural areas that will have lower safety levels than other areas).

As crisis management (Safety-layer 3) is an integral part of flood management, the new Flood Management Plan for Thessaly should also incorporate crisis management, particularly early warning and the creation of evacuation routes and safe havens.

The new Flood Management Plan for Thessaly is a complex technical and political exercise, and requires novel technical expertise, financial expertise and policy dialogues.

The institutional setting and financial resources to implement a new plan need to be in place.

5 SAFETY LEVEL 1: PREVENTION

5.1 Lessons learned

In order to protect the Pineios River Basin there is a need to "build back better". Before rehabilitating existing infrastructure or developing new infrastructure, a more detailed (and quantitative) analysis of the flood event should be conducted.

5.2 Flood history

The region of Thessaly is an important agricultural area for Greece. It accounts for approximately 25% of the total agricultural production of Greece and 5 % of the country's GDP. Approximately 500,000 ha of land (=5 million stremma) is cultivated on, of which approximately 50% is irrigated. The irrigated areas have gradually increased from approximately 50,000 ha in the 1960's to 250,000 ha at present. This development has put immense pressure on water resources.

The severe problems of water scarcity, declining water tables and water quality has brought about an unfortunate circumstance where water management has focused almost solely on obtaining water and very little attention has been paid to flood management and prevention.

It must be stressed that Thessaly is one of the most flood-prone regions of Greece. Floods are a ***recurrent phenomenon*** in Thessaly. Moreover, there is an evident increasing trend in the number and severity of floods in the region during the past several decades. Repairs after Cyclone Ianos in 2020 cost approximately € 170 million. It is anticipated that extreme events such as Storm Daniel will occur with both greater frequency and greater severity due to global warming and climate change. This expectation is based on the fact that the surface water temperatures in the Mediterranean are rising. Whereas Mediterranean cyclones like Medicane Ianos and Daniel form as a result of several meteorological conditions, they have been rare weather phenomena in the past. One major contributing cause is increased sea surface temperatures in the Mediterranean Sea seeing as warmer water results in greater evaporation, providing the necessary energy and moisture for medicane development and intensification. The heat wave in southern Europe in the summer of 2023 is likely a very significant factor in the development of medicanes and as long as global warming continues to rise, it is logical to assume that so will the intensity and frequency of torrential rain over many regions of Greece.

The areas of Karditsa–Enipeas, Larissa-Karla and Trikala-Neochoritis are particularly vulnerable. These areas are also among those that were affected the most by Storm Daniel.

Figure 4 indicates the locations where previous flooding events have taken place.

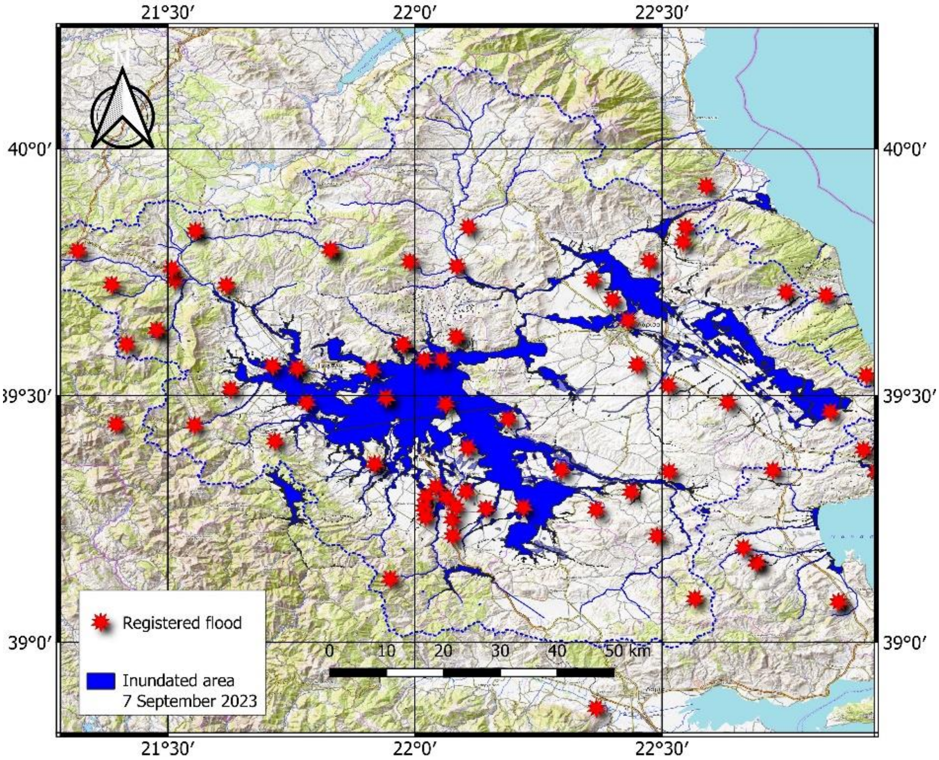


Figure 4: Historical flood events

5.3 Analysis of rainfall and floods

The devastating floods caused by Storm Daniel were inarguably anomalous. Paragraph 5.2 shows, however, that floods are recurrent in Thessaly. As recently as 2020 Medicane Ianos caused extensive damage and some of the infrastructure that was repaired has once again been damaged.

The volume of rainfall (in m^3) that fell on the various areas within the Pineios River Basin during Storm Daniel has been estimated on the basis of daily rainfall data from the National Observatory of Athens (Institute for Environmental Research)[5]. Figure 5 presents the locations of these rainfall stations, and the geographical areas to where the rainfall figures were attributed[6].

[5] N.B. 1: The data of the (local) rainfall stations at Itea and Mirini (both operated by T.O.E.B. Tauropou) was analyzed, but not included in the assessment. The same applies to 3 research stations near Agia (operated by the Pineios Hydrologic Observatory), as their data was well in line with the data of the Agia station (provided by the National Observatory of Athens).
N.B. 2: On 6, 7 and 8 September no data was recorded at the Smokovo station. As local staff reported that the rains in this area were less than in the rest of the Pineios river basin, no corrections were made. It should thus be kept in mind that the rainfall in the catchments that use the Smokovo data can be higher than is presented. The data from the Platykampos station was corrected to compensate for short interruptions.

[6] The Thiessen method may not always be applied in mountainous areas, but in regard to vast areas with cyclonic rainfall the method is considered appropriate for the estimation of rainfall volumes.

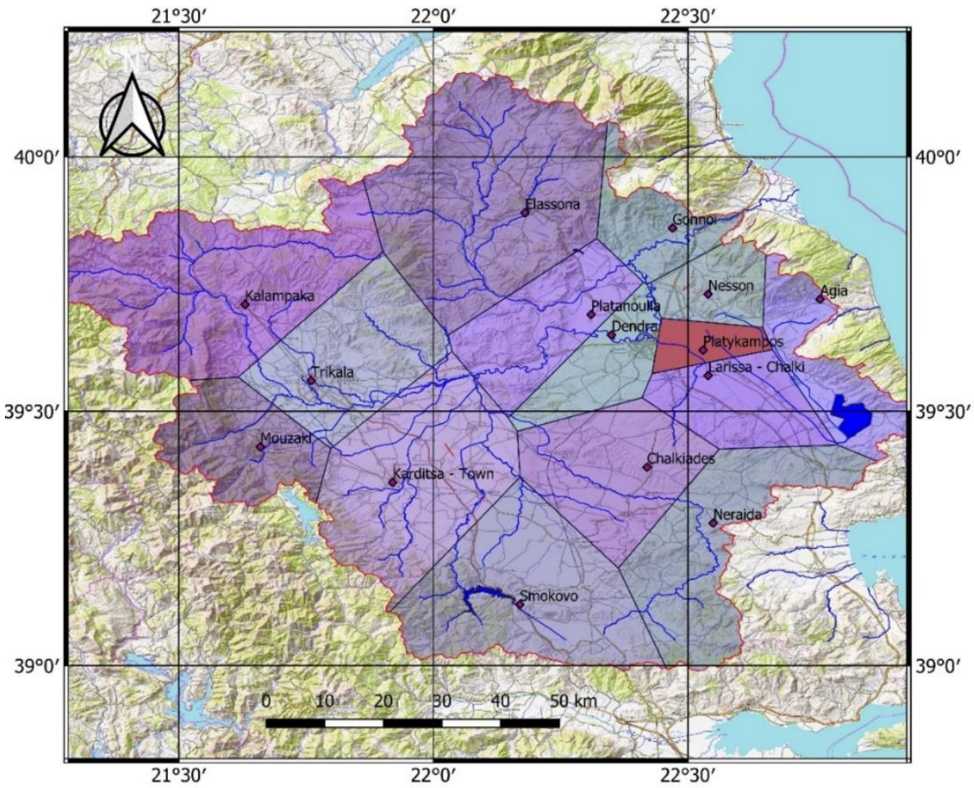


Figure 5: Rainfall stations and areas (Thiessen)

Calculations show that from 4 to 7 September an estimated 3,7 billion m^3 of rainfall fell over the entire Pineios River Basin (delineated in Figure 5), of which approximately 3 billion m^3 fell in 2 days' time (5 and 6 September).

The response of the surface water system was examined by analyzing the recorded water levels and discharges at the surface water monitoring stations. Table 1 presents a summary of the surface water stations, their catchment area and volume of rainfall. Because the inundation of areas started in the early morning of 6 September the volumes of rainfall of 4 and 5 September were also calculated.

Table 1. Surface water monitoring stations

Surface water monitoring station[7]	Catchment (km^2) (estimated)	Estimated volume of rainfall 4-7 September (million m^3)	Estimated volume of rainfall 4-5 September (million m^3)
Theopetra	Not determined	Not determined	Not determined
Lithaios	266	109	31
Magoula	247	143	44
Nomh	2,229	958	286
Enipeas	3,212	1,337	635
Tempi	9,352[8]	3,343	1,427

[7] The Gorgogyrh station has not been included in the assessment seeing as its data was deemed unreliable.

[8] Excluding the catchment of Lake Karla. Rainfall in this catchment (estimated at 365 million m^3) does not register at the Tempi station but flows to Lake Karla.

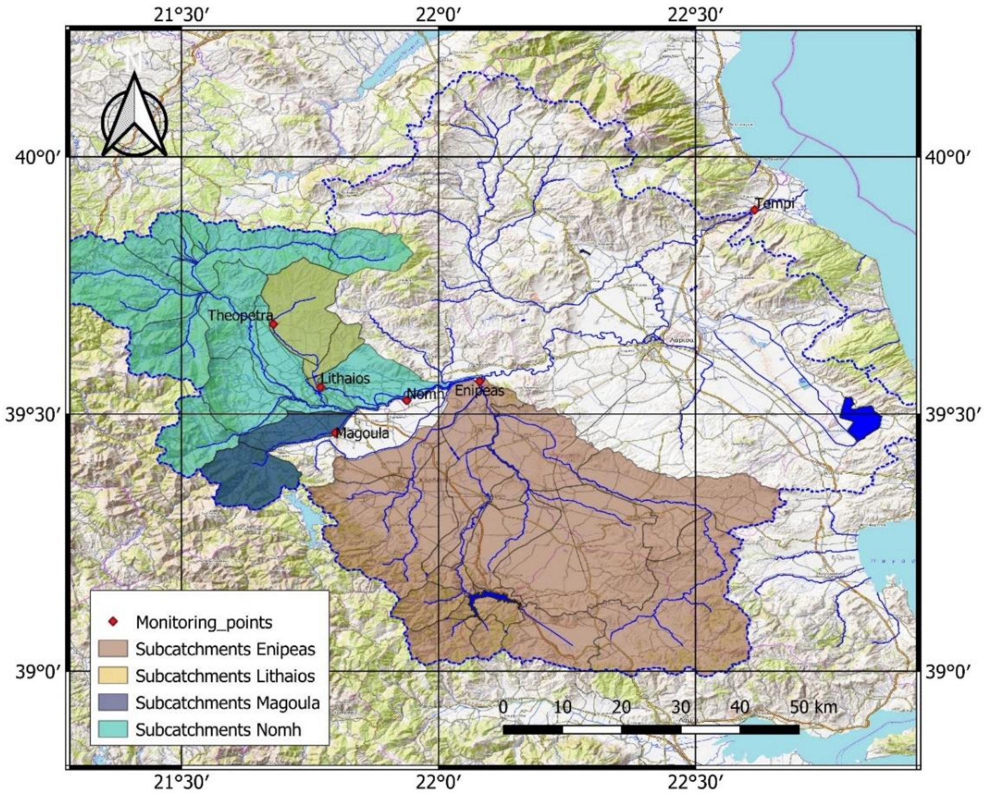
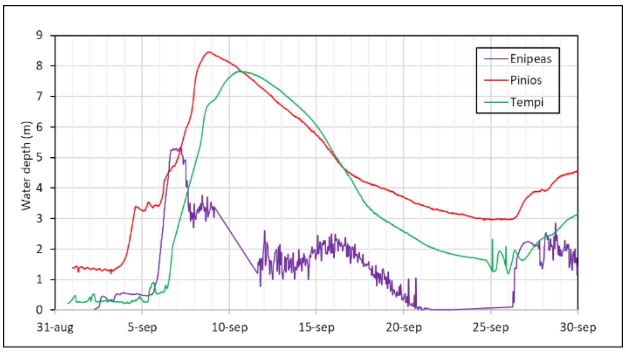
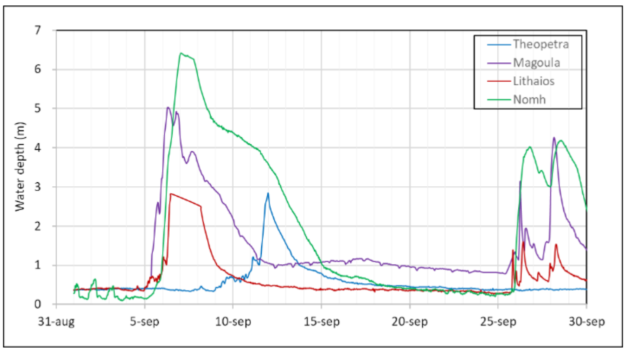


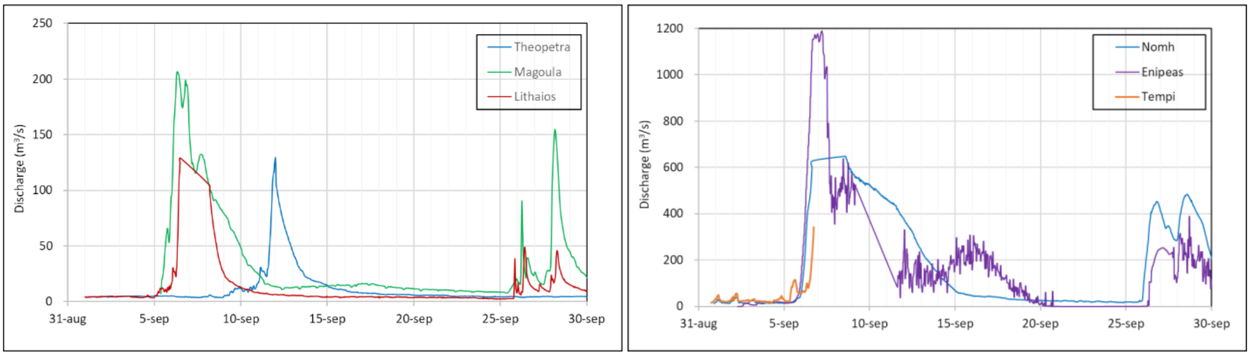
Figure 6: Surface water discharge monitoring stations and approximate catchment areas.

Figures below illustrate the observed water depths and discharges at the surface water monitoring points. With the exception of Theopetra, all monitoring locations demonstrate an almost instantaneous response to rainfall, with very short, high peak discharges.





Observed water depths.



Observed water discharges.

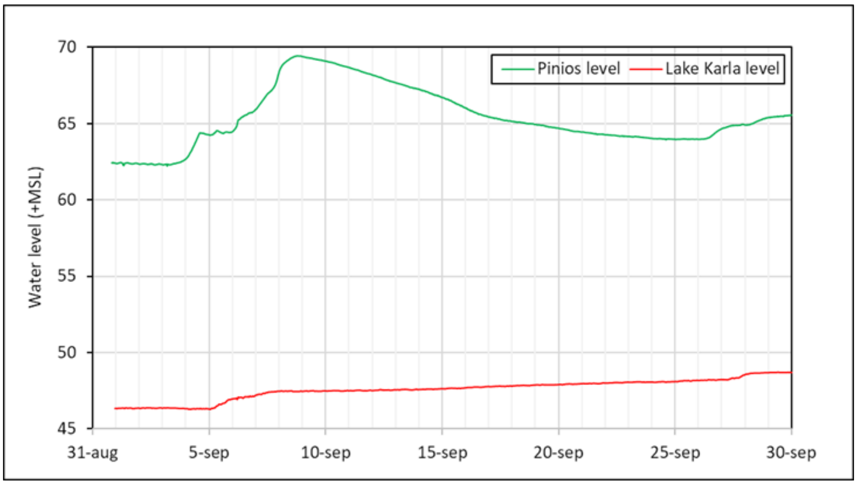
This means that there is hardly any attenuation of the surface runoff. In other words: there is hardly any water retention in these areas.

It is very unlikely that flood prevention can be realized solely by increasing the capacity of the discharge networks, e.g., by creating more "room-for-the-river". Such measures are certainly needed, particularly in the downstream areas. However, it is key that the floods be attenuated as much as possible. This requires the creation of retention capacity in the area.

5.4 Lake Karla

The sub-catchment of Lake Karla differs from the other sub-catchment in the Pineios River Basin, as its water is not discharged into the Pineios River. On the contrary: part of the water of the Pineios River is diverted towards Lake Karla in order to support agriculture and nature development. The sub-catchment of Lake Karla is actually a closed basin but it also has a man-made outlet: a tunnel that passes through the mountain and discharges at Volos and the Pagasetic Gulf. The design capacity of the outlet is 8.5 m^3/s (22 million m^3 per month).

Figure below shows that on 5 September the water level of Lake Karla was 46.3 m and increased approx. 1.2 m during the rains of 5-7 September, representing a volume of approx. 40 million m^3. Most of this water was probably discharged by the interceptor drain running along the eastern side of the valley. Estimations of the total inundated land outside Lake Karla vary. On September 20, HVA's experts on site estimated the inundated area to be 125-150 km^2. The volume of water in the inundated areas (excluding Lake Karla) was estimated at 450-500 million m^3. This would imply that approximately 30% of the inundations in the Lake Karla sub-catchment originated from the Pineios River. These estimates are tentative at present, but it is evident that there is a need to protect Lake Karla from flooding from the Pineios River.



Water levels Pineios River (Gyrtoni Barrage) and Lake Karla.

The previous figure also shows that the water level in the Gyrtoni Barrage increased approximately 7 meters in a few days' time, reaching its maximum in the evening of 8 September.

Water from the Lake Karla area can only be removed through the tunnel and evapo(transpi)ration. It may take 1 ½ - 2 years to recover the area. As the tunnel near Lake Karla will have to remove most of the water it is important to verify that the discharge capacity of the tunnel has not been compromised over the years. This can be done by a discharge measurement near the outlet in the Volos area, preferably with (calibrated) flow meters. These measurements can provide information on whether or not obstructions or sedimentation has occurred at the intake point.

6. THE WAY FORWARD

6.1 Immediate interventions

Immediate actions refer to the implementation of emergency and no-regret measures:

- Repair roads and dyke breaks.
- Mobilize compensations.
- Clear all water courses.
- Clear all dykes from trees and shrubs.
- Remove all debris and waste.
- Determine discharge with a flow meter (type Ott). Check the inlet and make necessary repairs in the case that the flow is significantly less than 8.5 m^3/s.
- Collect detailed geographical data on damage. Compose a map that identifies the most affected areas.

7. IMPACTS ON THE THESSALIAN AGRICULTURAL SECTOR

7.1 Livestock losses and carcass removal

One of the main objectives in a post-disaster situation in an area with livestock is to collect and dispose of carcasses so as to prevent the contamination of water and spreading of water-borne zoonotic diseases such as cholera, typhoid and leptospirosis. During the field visits to numerous farms and villages and agricultural areas, starting on September 18th, just 10 days after Storm Daniel, not a single dead animal was encountered at any of the farms and only 1 dead sheep was encountered in a field. This indicates that the animals were being disposed of in a very efficient, orderly and professional manner. There were some reports of leptospirosis and some minor complaints voiced by farmers that not all animals in their area had been collected yet and the odor was bothersome, but they acknowledged that they were in dialogue with the Ministry of Rural Development and Agriculture who had given them clear instructions on what to do, so communication was working very well (the Ministry had instructed the farmers to collect the carcasses in one place so that their front loaders could efficiently load them all in one go into trucks and thereby work more efficiently).

HVA team leaders received daily updates from the Ministry's Secretary General Mr. G. Stratakos on how many carcasses had been collected and it is our assessment that this very important aspect of the disaster response was exceptionally well-handled.

The data provided by the regional authorities in Karditsa, Larissa, Magnesia and Trikala regarding animal losses did not specify whether the animals were used to produce milk or meat. The total loss of bovine, ovine and porcine livestock as of September 25 was 103,774 and 131,795 fowl.

When comparing the mortality figures to the livestock population data of 2022-2023, it can be ascertained that approximately 13% of the cattle, 3% of the sheep and goats, 10% of the pigs and 5% of poultry had been lost. This figure is not definitive.

Area			**Mortality** (head)			
	Acres	**Hectares**	Sh&Gt	Cattle	Pigs	Birds
LARISA	555.742	224.901	23.940	2.871	9.263	12.221
KARDITSA	616.339	249.424	32.776	1.713	10.664	19.344
TRIKALA	170.305	68.920	13.612	1.636	1.325	100.230
MAGNISIA	41.432	16.767	5.395	489	90	-
Rigas Feraois	50.407	20.399				
	1.434.225	580.410	75.723	6.709	21.342	131.795

Figure 10

Initial figures puts the number of farm animals that perished due to the flooding at slightly over 100,000 cattle, sheep, goats and pigs and 130,000 fowl, which is a loss of **10%** and **5%** of the domesticated animal population, respectively.

The removal of carcasses was an important part of the response work due to risk of spreading of water-borne disease. Given the circumstances, this response was expeditious and safe.

7.2 Impacts on livestock and dairy farmers

The livestock farms in Thessaly typically adhere to a basic design in terms of size and mechanization. On average, farm size for goats and sheep ranges from 300 to 400 head, while dairy cattle and pig rearing farms have approximately 200 head.

Many farms in the Larissa area had been completely inundated by floodwaters, resulting in 100% loss of livestock and the submersion of equipment for an extended period. These farms, which typically house 500 - 1000 sheep on average, were well-designed and equipped with modern feeding and milking machinery. The estimated loss for each farm ranged between €1 to €3 million Euros.

Many farmers interviewed were in a state of shock and it was difficult for them to envisage a discernible path to recovery. Their immediate concern was in regard to compensation, including the timing and availability of such support, and the feasibility of continuing working as farmers.

Figure 11: Many farmers that were interviewed were still traumatized.

Sheep and goat farms often suffered complete livestock losses seeing as the sheep are considerably smaller than cattle and drowned in the high water. The farmers were unable to evacuate their livestock due to the absence of an effective warning system and an actionable evacuation plan.

Farmers reported that they were sent warning messages about Storm Daniel but they did not have nearly enough time to react. According to their estimations, they would need approximately 20 days to remove everything that was in their facilities. If they had received the warning system a day in advance, they could have rescued the animals, provided that they had had someplace safe and equipped with feed to take them to, but there was no evacuation plan. Moreover, they were not expecting a flood to this extent and they did not act promptly after the message. They attributed this to the fact that their ewes were pregnant, expecting to give birth in November, and they did not want to upset them. It was only after they saw the water close to their premises that they started trying to evacuate the animals.

The animals that were rescued cannot be utilized any more. Seeing as most milking equipment was destroyed and the animals far too many for the farmers to milk by hand, this resulted in udder engorgement.

A) Dissemination of warnings at an earlier stage of an impending flood and preparedness and online guides explaining clearly what to do would have mitigated the damage that was incurred.
B) Providing funds for restoring the herds should be done in conjunction with the consideration of the state of the processing facilities (value chain approach). If farmers have nowhere to sell their products, it creates a new problem.

Figure 12: The flash flooding is clearly evidenced by this destroyed bulk milk transport truck in Nea Lefki which could have been driven to safety but even that was not possible.

Figure 13: Total loss of milking machinery

7.3 Impacts on crop farmers

Farmers are apprehensive toward rebuilding their farms without comprehensive flood prevention measures being put in place.

Relocating farms is not a decision to be taken lightly but may very well be the only viable option if it ensures a high level of protection against future floods.

Farmers who have recently experienced the floods expressed a lack the motivation to continue their farming activities. Their immediate concern is providing for the livestock that survived, but their income is not sufficient to subsist on.

There are currently no farming cooperatives.

Providing farmers with assistance in setting up smaller, more flexible and more controllable cooperatives and/or clusters should be considered. This would also bolster their ability to engage in disaster preparedness and practice response.

7.4 Impacts on food processors (Value Chain Disruption)

In addition to the devastation on farms, the floods also had a profound impact on the processing sector. Extensive damage to a number of processing plants has rendered many of them inoperative. The damage varied greatly, from complete destruction in a matter of hours to some hardly being damaged at all.

The damage has disrupted the manufacturing process, market distribution, and the ability of producers to offload their products.

Recuperating from the damage will be very difficult seeing as the processors are now losing their clients. One processor that had a thriving export business of Feta cheese was on the way to the Anuga Food Fair and would have to inform all its clients that they could not deliver anything to them.

Figure 15: Completely destroyed Feta cheese factory.

The blocked transportation network adversely impacted food processing companies that could neither receive nor deliver any products.

7.5 Insurance and compensation issues

The HVA Field Team encountered and interviewed livestock owners with up to 5,000 animals who claimed that they were uninsured. The reason for this was attributed to not being able to afford insurance because they had self-financed their operations rather than taken loans and whereas they did not have any debts they now have no assets and all their hard work has been lost.

Farmers need to be urged to get insurance coverage. Awareness campaigns to increase or perhaps even mandate insurance coverage against **force majeure** at a reasonable rate for farmers would help mitigate their financial losses should flooding strike again.

Soft loans to farmers could serve as an incentive for farmers engaged in animal husbandry to re-build their herds, which can take up to 24 months.

END OF FIRST REPORT