MSc Program
Renewable Energy in Central and Eastern Europe

The potential hydro energetic assessment of the river in Albania with a monthly discharge flow estimation module

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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September 2011, Vienna

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Affidavit

I, **Ardian Bilibashi**, hereby declare

1. that I am the sole author of the present Master Thesis, "The potential hydro energetic assessment of the river in Albania with the monthly discharge flow estimation module“, 173 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

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Date Signature

Abstract

This thesis assesses the hydropower potential of a river in Albania using an estimation module that calculates the monthly discharge (surface and ground water) based on input variables such as monthly precipitation, intensity and frequency of rainfall, snowfall, air temperature and solar radiation as well as regional specific discharge. The monthly discharge simulations of this module help in a rapid assessment of the hydropower potential if no observed discharge data are available. The module is designed as a lumped, deterministic rainfall-runoff model. It is calibrated, validated and tested with observed discharge data from the Institute of Energy, Water and Environment of Albania, AKBN, and other official sources. The thesis specifically focuses on the Vjosa river. Potential sites for the construction and installation of new runoff hydropower plans with low dams at the Vjosa river are identified and the expected annual average power generation is estimated. The effect of future climate change on the power generation is also assessed.

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1 Introduction

1.1 Motivation

During the data processing and the preparation of the feasibility study for construction of new small hydropower plant, always I need to have a calculation tool to evaluation the monthly or the annual discharge water flow (surface and ground water) on the river site based on the quantity of the precipitation (local or regional rainfalls) and the parameters of his catchment area. This should create the possibility for determining the discharge water flows in the gauged or ungauged sites and assessing the potential hydro energy of the river‘s profile, its power generation capacity and the electricity production costs, as well as their estimations in case of the climate change factors.

Also, this requirement is necessary because the data time series observed in the field are not correct observed or missing. In particular the data observed during the period after the 1990 years have the reduced or degraded number of observations. Even where these data may exist, it is a high price to issue or to evaluate them increasing the costs of the study and the project design, in particular during their pre-feasibility stages.

1.2 Core objective

The core objective of this study is the design of the discharge flow estimation module that calculates the monthly discharge water flow (surface and ground water) (based on the input data like the monthly precipitation, the intensity and the events of the rainfall, the snowfall, the air temperature and the solar radiation intensity, the catchment area, the regional specific discharge) and the assessment of the potential hydroenergetic of a river, in case Vjosa river in Southern of Albania. Using the monthly discharge water flow simulation results, the module should help in the data processing and rapid assessment of the potential hydro energetic of rivers in the situation where the observed data are not available, not accurate or costs to issue them, reducing the cost and the time preparation of the hydropower plant feasibility study.

The module is designed as a lumped and deterministic rainfall-runoff modeling. It is calibrated, validated and tested with the observed data issued by Institurte of Energy, Water and Environment of Albania (IEWE) or the other official sources, determining the monthly discharge water flows of the proposed sites and the assessement of the potential hydro energetic of Vjosa river.

Also, it is assessed the effect of future climate change factors (precipitation reduction 40%, inceasing of the air temperature 2^{o}C and solar radiation 20%) in the discharge water flows and the power generation of the proposed hydropower plants in Vjosa river during on 2050.

Why Vjosa river?

It is the second river in Albania and actually it is not generate the electricity. The building of the new hydro energy resources in this region will increase the renewable energy production, the reduction of the electricity import, but they shall increase the sustainability of the Albanian Electricity Energy System (SEE) also; let means the reduction of the electricity transmission and the distribution losses, because the main generation hydropower plants (with a total capacity 1450 MW) are built in the Northern part of the country and they cover about 95% of the total electricity production.

The second is the fact that in the past, there are some studies for the assessement of the potential hydro energetic of Vjosa river, where their concepts are based on the hydropower plants with high dams and reservoirs, causing impacts in the environment and the social effects.

In this study, the assessment is based on the building of the “runoff” and low dams (10-30m) hydropower plants with the installed power capacity 400.4MW and the annual power generation more than 1,950GWh.

Some of the following questions would be considered by this study:

- Which is the rainfall-runoff modeling for the design of the module?
- Which is the runoff modeling structure of Vjosa river watershed?
- Which is the modeling efficiency compared with the observed data at each site?
- Which are the modeling input/output data, variables and their quantities?
- Is this a suitable modeling and easy to use by the human (user friendly)?
- Is feasible the potential hydro energetic of Vjosa river cascade?
- Which environment impact has the building of hydropower plants on the river?
- Can we use the modeling structure to the other catchments rivers in Albania?

The rainfall-runoff modeling should be developed considering two time periods of the monthly observed discharge water flow data in the Vjosa river: the calibration period 1965-1975 and the validation period 1976-1986. There should be estimated three sites belong the river: Kaludh (upperstream), Dragot (middlestream) and Dorza (downstream). Using the actual measurement meteorological data, it should be assessed the discharge water flows at the ungauged sites proposed for the building of the hydropower sources.

Refer to the effects of future climate changes, it should be estimated the predicted uncertain of the water flows and the plants power generation to the year 2050 (plants lifetime). A model that consider the snowmelt process should be designed and tested. Also, this module should be applied to another catchment area in Erzen river (at Ndroq site) in the Middle of Albania.

1.3 Literature

This study was prepared mainly based on data obtained from Institute of Energy, Water and Environment of Albania – IEWE (2011) (in response of my requirement dated on May 13, 2011), the data of the academic studies "Hydrology of Albania" (1984) and "Climate of Albania - Atmospheric Precipitation '(1978), AKBN – National Natural Sources Agency of Albania, METE - Ministry of Economy, Trading and Energy of Albania as well as scientific publications (Pano N. 2008 - “Pasurite ujore te Shqiperise”) and the official internet websites sources like GAISMA, UNESCO, FAO, SamSamWater which are presented in the reference of this study.

1.4 Structure of work

The structure of work contains the follow steps:

- design and implementation of the Discharge Flow Estimation Module (DFEM) and the comparison of its results with the observed monthly discharge water flows at Vjosa river sites. The module calculates the average monthly discharge flows obtained in a certain profile or site of the river (as example is Dorza site in Vjosa river) depending on the monthly hydrometeorology data (precipitation, temperature, solar radiation), hydrology and hydraulic parameters of the catchment area, etc. It is presented also the modeling structure, its validity performance and the efficiency, etc.

- using this module and the topographic study of the terrain, it is determined and assessed the potential hydro energetic of a river in Albania (Figure 1.1 - Vjosa river basin in Southern of Albania), its cascade profiles for the building of the new runoff hydropower plants with low dams, the power generation, the costs and the environment impacts.

- on the effects of future climate change factors, it is determined the impacts in the discharge water flows and the power generation of the proposed hydropower plants in Vjosa river during on 2050.

In Session 2 – *Method of approach*, it is explained the methodology for assessment of the potential hydroenergetic of the river within a defined catchment area, the design of the discharge water flow estimation module and and the data collection.

In Session 3 – *Discharge flow module*, it is explained the conceptual of the structure of the module, the relationships between the input and the output data or variables and the module flowchart. The procedural results of the module are given taking in consideration the observed discharge water flow at Dorza site in Vjosa river. There are considered two of 10-years periods with independent observed data: the period 1965-1975 for calibration of the module and the period of 1976-1986 for its validation. The results are tested by “goodness on fit” methods for their performances and the efficiencies. Also it is explained the module with snowmelt, even there are not data available for the snowfall or snowpack catchment areas. Using the long time data of the period 1950-1990, the discharge water flow prediction is calculated and estimated by the module. In order to estimate the design of the discharge water flows of each plant (Q_{design}), a simple method is descripted for the calculation of the Flow Duration Curve (FDC). To demonstrate the application of the DFEM module in the other catchment areas in Albania, an example at Ndroq site in Erzen river is explained.

Session 4 – *Vjosa river assessment* describes the potential hydro energetic of Vjosa river defining the plants capacities and their generations belong river longitudinal profiles based on the discharge water flows calculated by the module at the gauged or ungauged outlets of the defined catchment areas. The long time data series (observed discharge flows, precipitation, air temperature and solar radiation) are used for the calibration of the module during on 1950-1985 at the gauged reference sites: at upperstream (Kaludh), at middlestream (Dragot) and at downstream (Dorza). Considering the actual measure meteorological data, it is calculated the monthly discharge water flows for each site. A simple method is applied for the calculation of the monthly power generation of the hydropower plant, where is defined the design water flow and the power capacity. The power generation is calculated for normal, dry and wet conditions based on CN curve number values estimated by the module. The last is the financial analysis for the performance and the feasibility of the proposed plants, paybacks and the electricity production costs based on the actual selling price of the electricity.

The effect of future of the climate change in Vjosa river assessment is described in Session 5 – *Climate change impacts*, where the actual meteorological data are processed with the climate factors to determine the impact data on 2050. On these change factors, there are calculated the predicted uncertain discharge water flows and the power generation at each plant site, in order to estimate the effects of these impacts.

Results and discussion and *Conclusions* are described in Sessions 6 and 7. The literature references are in Session 9 - *References*, while *Annexes* and the detail information or supplement data are included in Session 10.

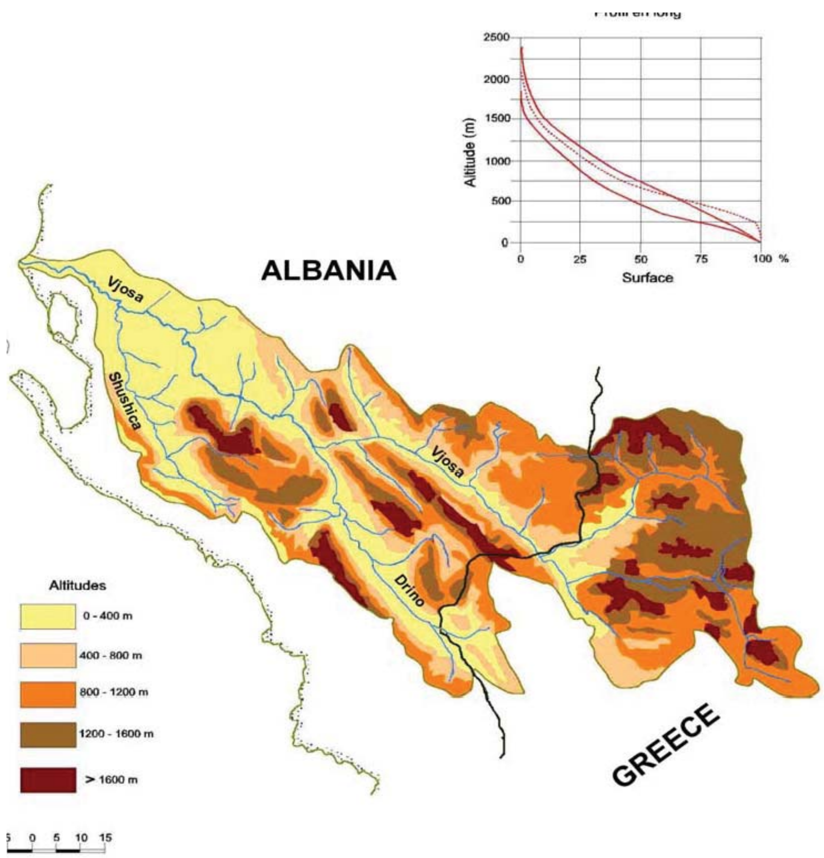

Figure 1.1- Vjosa river basin in Southern of Albania (Source: M.Ndini at all. 2008)

Photo 1.1- Vjosa river in Southern of Albania (source: A.Bilibashi)

2 Method of approach

2.1 Methodology

To evaluate the potential hydro energetic of a river (Vjosa river), are taken into the consideration the hydrology, the meteorology, the topography, the geomorphology, the environment and the climate of its watershed or catchment area and the related official data informations. Based on my site inspection in Vjosa river longitudinal profiles, the key data have been designated to build the new small & medium hydropower plants. For each site, it is used the topographic maps 1:10 000 and 1:25 000, Global Mapper v.11, Internet Google Earth and Map software and it is calculated the plant gross head (headrace and tailrace levels), catchment areas, pools or backwaters.

The estimation of the power capacity, the electricity generation and the financial investment (including the electricity production costs) of the Vjosa river cascade, has been done determining initially, for each plant, the monthly discharge water flows, flow duration curve and discharge flow design Q_{design}.

Before starting, only a few sites had the hydrological and meteorological data available issued by:

- Instituerte of Energy, Water and Environment of Albania 1984 – “Hidrologjia e Shqiperise” for Vjosa river period 1950-1975.
- AKBN – National Natural Sources Agency of Albania.
- Pano N. 2008 - “Pasurite Ujore te Shqiperise”, for Biovizhde and Dorze sites.
- Selenica A. and Morell M. Dec2000, - “Les resources en eau de l’Albanie” (MEDHYCOS Project) for Vjosa river period 1950-2000.
- Co-PLAN Institute for Habitat Development - “Sustainable Energy for Albania”
- Hydro meteorological data by GAISMA, UNESCO, FAO, SamSamWater websites sources, etc.

The study has two parts: the first part determinates the discharge water flows for the gauged and ungauged sites within a certain catchment areas. It is chosen to determine the average monthly discharge water flows, making possible the calculation of the monthly energy production and the sale of electricity with the price determined by Energy Regulatory Authority of Albania.

The discharge water flow estimation is done by the new module that process the monthly data of the precipitation P (mm), the rain intensity and the events, the air temperature Ta (^oC), the solar radiation Ra ($W/m^2/day$), the catchment area (km^2) and its altitude (m), the river length (m) and slope (%), etc.

This module is a lumped and deterministic type of the rainfall – runoff modeling and it is named **D**ischarge **F**low **E**stimation **M**odule (DFEM) with the below features:

- It considers a few input data, variables and parameters to be optimized.

- a mathematical relationship Q=f(R) between the effective rainfall and discharge water flow is developed where the runoff (R) contains all surface and groundwater flows and the deficit (D) contains all losses (evapotranspiration, soil infiltration). The module runs on MS Excel format.

- the discharge water flow module is applied at Dorza site in Vjosa river and it is calibrated using the observed data during the period 1965-1975 and then it is validated using the observed data in next period 1976-1986.

- after the calibration and validation, the “goodness on fit” tests are performed to examine the efficiency and the performance of the module. These tests are mass balance error, Nash-Sutcliffe efficiency criteria, Schulz criteria and the linear correlation R^2.

- to estimate the actual discharge water flows (on 2011), the module is calibrated using the average observed data of both period (1965-1975 & 1976-1986) or the observed data during the period 1950-1985 published by AKBN (given in Tables A.10.4.19, 29 & 21 in Annex 10.4.)

- the flow duration curve (FDC) is defined in simple way ranking the discharge values by magnitude; divide the range of average value into class limits and add up the total numbers of the value that are greater than the lower limit for each successive class; the cumulative number of ooccurences is converted in percentage of the time.

- the monthly power generation and the power capacity is calculated based on the concept how much energy produces 1m^3/s discharge water flow.

- based on the calculated FDC, it is detemined discharge flow design Q_{design} at the outlet of the catchment area and the power capacities of the hydropower plants.

On the influence of the climate change factors (precipitation, air temperature, solar radiation) it is predicted the impacts in the actual meteorological measure data and it is determined the discharge water flows and the predicted uncertain power generation of the proposed hydropower plants in Vjosa river during on 2050.

The second part is the analyse, the configuration and the assessment of Vjosa river cascade, determining the sites or the profiles for the construction and the installation of the new runoff hydropower plants with low dams, i.e. geographical position, the head gross, net head, discharge flow, flow duration curve, power capacity, electricity generation. For each plant is estimated the economic efficiency (W>0) considering the specific investment cost, the selling price, the initial total investment, the lifetime 35 years, the interest rate p=7% (q=1.07%). (Drobir H. 2010 - “Hydraulic design of small hydroelectric power plants” Lecture of MSc Program Renewable Energy in Central and Eastern Europe and Retscreen Clean Energy Project Analysis software). The results and the discussions are presented and concluded in the proper sessions, while in the annexes are given the detailed information, hydrology and meteorology data, etc.

The assessement of the potential hydro energetic of Vjosa river cascade includes also Kalivaci HPP with a power capacity of 90MW and annual generation 400GWh. This plant is a concessionaire contract between Albanian Government and Italian company – Bechetti Group, but it has not commissioned yet because of the proprietary problems with the owners as a result of the terrain floods by the reservoir (the headrace level is El.110-115m asl). In this study, as a part of the cascade, it is proposed a new configuration: Dorza runoff hydropower plant with low dam (H_{gross}=40m) and the headrace level to El.100m asl.

In the upperstream of Vjosa river (EL.265 up to El.180m asl) is developed the idea to build nine straflomatrix hydropower plants with a total capacity of 60-70MW, but this idea is not yet in practice (E. Cuci et all 2008). In this study, this idea is considered as a part of the cascade with a capacity of 67.6MW and the power generation of 336GWh (Vjosa 10.2MW, Vjosa 32.8MW and Vjosa 24.6MW), but without any intervention or comments on it. In Figure 4.2 is shown the runoff hydropower plants with low dams in Vjosa river cascade.

2.2 Data collection

The input data or variables are issued by:

- Institute of Energy, Water and Environment of Albania and its publications "Hidrologjia e Shqiperise"1985 and "Klima e Shqiperise 'Rreshjet atmosferike" 1978;
- AKBN – National Natural Sources Agency of Albania;
- Publication by Pano N. 2008 "Pasurite ujore te Shqiperise";
- Publication by Selenica A. and Morell M. December 2000, - "Les resources en eau de l'Albanie";
- Retscreen Clean Energy Project Analysis software developed by CANMET (www.retscreen.net),
- GAISMA website internet data (http://www.gaisma.com/en/dir/al-country.html),
- UNESCO(http://webworld.unesco.org/water/ihp/db/shiklomanov/part'4/EUROPA/europa.html, etc.
- FAO (www.fao.org) and SamSamWater (www.samsamwater.com)

On May 13, 2011, I sent a request to Institute Energy, Water and Environment of Albania to issue the necessary observed data for some rivers in Albania, including Vjosa river data. The required observed data were the precipitation, the air temperature, the solar radiation, the snowfall and the discharge water flows for important stations distributed in some rivers. After the meeting with Prof. Dr. Mr.

Marenglen Gjonaj, General Director, the institute defined its representative Dipl. Eng. Mr. Klodian Zaimi. He sent to me three email data files on 13 and 23 June 2011 with Vjosa river watershed precipitation and the discharge water flows data at the observed sites: Petran, Permet, Ura Leklit, Selenica, Dorze during on 1960-1975 and 1976-1986. Also, the institute furnished me with two academic study publications "Hidrologjia e Shqiperise 1984" and "Klima e Shqiperise – Rreshjet atmosferike 1978". An academic book is published by Mr. Niko Pano on 2008 – "Pasurite Ujore te Shqiperise" that contains the important discharge water flows data for Biovizhde and Dorza sites at upperstream of Vjosa river. As the part of MEDHYCOS project, the autors Selenica A. and Morell M. on December 2000 published the study - "Les resources en eau de l'Albanie", where the main data of the Vjosa river are shown. Also, in this study are used the data and materials from Co-PLAN Institute of Habitat Development - "Sustainable Energy of Albania" and the internet data from GAISMA, UNESCO, FAO and SamSamWater official websites, etc. The methodology structure is shown in Figure 2.1

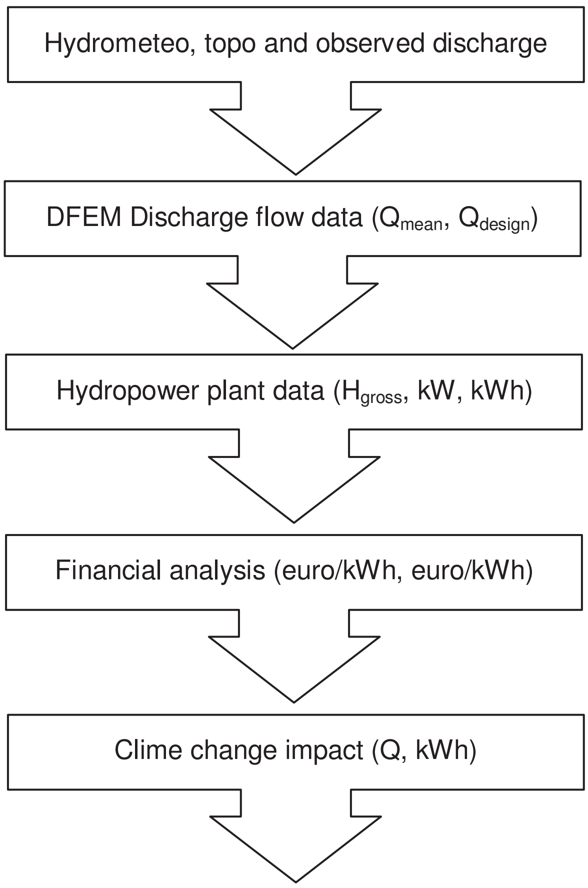

Figure 2.1- Methodology's structure

3 Discharge flow module

3.1 The module structure

The discharge flow estimation module (DFEM) calculates the monthly effective precipitation R_m (mm), and the deficit (losses) D_m (mm) (evapotranspiration, infiltration) based on the monthly and annual events and the water balance:

$$\sum P_m = \sum R_m + \sum D_m \qquad m = 1, 2, \ldots 12 \text{ (months)} \qquad (1)$$

The quantities of these events are found using IMP 5.0 - Integrated Power Analysis v.5.0 software, developed by Powell Group Inc. where the input data are: the average annual precipitation (mm) and 10year return period 24 hours rainfall. These input data are given by Institute of Energy, Water and Environment of Albania and the publication by Pano.N- "Pasurite Ujore te Shqiperise", 2008, p.155). The results or output data of this program application are: the average duration rain event (e) in hour, the average intensity (i) rain event in mm/h and the average for the year rain events (E).

There are some considerations: the production between the event duration and the intensity (e*i) gives the quantity of rainfall per event (mm/event); the ratio of the monthly precipitation to the quantity of rainfall per event (P_m/e*i) gives the quantity of events (e_m) for each month; thus, it is defined the ratio (e_m/E) which presents a constant proportionality (Beven K. 2001 "Rainfall - Runoff Modeling The Primer", p.30). This ratio is being multiplied by the monthly precipitation (P_m):

$$R_m = P_m * e_m/E \qquad (2)$$

giving the monthly effective rainfall R_m(mm) results.

It should be emphasized these conditions:

- the effective rainfall R_m presents the source of surface and groundwater flows or discharge water flow at the outlet of catchment area,
- each monthly effective rainfall R_m is shifted 30 days to the next month (i.e. October total effective rainfall is the shifted rainfall of September),

- no any boundary exists between runoff generation and routing. (Beven K. 2001 "Rainfall - Runoff Modeling, The Primer, p.17).

The monthly and the annual values of the evapotranspiration ET_{om} are calculated using Turc formula, based on the monthly air temperature (Ta) and real solar radiation (Ra) of the site (source data: www.gaisma.com/en/dir/al-country.html and Pano N. - "Pasurite Ujore te Shqiperise"). The average annual value of ETo actual evapotranspiration (mm), is taken as the minimum current value of deficit (losses). The same like effective rainfall definition, the product of:

$$D_m = ETo * e_m/E \qquad (3)$$

gives the monthly deficit or loss D_m (mm). Also, the ratios of R_m and D_m with P_m defines the runoff coefficient C_o (R_m/P_m) and the infiltration coefficient C_{inf} (D_m/P_m).

The precipitation amount P includes the rainfall and snowrain but not the snowfall. As a result, the predicted monthly discharge flow Q_m from the effective rainfall R_m doesn't include the discharge water flow from the snowmelting of the snowpack (Q_{sm}). This melting discharge flow is calculated separated and it is added to the total outlet discharge flow of the catchment:

$$Q_m = Q_{r\,m} + Q_{sm}. \qquad (4)$$

The monthly snow melting discharge flow is based on the below formula (Martinec J. "Snowmelt – Runoff Model for stream flow forecasts" – Nordic Hydrology 6, 1975, Copenhagen Denmark p.145-154):

$$Q_{sm} = 1.1 * a * (T - T_o) * A_s * (1 - k) + Q_{sm\,-1} * k * 1000/86400 \qquad (5)$$

where:

Q_{sm} – runoff from snow melt (m^3/s)
a – degree – day factor (°C/day)
T – air temperature ($T_a - T_s$) where $T_s = h_s * 0.5$ °C /100m
T_o – snow melt point temperature (0 °C)
k – recession coefficient (see discharge flow module Q_r on page 15)
A_s – snow coverage area (km^2)
Q_{sm-1} – previous snow melt runoff

The ratio 10000/86400 presents the conversion from cm to m^3/s. the average air temperature lapse rate is 0.5°C /100m (Pano N. 2008, p.69). In DFEM module, the snow coverage area (%) is defined like input variable:

$T < T_o$	$S_{m-1} + S_m$	where,	S is snow coverage are (%)
$T > T_o$	S_m		(m = 1,2…12)

and the snow area (km^2) is defined:

$$A_s = S_m * A_c * h_s / H$$

where

A_c – catchment area (km^2)

S_m – snow coverage (%)

h_s – catchment altitude covered by snow (m) measured from the top

H – catchment altitude (m)

Thus, it is defined the monthly effective runoff (2) and snowmelt discharge flows (5) where the input variables are: monthly precipitation P_m, air temperature T_a and R_a real solar radiation, 10year/24h return period, (events -e_m and intensity -i are calculated by IMP 5.0 software), catchment area A_c and its altitude H (m), °C/100m lapse rate, q_{ref} specific discharge flow (in l/s/km^2), constant coefficient n = 0.55, snow coverage altitude h_s (m) and snow coverage area S_m in % (for five months: November, December, January, February and March).

The monthly discharge flow Q_{rm} from the monthly effective rainfalls is calculated using the following formula:

$$Q_{rm} = A_m * R_m^{k_m} \qquad (m = 1,2\ldots12) \qquad (6)$$

where:

A_m outlet catchment discharge flow per day (surface & groundwater)

$$A_m = (A_r * q_m) / T_c \qquad (7)$$

A_r runoff area calculated by: (IMP5 Manual–Runoff area estimation)

$$A_r = A_c * P / P_{max} \qquad (8)$$

P_{max} maximum annual precipitation and P is average annual precipitation

$$P_{max} = K * P \qquad (9)$$

K clime coefficient is defined by historical data (Pano N. 2008)

$$K = \frac{(Q_{nov}+Q_{dec}+Q_{jan}+Q_{feb}+Q_{mar})}{(Q_{feb}+Q_{mar}+Q_{apr}+Q_{may}+Q_{jun})} \quad (10)$$

It is also the coefficient that defines the hillslope (footslope) response to rainfall (Pano N. 2008).

T_c time concentration (in days) calculated by Kirpich formula (1940):

$T_c = 0.02 * L^{0.77} / S^{0.358} / 24h$ (days) (11)

L river length $SQRT(A_c/3.14)$ (m)

S slope $S = H / L$ (%) (H – catchment altitude)

R_m monthly runoff (mm)

k_m constant (or recession coefficient in snow melting formula) defined by:

$logA_m / log(R_{annual}/12)$ (m = 1,2…12) (12)

q_m monthly specific discharge flow (l/s/km^2) defined by:

$q_m = q_{ref} * e^{(-CN \times n \times b)}$ (13)

q_{ref} specific discharge reference, defined as below: (Pano N. 2008)

q_{ref} = 0.010 l/s/km^2 ($P \leq 1000$mm)

q_{ref} = 0.020 l/s/km^2 (1000mm < P > 1700mm)

q_{ref} = 0.040 l/s/km^2 ($P \geq 1700$mm)

CN curve number (CN II) defined by:

$CN = 25400/(2*D_{oct}+254)$, where D_{oct} is the deficit during October

n constant value 0.55

b runoff coefficient defined by: $b = -0.1 * R_m / R_{annual}$ (14)

The DFEM output data are: monthly discharge flow (Q_m), monthly specific discharge (q_m), annual precipitation (P), annual deficit (D), annual runoff (R), runoff area (A_r), length (L), slope (S), curve number (CN) with Antecedent Moisture Condition Class II, runoff coefficient (C_o) infiltration coefficient (C_{inf}), time concentration (T_c) and $Q_{max} = C_o * A_r * i_{max}$ (not in the scope of this study).

Based on the above structure, the module is built in MS Excel format, very simple and popular for the users. DFEM user interface and the module intermediate variables data are shown in Figure A.10.1 and Table A.10.1 in Annex A.10.1. In Figure 3.1 is presented the DFEM module structure for the estimation of the discharge water flow in the outlet of the catchment area.

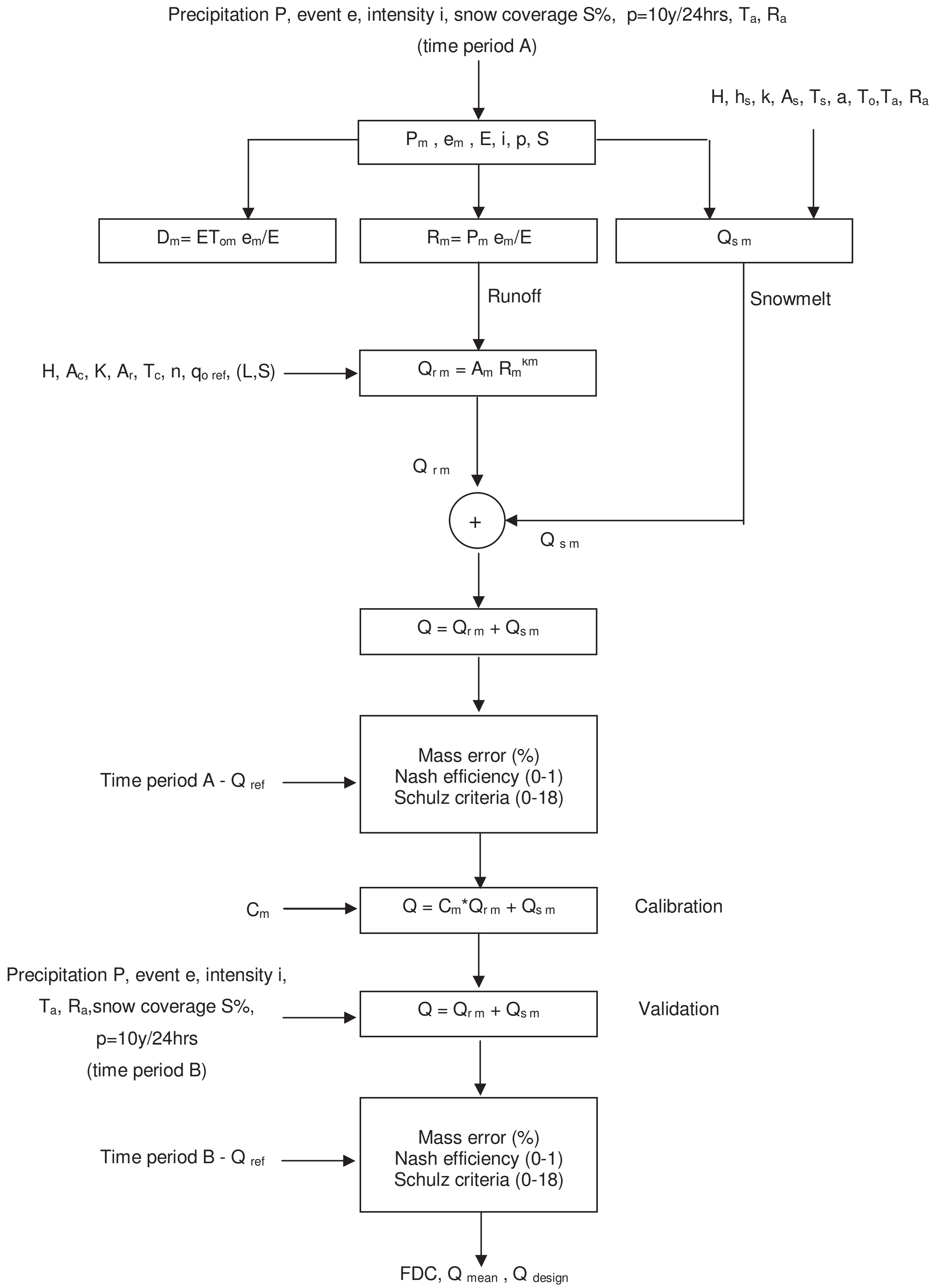

Figure 3.1- DFEM - Discharge water flow module structure

3.2 The procedural results

This session presents the procedural results of DFEM module applied for the calculation of the discharge water flows and FCD at Dorza site (N40°23'53", E19°48'06"), located in the downstream of Vjosa river.

Photo 3.1- Dorza site at Vjosa river

Dorza site is shown in Photo 3.1 and the observed discharge flows data during the period 1948 – 1990 (10.4 – Hydro meteorology data) are in Figure 3.2.

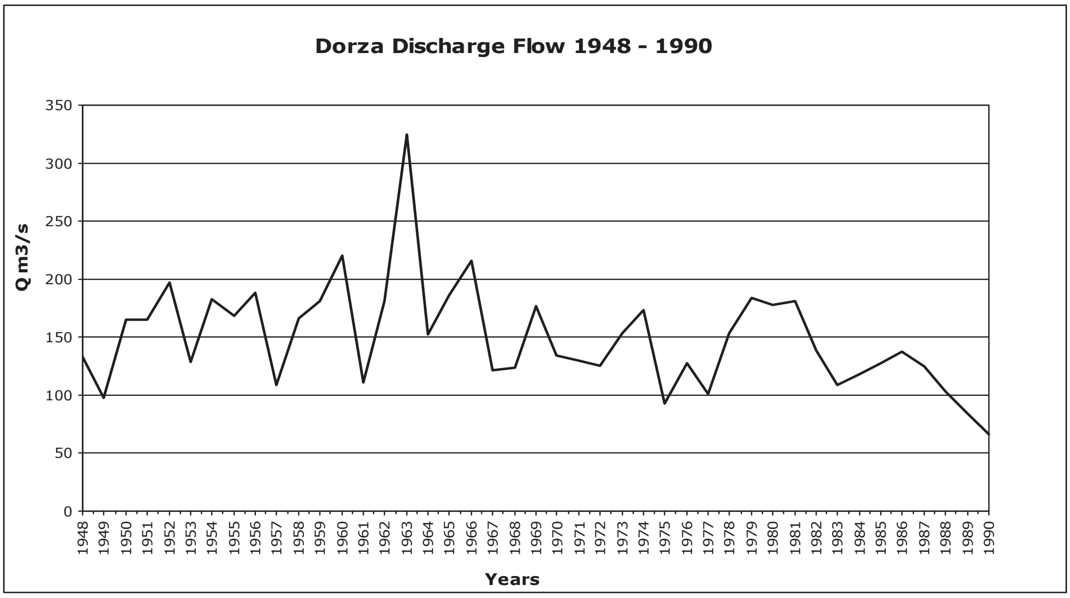

Figure 3.2- Dorza observed discharge flows on 1948-1990 (Pano N.2008, AKBN)

The observed data are issued by Institute of Energy, Water and Environment of Albania, AKBN and the other official publications. There are chosen two time periods: 1965-1975 for module calibrating and 1976-1986 for its validation.

The module input data are:

- catchment area	Ac = 5420 km^2	
- catchment height	H = 963 m	
- snow cover height	S = 200 m	
- temp lapse rate	t = 0.5 ^oC/100 m	(Pano N. 2008)
- 10y/24hrs	p = 120mm/hrs	(Pano N. 2008)
- event hrs	e = 3 hrs	(IMP 5.0 software)
- intensity	I = 1 mm/hrs	(IMP 5.0 software)

During this period the temperature is decrease 0.6^{o}C and after 1975 it is increased by 1.2^{o}C. (Pano N. 2008 p.77).

The meteorological variables (input data) and observed discharge flows during on *1965-1975*, are given in Table 3.1 & 3.2. It is not considered the snowfalls, because those are snowrain or a part of the precipitation. (recommend by Institute of Energy, Water and Environment of Albania).

Table 3.1 Meteorological data of Tepelena region during on 1965-1975
(source: Institute of Energy, Water and Environment of Albania)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation Mm	171	162	100	72	73	42	31	30	58	129	198	201
Snow area %	0	0	0								0	0
Temperature ^{o}C	0.8	1.7	5.0	9.8	15.2	19.4	22.5	22.4	17.8	12.6	6.6	1.8
Radiation w/m^2/day	1950	2570	3650	4470	5740	6720	6940	6070	4450	3020	1960	1580

Table 3.2 The observed discharge flows at Dorza site during the period 1965-1975
(sources: Pano N. 2008, AKBN and Hidrologjia e Shqiperise 1985)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Q flow ref m3/s	63.7	117.9	219.0	241.8	225.2	212.5	201.6	154.7	80.8	47.7	33.1	32.3

The results of the module (output data) are shown in Table 3.3:

Table 3.3 DFEM discharge flow at Dorza site on 1965-1975

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	73.2	166.2	297.6	302.6	240.6	223.3	125.1	88.9	90.2	55.5	43.2	42.5	145.8
q specific $l/s/km^2$	0.023	0.031	0.042	0.043	0.038	0.036	0.028	0.025	0.025	0.022	0.021	0.021	0.029
Qs flow m^3/s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Runoff Mm	47	105	161	163	139	132	82	58	59	34	25	25	1031

Precipitation (P)	1267	mm
Deficit (D)	237	mm
Runoff (R)	1031	mm
Rain event	3	mm/event
Length (L)	39	km
Slope (S)	0.025	%
Runoff area (Ar)	4664	km^2
Co	0.81	
Cinf	0.23	
TC	18	days
CN	84	
K	1.2	

The comparition between the observed and DFEM discharge flows at Dorza during on 1965-1975, are shown in Figure 3.3.

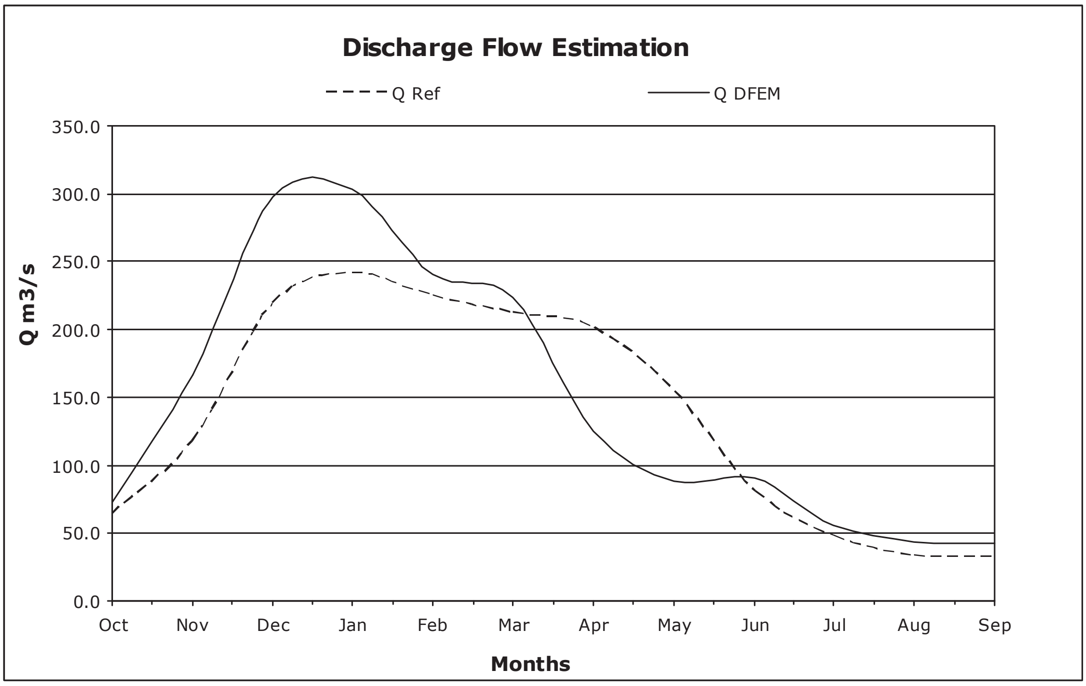

Figure 3.3- Dorza observed and Q-DFEM discharge flows during on 1965-1975

The goodness on fit tests were performed to examine the efficiency and the performance of the module: (Monar P. – Watershed Modelling Calibration).

- Mass balance error

$$m = 100\frac{\sum_{i=1}^{n}(Q_{sim,i} - Q_i)}{\sum_{i=1}^{n} Q_i}$$

where the result is in % and perfection is m = 0.

- Nash-Sutcliffe efficiency criteria

$$E = 1 - \frac{\sum_{i=1}^{n}(Q_{sim,i} - Q_i)^2}{\sum_{i=1}^{n}(Q_i - \overline{Q})^2}$$

where the result is classified from 0 (insufficient) up to 1.0 (excellent).

- Schulz criteria.

$$D = 200\frac{\sum_{i=1}^{n}\left|Q_{sim,i} - Q_i\right|Q_i}{n(Q_{\max})^2}$$

where the result is classified from 0 (very good) up to more 18 (insufficient).

These goodness on fit tests are shown in Table 3.4.

Table 3.4 The goodness on fit data for Dorza site uring on 1965-1975

	Q-DFEM	Q Ref	Mass error	N-S efficiency	Shulz criter
Oct	73.2	63.7	-15	1.0	0
Nov	166.2	117.9	-41	0.0	0
Dec	297.6	219.0	-36	0.1	0
Jan	302.6	241.8	-25	0.7	0
Feb	240.6	225.2	-7	1.0	0
Mar	223.3	212.5	-5	1.0	0
Apr	125.1	201.6	38	0.0	0
May	88.9	154.7	43	0.0	0
Jun	90.2	80.8	-12	1.0	0
Jul	55.5	47.7	-16	1.0	0
Aug	43.2	33.1	-30	1.0	0
Sep	42.5	32.3	-32	1.0	0
Mean	145.8	135.9	-7	0.6	0

The linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.79 and it is shown in Figure 3.4.

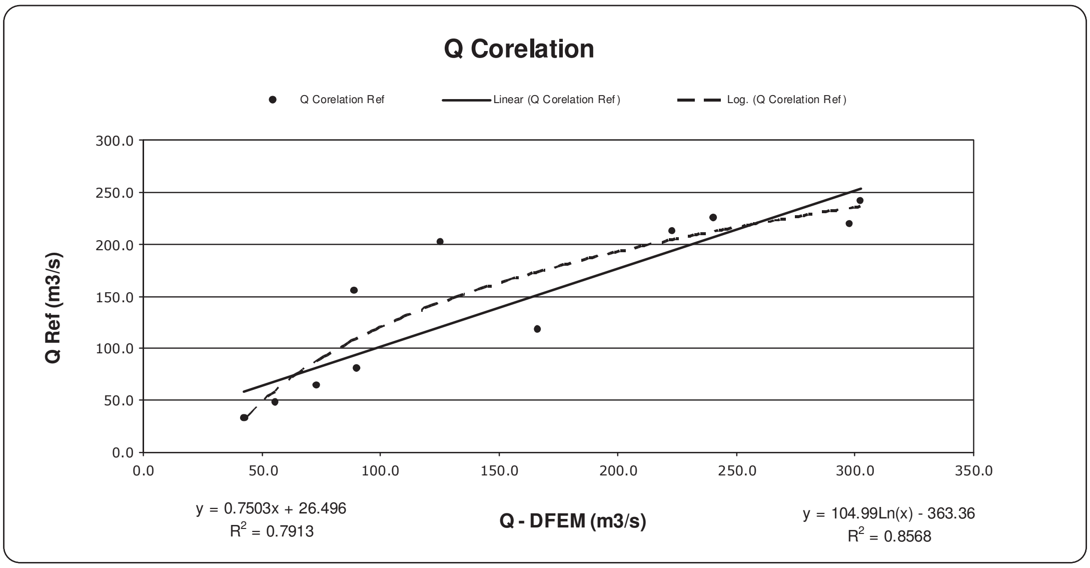

Figure 3.4- The correlation R^2 between the observed and Q-DFEM discharge flows at Dorza site during 1965-1975

Using the same method it was calculated DFEM dicharge flows during the period *1976-1986* with the meteorological variables (input data) and observed discharge flows (given in Table 3.5 & 3.6),

Table 3.5– Meteorological data of Tepelena region during the period 1976-1986 (source: Institute of Energy, Water and Environment of Albania and GAISMA (http://www.gaisma.com/en/dir/al-country.html)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation mm	175	166	95	73	76	40	29	30	55	116	191	194
Snow area %	0	0	0								0	0
Temperature °C	2.6	3.5	6.8	11.4	17.0	21.2	24.3	24.2	19.6	14.4	8.4	3.6
Radiation $w/m^2/day$	1950	2570	3650	4470	5740	6720	6940	6070	4450	3020	1960	1580

Table 3.6– The observed discharge flows at Dorza site during the period 1976-1986 (source: Pano N. 2008, AKBN and Institute of Energy, Water and Environment)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Q flow ref m3/s	53.0	145.5	228.6	219.8	222.4	176.5	186.4	134.1	78.0	44.5	33.6	32.0

The module results (output data) are shown in Table 3.7.

Table 3.7 DFEM discharge flow at Dorza site on 1976-1986

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	63.4	129.9	238.0	243.3	212.1	197.7	106.1	81.5	84.7	49.4	38.5	39.3	123.7
q specific $l/s/km^2$	0.022	0.028	0.037	0.037	0.035	0.033	0.026	0.024	0.024	0.021	0.020	0.020	0.027
Qs flow m^3/s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Runoff mm	43	92	151	154	139	131	75	57	60	32	23	24	980

Precipitation (P)	1241	mm
Deficit (D)	260	mm
Runoff (R)	980	mm
Rain event	3	mm/event
Length (L)	37	km
Slope (S)	0.026	%
Runoff area (Ar)	4353	km^2
Co	0.79	
Cinf	0.27	
TC	17	days
CN	84	
K	1.2	

The observed and DFEM charge flows during the period 1976-1986, are presented in Figure 3.5.

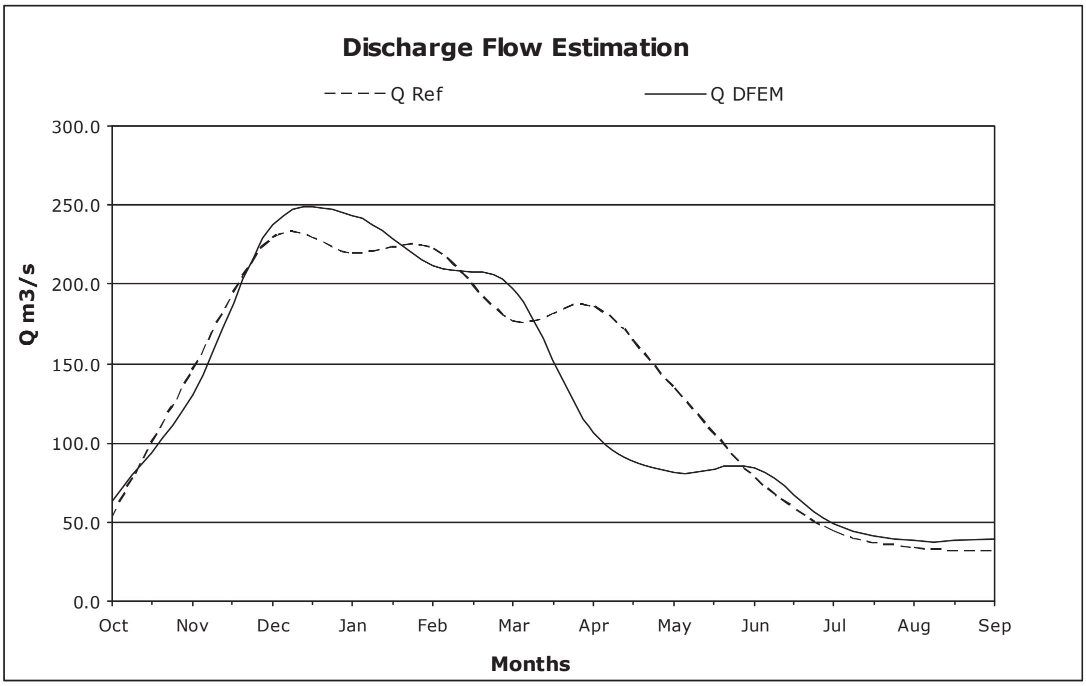

Figure 3.5- Dorza observed and Q-DFEM discharge flows during on 1976-1986

The goodness on fit tests to examine the efficiency and the performance of the module are shown in Table 3.8:

Table 3.8 Discharge flow and the goodness on fit data for Dorza site on 1976-1986

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	63.4	53.0	-20	1.0	0
Nov	129.9	145.5	11	0.0	0
Dec	238.0	228.6	-4	1.0	0
Jan	243.3	219.8	-11	0.9	0
Feb	212.1	222.4	5	1.0	0
Mar	197.7	176.5	-12	0.8	0
Apr	106.1	186.4	43	0.0	0
May	81.5	134.1	39	0.0	0
Jun	84.7	78.0	-9	1.0	0
Jul	49.4	44.5	-11	1.0	0
Aug	38.5	33.6	-15	1.0	0
Sep	39.3	32.0	-23	1.0	0
Mean	123.7	129.5	5	0.7	0

The linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.85 and it is shown in Figure 3.6.

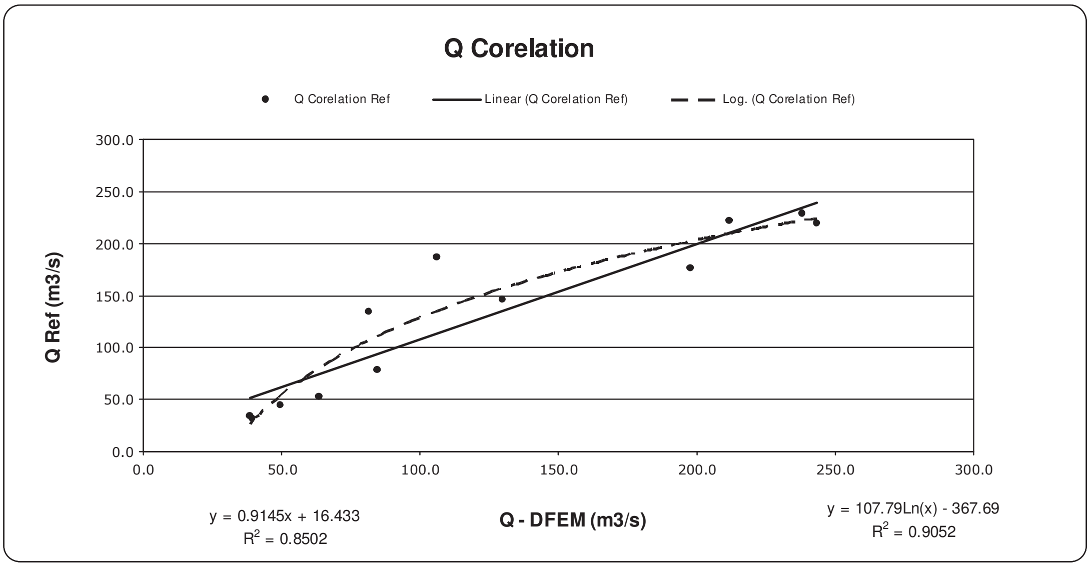

Figure 3.6- The correlation R^2 between the observed and Q-DFEM discharge flows during 1976-1986

3.3 Calibration and validation

The calibration and validation of the module (DFEM) is made as follows: the module during on 1965-1975 is calibrated by changing the calibration constants C_m which are multiplied by the discharge flows $Q_{r\,m}$ (4) as below:

$$Q = C_m * Q_{r\,m} + Q_{s\,m} \qquad (15)$$

In Table 3.9 are shown the monthly calibration constants C_m .

Table 3.9 Calibration constant C for Dorza site on 1965-1975

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Calibration C	0.87	0.71	0.74	0.80	0.94	0.95	1.61	1.74	0.90	0.86	0.77	0.76

The calibration constants C_m are changed by “Goal seek” function, where Q-DFEM cells are changed to fixed Q-observed cells by changing calibration cells. As a result, it is performed new Q-DFEM monthly discharge flows identical with the observed one during on 1965-1975 like the Figure 3.7.

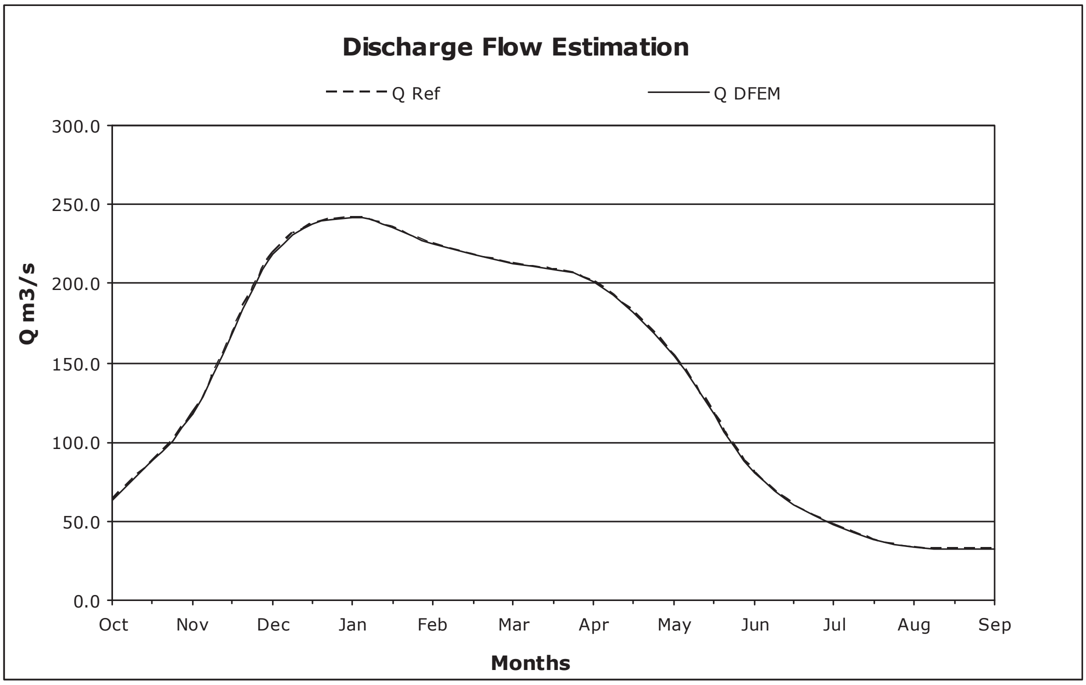

Figure 3.7- Dorza observed and calibrated Q-DFEM discharge flows on 1965-1975

The validation is made applying the calibrated constants cells to Q-DFEM formula module with input data 1976-1986. The results data and “goodness on fit” tests are shown in Table 3.10.

Table 3.10 Validation of DFEM discharge flow and the goodness on fit data for Dorza site on 1976-1986

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	55.2	53.0	-4	1.0	0
Nov	92.2	145.5	37	0.0	0
Dec	175.2	228.6	23	0.7	0
Jan	194.4	219.8	12	0.9	0
Feb	198.5	222.4	11	0.9	0
Mar	188.2	176.5	-7	0.9	0
Apr	170.9	186.4	8	0.9	0
May	141.8	134.1	-6	0.0	0
Jun	75.9	78.0	3	1.0	0
Jul	42.4	44.5	5	1.0	0
Aug	29.5	33.6	12	1.0	0
Sep	29.9	32.0	7	1.0	0
Mean	116.2	129.5	10	0.8	0

The linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.92 and it is shown in Figure 3.9.

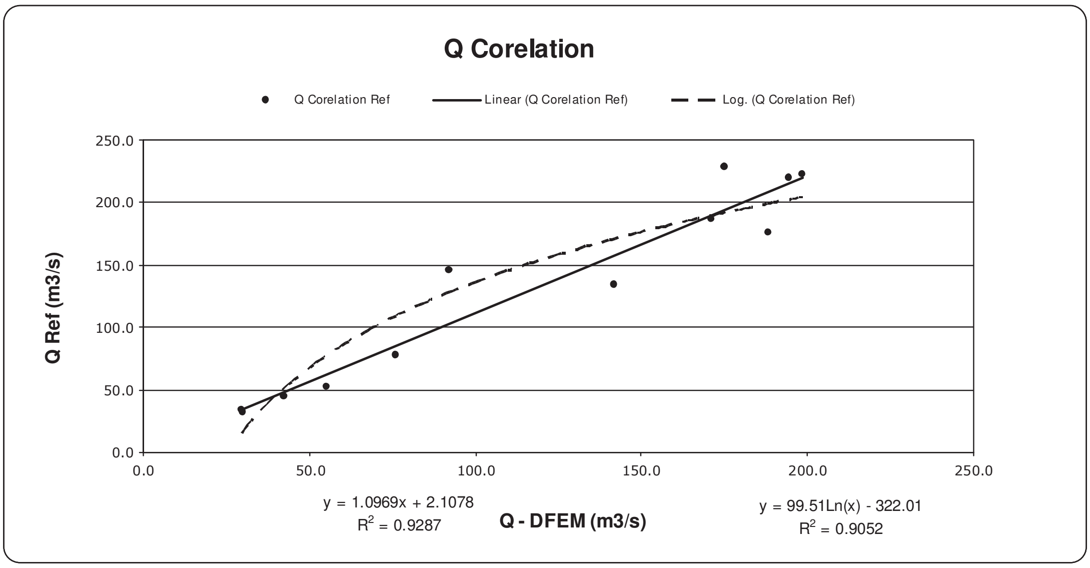

Figure 3.8- The correlation R^2 between observed and validated Q-DFEM discharge flows at Dorza site on 1976-1986.

The observed and DFEM discharge flows on 1976-1986, are shown in Figure 3.9.

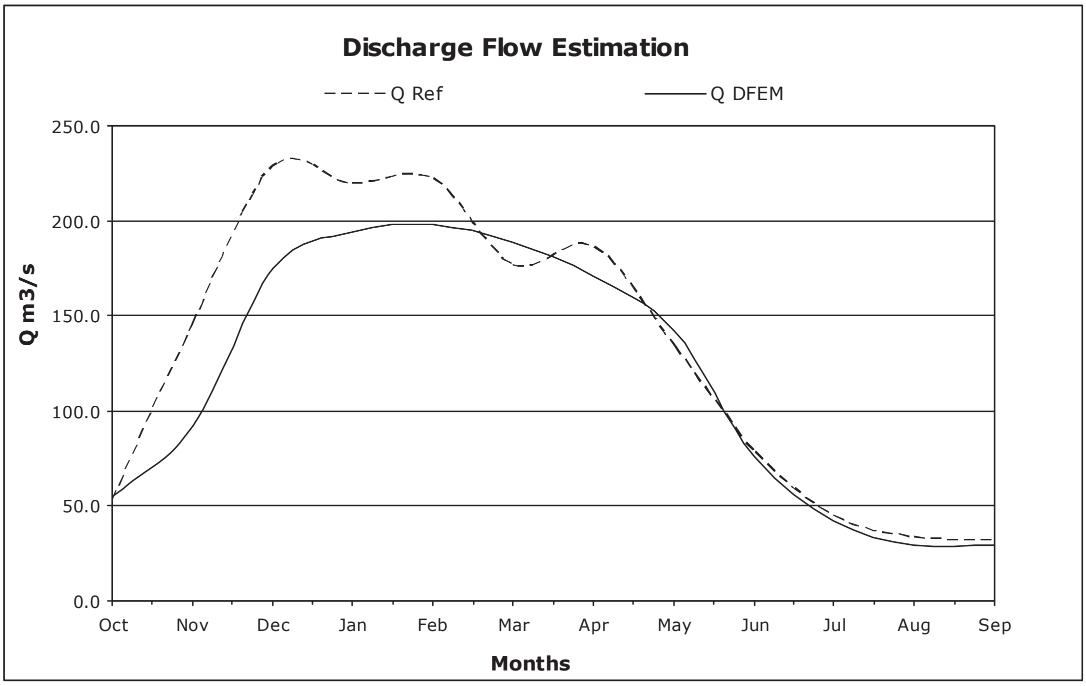

Figure 3.9- Dorza observed and validated Q- DFEM discharge flows on 1976-1986

Using the DFEM module, it is assumed:

(i)- in both case applications (1965-1975 and 1976-1986), the monthly discharge flows calculated by DFEM, are within the goodness on fit criteria and they are evaluated as very good (Tables 3.4 & 3.8). The linear correlation R^2 more than 0.80;

(ii)- calibrating the discharge module on 1965-1975 and validating it on 1976-1986, results that the monthly validated discharge flows are within the goodness on fit criteria and they are evaluated as very good (Table 3.10). The linear correlation R^2 is 0.92.

In the above results, it is considered the curve number (CN) has Antecedent Moisture Condition Class II or CN (II). The relations between the class CN(II) and CN(I) or CN(III) are as below:

CN(I) = 4.2*CN(II) / 10 - 0.058*CN(II) dry condition
CN(III) = 23*CN(II) / 10 + 0.13*CN(II) wet condition

Replacing the CN(II) with CN(I) and CN(III), it should be calculated the discharge flows during the dry and wet periods. (This is applied for Vjosa river in Annex 10.9.)

Table 3.11 Curve number CN Classes for Dorza site

Curve number	1960-1975	1976-1986
CN(II)	83	84
CN(I)	67	69
CN(III)	91	92

3.4 Module with snowmelt

During the period 1965-1975 or 1976-1986, is mentioned the snowfalls are not considered in the meteorological data input , because they are snowrains or as a part of the precipitation. (This is a recommendation given by Institute of Energy, Water and Environment of Albania). Thus, the observed data don't have the snowfalls recording, but snowrains only.

In DFEM User interface module (Figure A.10.1 of Annex 10.1) is designed the snow coverage in the percent of the total catchment area (Table 3.1 & 3.5), while the snow months are November, December, January, February and March. In this session the module is demonstrated, filling the snow coverage percents cells for both periods: (These snow coverage values in % are not observed but are given only for the demostration).

- 1965-1975 snow coverage: Nov 10%; Dec 20%; Jan 30%; Feb 30%; Mar 20%

The discharge flows results, considering the snow coverage area (in %), are show in Figure 3.10 and Table 3.12.

Table 3.12 DFEM discharge flow at Dorza site with snowmelting on 1965-1975

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	64.1	123.7	226.7	244.5	232.5	235.3	231.8	174.4	93.5	56.0	38.5	35.9	146.4
q specific $l/s/km^2$	0.023	0.031	0.042	0.043	0.038	0.036	0.028	0.025	0.025	0.022	0.021	0.021	0.029
Qs flow m^3/s	0.0	4.9	5.3	0.0	5.1	20.8	28.9	18.8	12.2	8.0	5.2	3.4	9.4
Runoff mm	47	105	161	163	139	132	82	58	59	34	25	25	1031

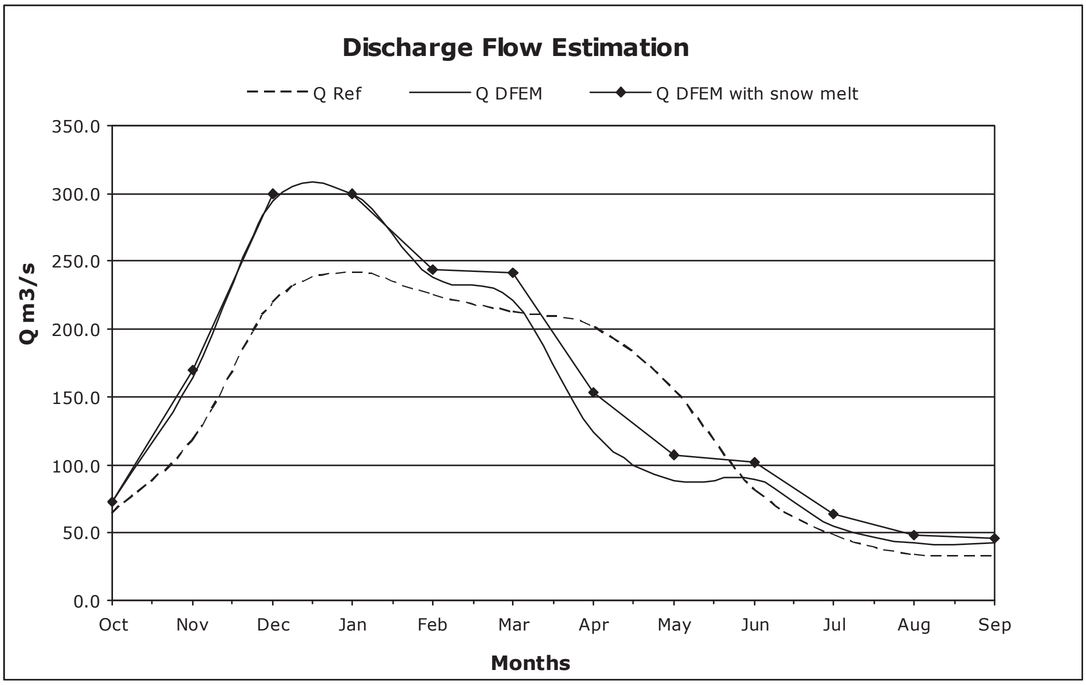

Figure 3.10- DFEM no snowfall and DFEM with snowfall at Dorza site on 1965-1975

- 1976-1986 snow coverage: Nov 10%; Dec 10%; Jan 20%; Feb 20%; Mar 10%,

  The results are in the Figure 3.11 and Table 3.13.

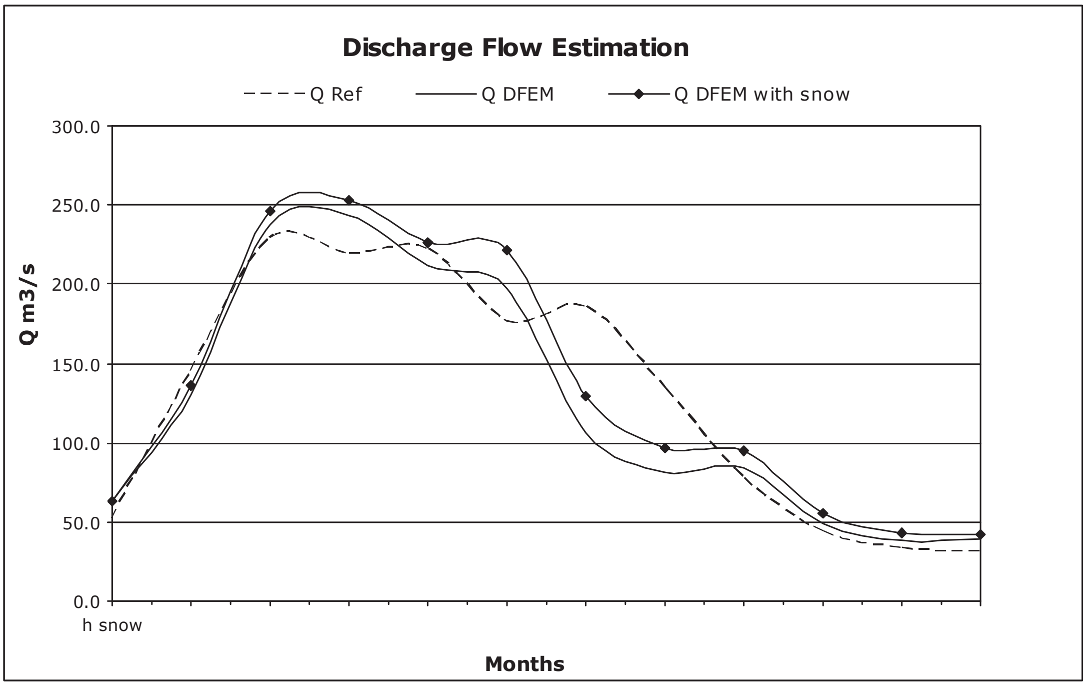

Figure 3.11- DFEM no snowfall and DFEM with snowfall at Dorza site on 1976-1986

Table 3.13 DFEM discharge flow at Dorza site with snowmelting on 1976-1986

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	63.4	136.0	246.2	252.6	226.4	221.3	129.8	96.9	94.8	55.9	42.8	42.1	134.0
q specific $l/s/km^2$	0.022	0.028	0.037	0.037	0.035	0.033	0.026	0.024	0.024	0.021	0.020	0.020	0.027
Qs flow m^3/s	0.0	6.0	8.2	9.3	14.3	23.5	23.8	15.4	10.0	6.5	4.2	2.8	10.3
Runoff Mm	43	92	151	154	139	131	75	57	60	32	23	24	980

The module calibration and validation with snowmelt discharge is described below. In Table 3.14 is shown the monthly calibration constants C_m with snow melting.

Table 3.14 Calibration constant C for Dorza site with snow on 1965-1975

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Calibration C	0.87	0.68	0.72	0.80	0.91	0.86	1.38	1.53	0.76	0.72	0.65	0.68

The validation is made applying the calibration constants C_m in Q-DFEM module input data 1976-1986 with snow coverage values. The results data and goodness on fit tests are shown in Table 3.15.

Table 3.15 Validation of DFEM discharge flow with snowmelt and the goodness on fit data at Dorza site on 1976-1986.

- DFEM module discharge flows. specific disharge flows, snowmelt discharge flows and runoff data

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	55.2	94.4	179.1	203.7	208.3	193.3	170.2	140.1	74.4	41.8	29.1	29.5	118.3
q specific $l/s/km^2$	0.022	0.028	0.037	0.037	0.035	0.033	0.026	0.024	0.024	0.021	0.020	0.020	0.027
Qs flow m^3/s	0.0	6.0	8.2	9.3	14.3	23.5	23.8	15.4	10.0	6.5	4.2	2.8	10.3
Runoff Mm	43	92	151	154	139	131	75	57	60	32	23	24	980

- Goodness on fit data

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	55.2	53.0	-4	1.0	0
Nov	94.4	145.5	35	0.0	0
Dec	179.1	228.6	22	0.8	0
Jan	203.7	219.8	7	1.0	0
Feb	208.3	222.4	6	1.0	0

Mar	193.3	176.5	-9	0.9	0
Apr	170.2	186.4	9	0.9	0
May	140.1	134.1	-4	0.0	0
Jun	74.4	78.0	5	1.0	0
Jul	41.8	44.5	6	1.0	0
Aug	29.1	33.6	13	1.0	0
Sep	29.5	32.0	8	1.0	0
Mean	118.3	129.5	9	0.8	0

The linear correlation R^2 between the observed and DFEM discharge water flows is calculated 0.93 and it is shown in Figure 3.12.

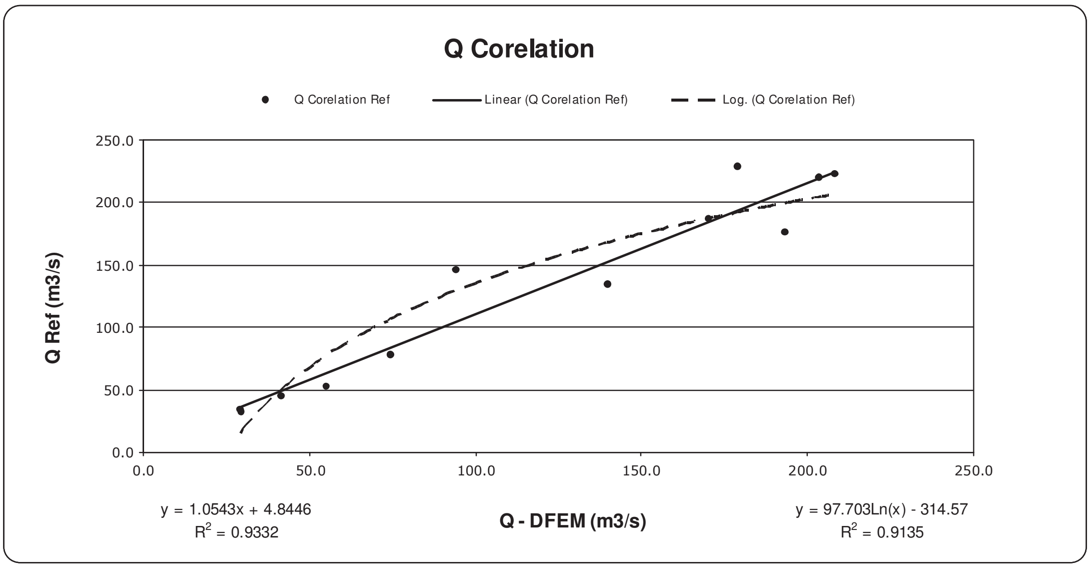

Figure 3.12- The correlation R^2 between observed and validated Q-DFEM discharge flows with snowmelt at Dorza site on 1976-1986.

Dorza site observed and calibrated Q-DFEM discharge water flows during on 1976-1986 with snowmelt are shown in Figure 3.13.

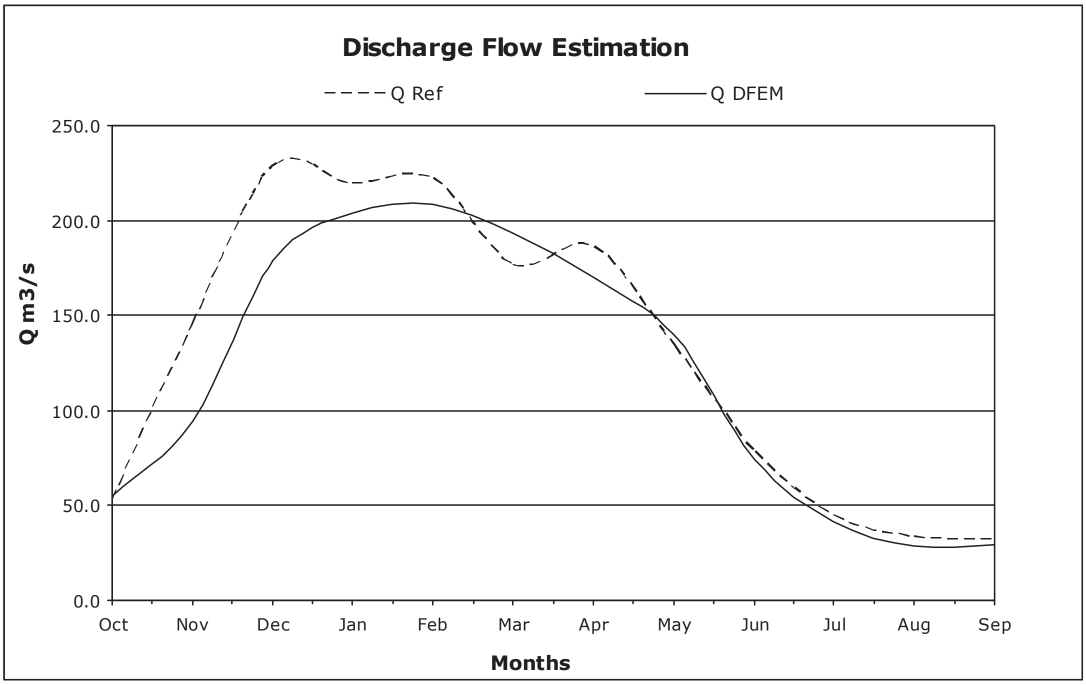

Figure 3.13- Dorza site observed and Q-DFEM discharge flows on 1976-1986 with snowmelt and input variables Nov 10%; Dec 10%; Jan 20%; Feb 20%; Mar 10%.

3.5 Discharge flow prediction

Based on the same methodology explained, DFEM module is applied for a long time period 1960 - 1990.

Also, another study "Les resources en eau de l'Albanie" by Selenica A. and Morell M. on December 2000, (part of MEDHYCOS Project), has covered the entire time period 1960-2000 of Dorza hydro meteorological data. This is explained in detail in Annex 10.2 - Dorza site.

After the calibration during on 1960-1990, the module is validated on 2011 and calculated the predicted discharge flow using GAISMA website data. The module is applied for year 2050 to predict the uncertain discharge ware flows when the precipitation should be decrease 40%, air temperature should be increase 2^{o}C and the solar radiation should be increased 20% of the actual meteorological values issued by GAISMA (http://www.gaisma.com).

The meteorological input data and the observed discharge flows during the time period 1960-1990, are given Tables 3.16 and 3.17.

Table 3.16 Meteorological data of Tepelena region during the period 1960-1990 (source: Institute of Energy, Water and Environment of Albania and GAISMA (http://www.gaisma.com/en/dir/al-country.html)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation mm	173	164	98	72	74	41	30	30	56	122	195	197
Snow area %	0	0	0								0	0
Temperature ^{o}C	1.7	2.6	5.9	10.6	16.1	20.3	23.4	23.3	18.7	13.5	7.5	2.7
Radiation $w/m^2/day$	1950	2570	3650	4470	5740	6720	6940	6070	4450	3020	1960	1580

Table 3.17 Dorza observed discharge flows during the period 1960-1990 (source: Pano N. 2008, AKBN and Hidrologjia e Shqiperise 1985)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Q flow ref m3/s	66.3	158.8	270.1	257.4	257.7	221.6	213.4	159.5	89.3	52.0	38.0	36.0

The module output data are shown in Table 3.18, as follows:

Table 3.18 DFEM discharge flow at Dorza site on 1960-1990

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	67.6	148.5	275.2	280.8	232.3	215.5	115.6	84.8	87.2	51.7	40.2	40.3	136.6
q specific $l/s/km^2$	0.023	0.031	0.042	0.043	0.038	0.037	0.028	0.025	0.025	0.022	0.021	0.021	0.029
Qs flow m^3/s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Runoff Mm	45	98	156	158	139	131	78	58	59	33	24	24	1005

Precipitation (P)	1254	mm
Deficit (D)	249	mm
Runoff (R)	1005	mm
Rain event	3	mm/event
Length (L)	37	km
Slope (S)	0.025	%
Runoff area (Ar)	4378	km^2
Co	0.80	
Cinf	0.25	
TC	18	days
CN	84	
K	1.2	

The goodness on fit tests to examine the efficiency and the performance of the module are shown in Table 3.19.

Table 3.19 Discharge flow and the goodness on fit data for Dorza site on 1960-1990

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	67.6	66.3	-2	1.0	0
Nov	148.5	158.8	7	0.0	0
Dec	275.2	270.1	-2	1.0	0
Jan	280.8	257.4	-9	1.0	0
Feb	232.3	257.7	10	0.9	0
Mar	215.5	221.6	3	1.0	0
Apr	115.6	213.4	46	0.0	0
May	84.8	159.5	47	0.0	0
Jun	87.2	89.3	2	1.0	0
Jul	51.7	52.0	0	1.0	0
Aug	40.2	38.0	-6	1.0	0
Sep	40.3	36.0	-12	1.0	0
Mean	136.6	151.7	10	0.7	0

The linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.85 and it is shown in Figure 3.14.

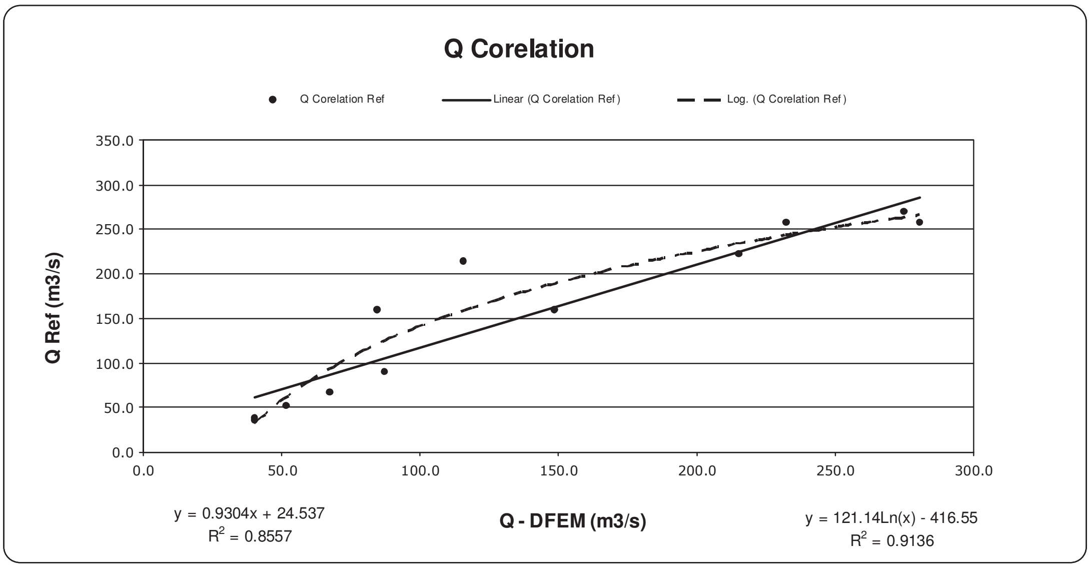

Figure 3.14- The correlation R^2 between the observed and Q-DFEM discharge flows on 1960-1990.

The observed and DFEM discharge flows at Dorza site on 1960-1990, are presented in Figure 3.15.

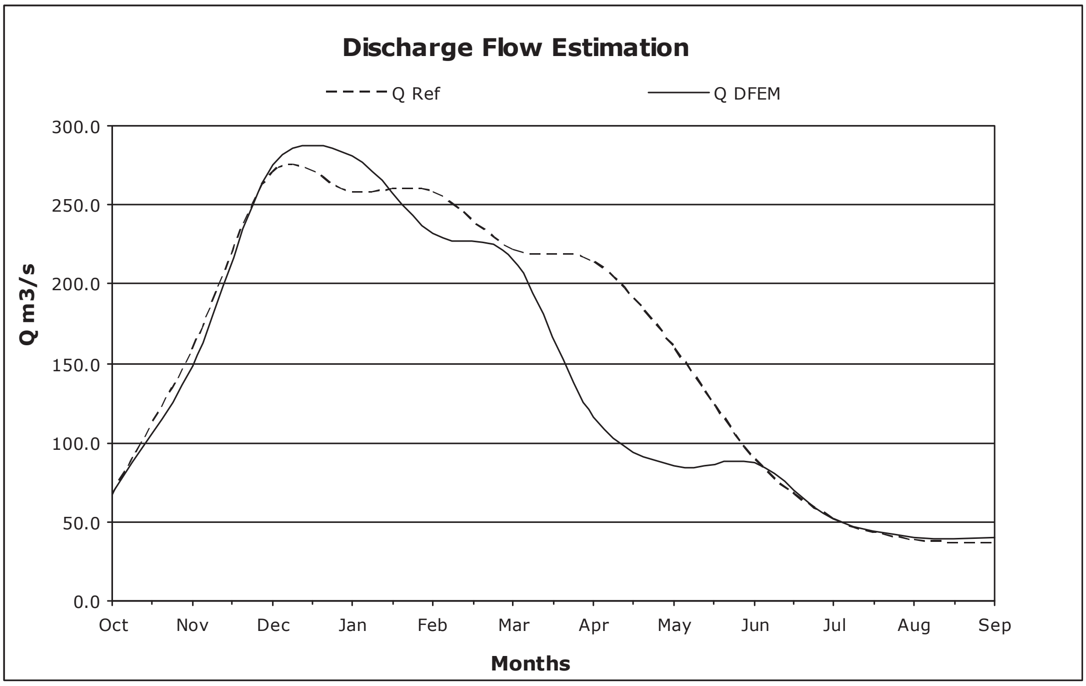

Figure 3.15- Dorza observed and Q-DFEM discharge flows on 1960-1990

The monthly calibration constants C_m is shown in Table 3.20.

Table 3.20 Calibration constants C_m for Dorza site on 1960-1990

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Calibration C	0.98	1.07	0.98	0.92	1.11	1.03	1.85	1.88	1.02	1.01	0.95	0.89

The validation is done applying the calibration constants C_m in Q-DFEM module with the GAISMA input data in Table A.10.4.15– Tepelena observed meteorological data.

Table 3.21 Meteorological data of Tepelena region predicted on 2011
(source: GAISMA http://www.gaisma.com/en/dir/al-country.html)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation Mm	164	147	117	89	72	41	28	35	68	138	207	214
Snow area %												
Temperature ^oC	2.6	3.5	6.8	11.4	17.0	21.2	24.3	24.2	19.6	14.4	8.4	3.6
Radiation $w/m^2/day$	1950	2570	3650	4470	5740	6720	6940	6070	4450	3020	1960	1580

Table 3.22 Dorza observed discharge flows during the period 1960-1990

(source: Pano N. 2008, AKBN and Hidrologjia e Shqiperise 1985)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Q flow ref m3/s	66.3	158.8	270.1	257.4	257.7	221.6	213.4	159.5	89.3	52.0	38.0	36.0

The module output data are shown in Table 3.23, as follows:

Table 3.23 DFEM discharge flow at Dorza site on 2011

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	74.9	170.5	268.3	263.3	219.5	177.1	243.2	185.7	82.4	49.8	34.8	39.0	150.7
q specific $l/s/km^2$	0.024	0.032	0.042	0.043	0.035	0.033	0.029	0.026	0.024	0.021	0.020	0.021	0.029
Qs flow m^3/s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Runoff Mm	55	111	166	172	132	118	94	71	58	33	22	28	1060

The results and goodness on fit tests are shown in Table 3.24.

Table 3.24 Discharge flow and the goodness on fit data for Dorza site on 2011

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	74.9	66.3	-13	1.0	0
Nov	170.5	158.8	-7	0.0	0
Dec	268.3	270.1	1	1.0	0
Jan	263.3	257.4	-2	1.0	0
Feb	219.5	257.7	15	0.9	0
Mar	177.1	221.6	20	0.6	0
Apr	243.2	213.4	-14	0.8	0
May	185.7	159.5	-16	0.0	0
Jun	82.4	89.3	8	1.0	0
Jul	49.8	52.0	4	1.0	0
Aug	34.8	38.0	8	1.0	0
Sep	39.0	36.0	-8	1.0	0
Mean	150.7	151.7	1	0.8	0

The linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.94 and it is shown in Figure 3.16.

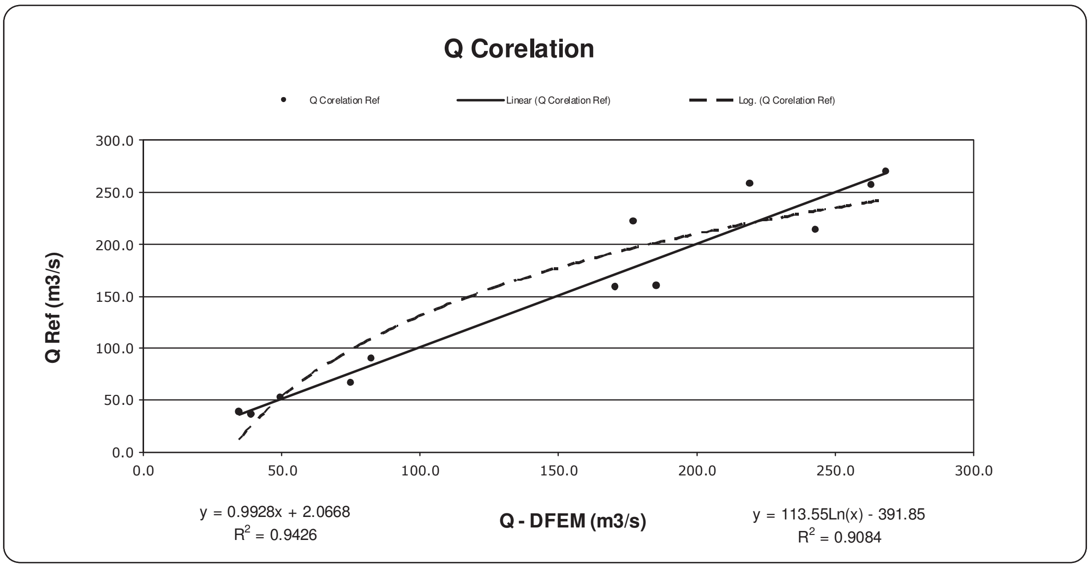

Figure 3.16- The correlation R^2 between observed and validated Q-DFEM discharge flows on 2011.

The module results are:

Precipitation (P)	1320	mm
Deficit (D)	260	mm
Runoff (R)	1060	mm
Rain event	3	mm/event
Length (L)	37	km
Slope (S)	0.025	%
Runoff area (Ar)	4378	km^2
Co	0.80	
Cinf	0.25	
TC	18	days
CN	82	
K	1.2	

Dorza observed (on 1960-1990) and predicted Q-DFEM discharge water flows on 2011 are shown in Figure 3.17.

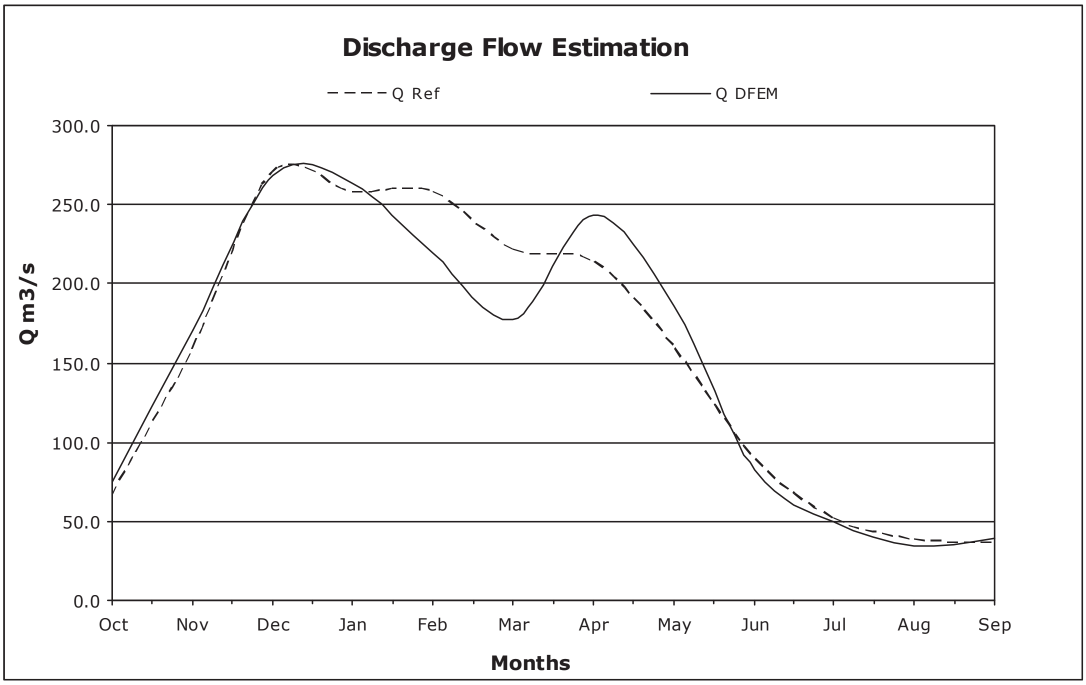

Figure 3.17- Dorza observed and predicted Q-DFEM discharge flows on 2011

The DFEM validation on 2050 is done applying the calibration constants C_m in Q-DFEM module that are calculated using the input data 1960-1990 of Institute of Energy, Water and Environment, with the predicted uncertain input data of year 2050: precipitation should decrease 40%, air temperature should increase 2^{o}C and solar radiation should increase 20%).

Table 3.25 Uncertain meteorological data of Tepelena region predicted on 2050 (source: Institute of Energy, Water and Environment of Albania)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation Mm	104	98	59	43	45	25	18	18	34	73	117	118
Snow area %												
Temperature ^{o}C	3.7	5.6	7.9	12.6	18.1	22.3	25.4	25.3	20.7	15.5	9.5	4.7
Radiation w/m^2/day	2340	3084	4380	5364	6888	8064	8328	7284	5340	3624	2352	1896

Table 3.26 Dorza observed discharge flows during the period 1960-1990 (source: Pano N. 2008, AKBN and Hidrologjia e Shqiperise 1985)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Q flow ref m3/s	66.3	158.8	270.1	257.4	257.7	221.6	213.4	159.5	89.3	52.0	38.0	36.0

The module output data are shown in Table 3.27, as follows:

Table 3.27 Uncertain DFEM discharge flow at Dorza site on 2050

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	37.9	94.4	158.4	150.8	152.2	131.2	126.1	92.9	52.1	28.9	20.4	19.4	88.7
q specific $l/s/km^2$	0.014	0.018	0.022	0.023	0.021	0.020	0.016	0.015	0.015	0.014	0.013	0.013	0.017
Qs flow m^3/s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Runoff Mm	20	43	69	70	61	58	35	26	26	15	11	11	445

The results and goodness on fit tests are shown in Table 3.28.

Table 3.28 Uncertain Discharge flow and the goodness on fit data for Dorza site on 2050

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	37.9	66.3	43	0.9	0
Nov	94.4	158.8	41	0.0	0
Dec	158.4	270.1	41	0.1	0
Jan	150.8	257.4	41	0.0	0
Feb	152.2	257.7	41	0.0	0
Mar	131.2	221.6	41	0.0	0
Apr	126.1	213.4	41	0.0	0
May	92.9	159.5	42	0.0	0
Jun	52.1	89.3	42	0.6	0
Jul	28.9	52.0	44	0.9	0
Aug	20.4	38.0	46	1.0	0
Sep	19.4	36.0	46	1.0	0
Mean	88.7	151.7	42	0.4	0

The linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.99 and it is shown in Figure 3.18.

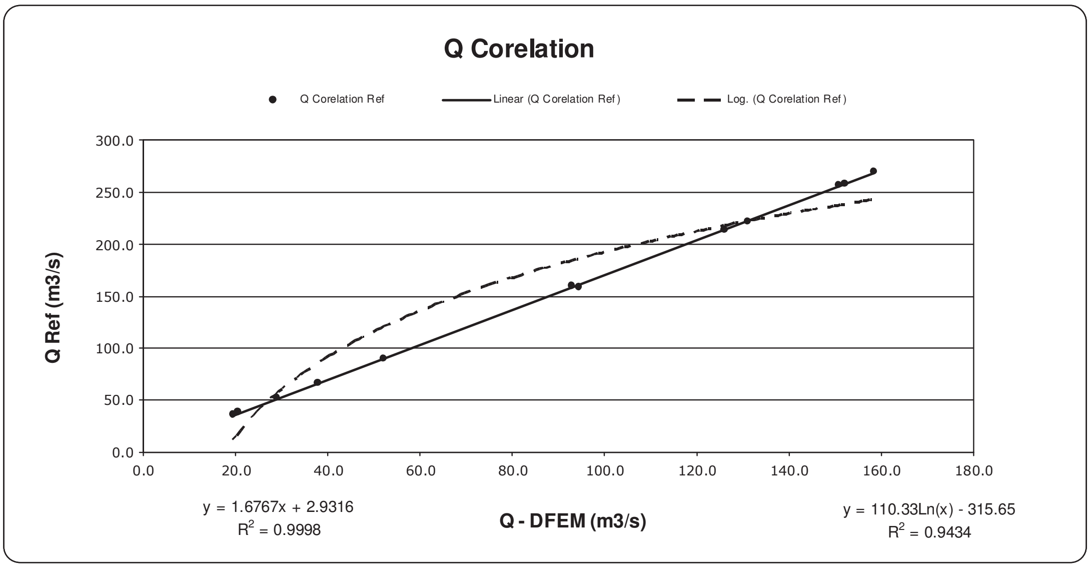

Figure 3.18- The correlation R^2 between observed and uncetain Q-DFEM discharge flows on 2050.

The module results are:

Precipitation (P)	752	mm
Deficit (D)	307	mm
Runoff (R)	445	mm
Rain event	3	mm/event
Length (L)	37	km
Slope (S)	0.025	%
Runoff area (Ar)	4378	km^2
Co	0.59	
Cinf	0.69	
TC	18	days
CN	81	
K	1.2	

Dorza observed (on 1960-1990) and predicted uncertain Q-DFEM discharge water flows on 2050 are shown in Figure 3.17.

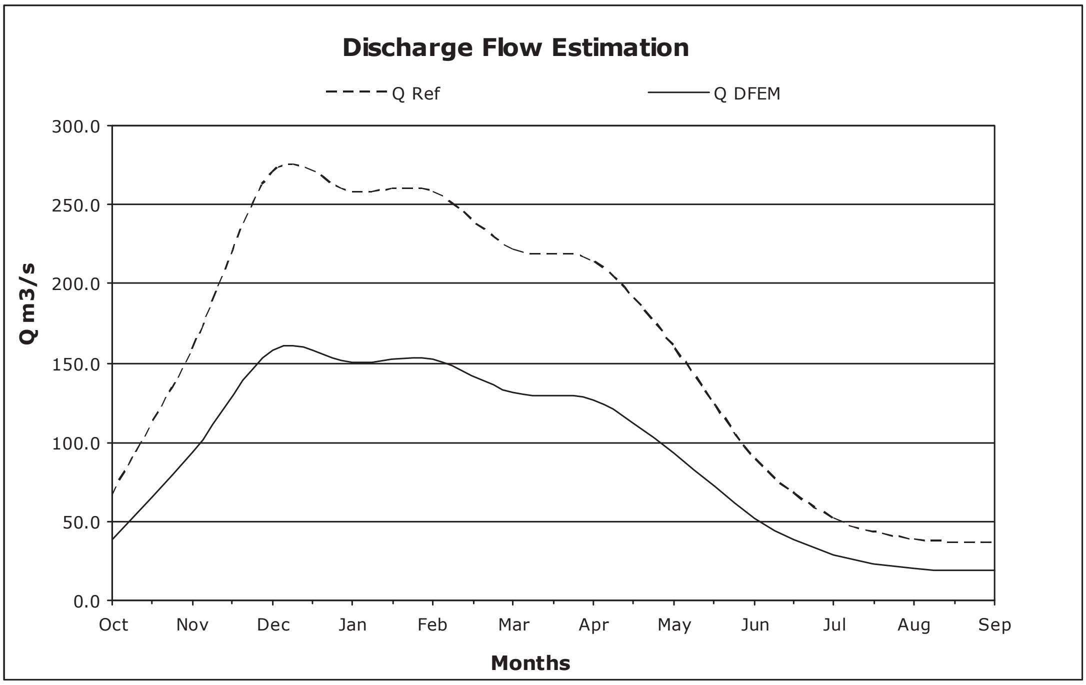

Figure 3.19- Dorza observed and uncertain Q-DFEM discharge flows on 2050

The results present the uncertain monthly discharge flows on 2050 should be reduced to 42%. The performance and the efficiency are within the goodness on fit criteria. The linear correlation R^2 is 0.99.

3.6 Flow duration curve

A simple method is applied for the calculation of the flow duration curve FDC. In the following case, it is considered the predicted discharge flows on 2011, where the monthly discharge water flow module is validated (Table 3.24). The main steps for calculation of FDC are described as below:

- The monthly discgarge flows is sorted descending, where is calculated the maximum and mninimum values of this rank. In case these values are: max. 298 and min. 39.

Table 3.29 Dorza DFEM data and discharge sorting

Q-DFEM Data	
Oct	74.9
Nov	170.5
Dec	268.3
Jan	263.3
Feb	219.5

Sorting
268.3
263.3
243.2
219.5
185.7

Mar	177.1		177.1
Apr	243.2		170.5
May	185.7		82.4
Jun	82.4		74.9
Jul	49.8		49.8
Aug	34.8		39.0
Sep	39.0		34.8
Mean	150.7	Max	268.3
		Min	34.8

- define the class limit value 24 (i.e. 268.3 / 11 = 24 in Table 3.29)

- define the class limits (column 2 & 3 in Table 3.30) which starts with range 0–24. In the successive row, the lower limit is the upper limit of the previous class (24) plus 1 (i.e. 24 +1=25).

- The upper limit of the successive row is defined adding the class value (24) to lower one (i.e. 25 + 24 = 49) and so on.

Table 3.30 Dorza DFEM class limit and occurrence

No	Class limit		Occurrence
1	0	24	0
2	25	49	2
3	50	74	1
4	75	99	2
5	100	124	0
6	125	149	0
7	150	174	1
8	175	199	2
9	200	224	1
10	225	249	1
11	250	274	2
			360
	Class value		24

- from the monthly discharge flow and class limit, define the occurrence (column 4 in Table 3.30).

- define the cumulative days (column 1 in Table 3.31) multiplying 30 days/month by occurrence O_i value of this month and adding the previous value d_{i-1} (i.e. $d_i = 30 * O_i + d_{i-1}$).

- define the not exceeded time flow (i.e. t_f = 100* d_i /360) and the equally or exceeded time flow (i.e. 100 - t_f) (columns 2 & 3 in Table 3.31).

- define FDC value that starts with highest number of occurrence (i.e. 3) that is adding to the lower limit of the class (i.e. in column 4 of Table 3.30, the highest number is 3). Add this number to the low limit number (i.e. add 3 to 19 and the result is 22).

Table 3.31 Dorza DFEM time flow and FDC scale

Cumulative days	Not exceeded time flow	Equalled or exceeded time flow	FDC value
0	0	100	2
60	17	83	27
90	25	75	52
150	42	58	77
150	42	58	102
150	42	58	127
180	50	50	152
240	67	33	177
270	75	25	202
300	83	17	227
360	100	0	252

The frequency distribution is shown in Figure 3.20.

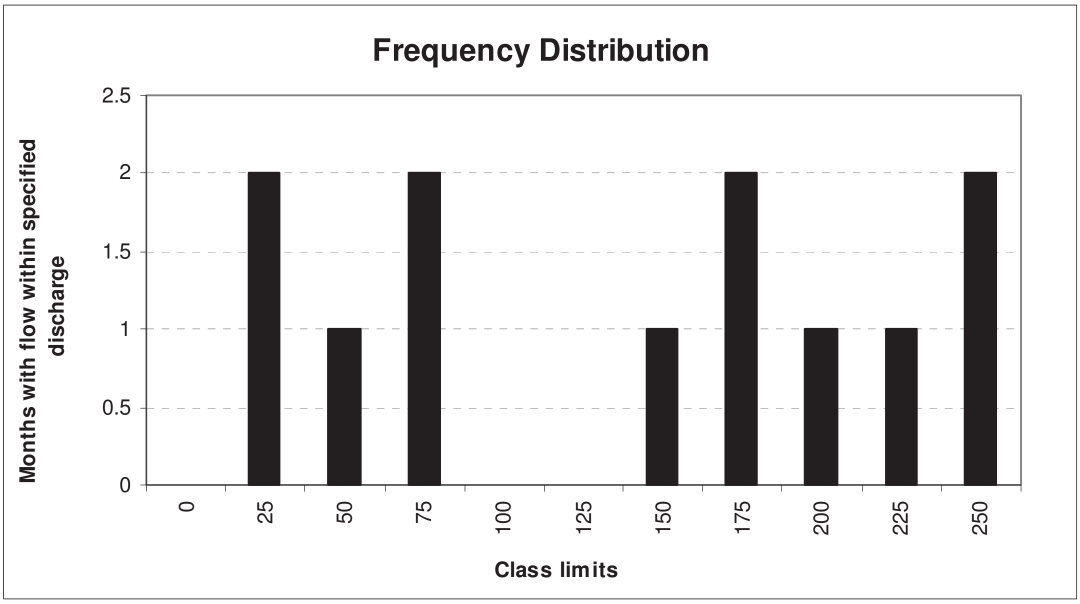

Figure 3.20- Frequency distribution of the monthly discharge flow at Dorza site

The flow duration curve is shown in Figure 3.21. The discharge design Q_{design} is defined where the curve cuts the Y-axis i.e. Q_{design}= 193m3/s. The X-axis presents the month-days (in percent) i.e 0% presents 30 days of year, 10% presents 60days, etc.

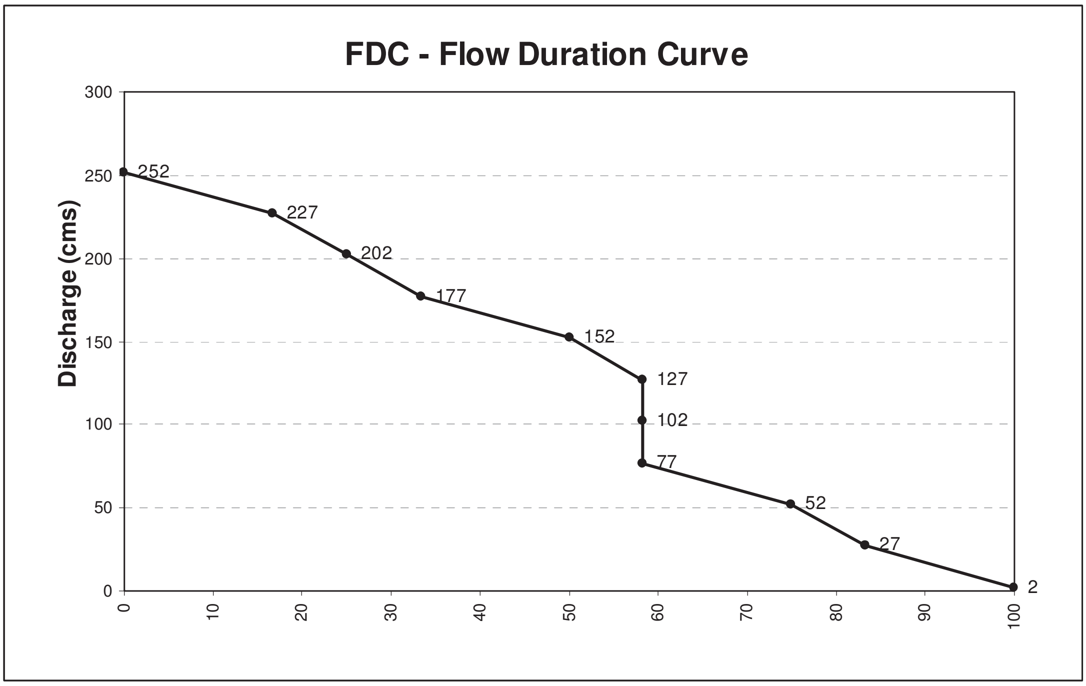

Figure 3.21- Flow Duration Curve of discharge flow at Dorza site in Vjosa river on 2011.

3.7 Other application

To answer the question in the core objective: “Can we use the modeling structure to the other catchments in Albania?”, here is a DFEM module application of Ndoq site (N41°16’03”, E19°38’43”) at Erzeni river, in the Middle part of Albania.

The main characteristics are:

- catchment area	Ac = 663 km^2	
- catchment altitude	H = 481 m	
- snow area altitude	S = 50 m	
- temperature rate	t = 0.5 °C/100 m	
- 10y/24hrs	p = 125 mm/hrs	(Pano N. 2008)
- event hrs	e = 3.5 hrs	(IMP 5.0 software)
- intensty	I = 1.3 mm/hrs	(IMP 5.0 software)

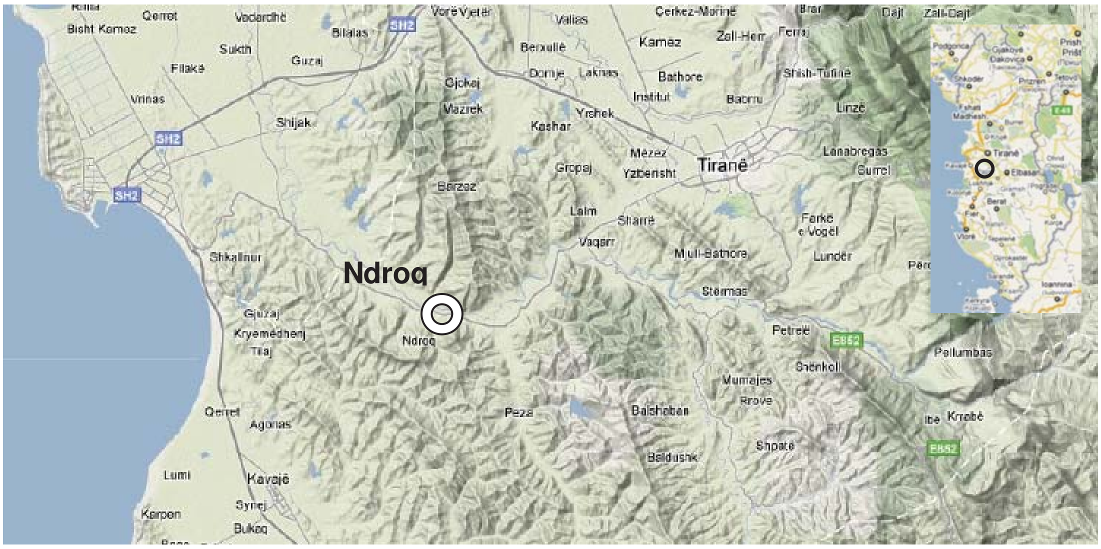

Photo 3.2- Ndroq site at Erzeni river

The meteorological input data and the observed discharge water flows during the period *1960-1975*, are given in Table 3.32 & 3.33. (It is not considered the snowfalls, because those are snowrains or a part of precipitation).

Table 3.32– Meteorological data of Tirana region on 1960-1975
(source: Institute of Energy, Water and Environment of Albania)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation Mm	167	149	123	96	79	59	29	44	69	120	186	162
Snow area %	0	0	0								0	0
Temperature °C	-1.5	-0.1	3.9	8.8	14.4	18.4	21.4	21.4	16.5	10.9	4.5	-0.6
Radiation $w/m^2/day$	1820	2450	3580	4350	5660	6640	6870	6030	4350	2900	1870	1510

Table 3.33– Ndroq observed discharge flows on 1960-1975
(source: Hydro meteorology Institute – Hidrologjia e Shqiperise 1985)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Q flow ref m3/s	6.6	15.7	22.1	27.1	25.8	24.5	19.1	14.6	8	3.7	2.7	4.2

The results of the module (output data) are shown in following Table 3.34:

Table 3.34 DFEM discharge flow at Ndroq site on 1960-1975

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	10.7	17.0	27.2	23.2	24.0	21.1	17.3	13.9	11.8	9.6	6.2	8.0	15.8
q specific $l/s/km^2$	0.024	0.031	0.041	0.037	0.037	0.035	0.031	0.027	0.025	0.023	0.020	0.022	0.029

Qs flow m^3/s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Runoff Mm	58	101	155	136	140	124	103	81	66	49	24	37	1073

Precipitation (P)	1282	mm
Deficit (D)	209	mm
Runoff (R)	1073	mm
Rain event	3.5	mm/event
Length (L)	13	km
Slope (S)	0.037	%
Runoff area (Ar)	529	km^2
Co	0.84	
Cinf	0.19	
TC	7	days
CN	87	
K	1.3	

The observed and DFEM discharge water flows during the period 1960-1975, are shown in Figure 3.22.

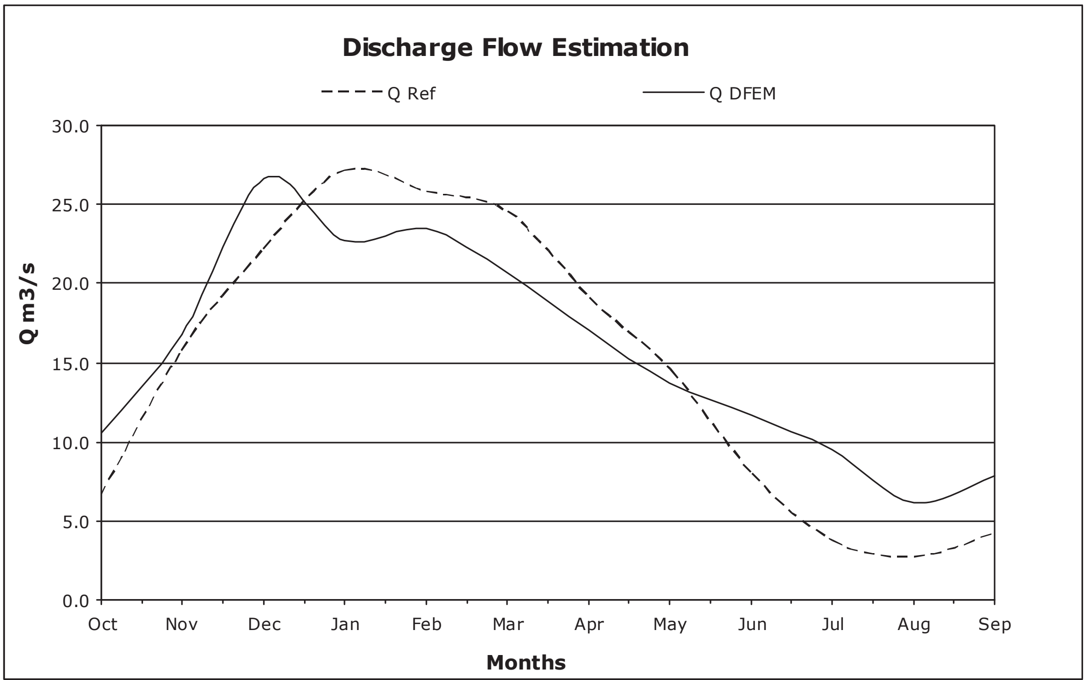

Figure 3.22- Ndroq observed and Q-DFEM discharge flows on 1960-1975

The goodness on fit tests are shown in Table 3.35.

Table 3.35 Discharge flow and the goodness on fit data for Ndroq site on 1960-1975

	Q-DFEM	Q Ref	Mass error	N-S efficiency	Shulz criter
Oct	10.7	6.6	-62	0.7	0

Nov	17.0	15.7	-8	0.0	0
Dec	27.2	22.1	-23	0.5	0
Jan	23.2	27.1	14	0.9	0
Feb	24.0	25.8	7	1.0	0
Mar	21.1	24.5	14	0.9	0
Apr	17.3	19.1	9	0.9	0
May	13.9	14.6	5	0.0	0
Jun	11.8	8	-48	0.7	0
Jul	9.6	3.7	-158	0.7	0
Aug	6.2	2.7	-130	0.9	0
Sep	8.0	4.2	-89	0.9	0
Mean	15.8	14.5	-9	0.7	0

Also, the linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.89 and it is demonstrated in Figure 3.23.

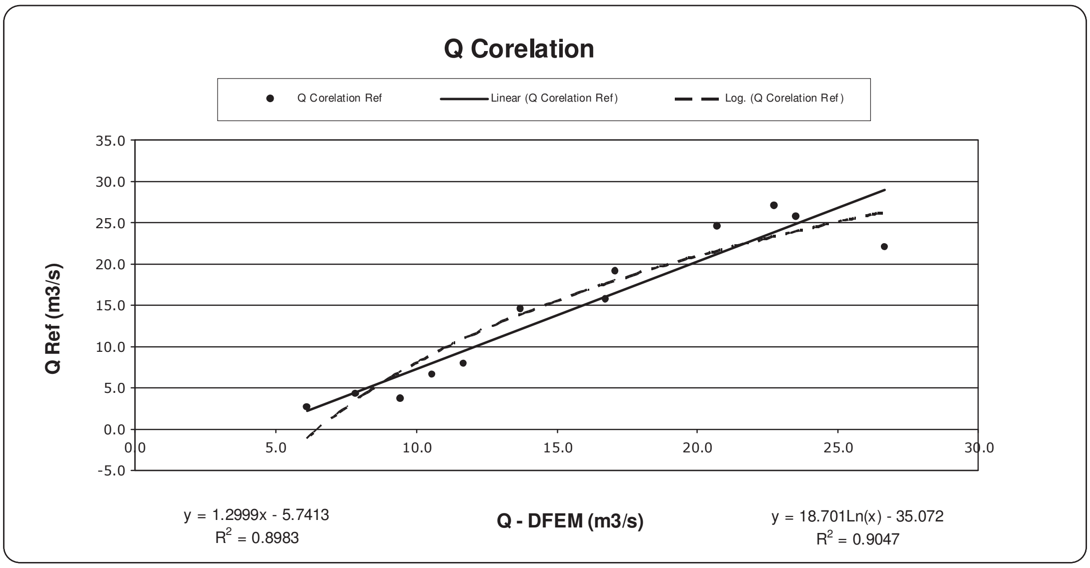

Figure 3.23- The correlation R^2 between observed and Q-DFEM discharge flows at Ndroq site on 1960-1975

Let to apply DFEM module using the meteorological input data and the observed discharge flows in Ndroq site during the period *1976-1985*, are given in Table 3.35 & 3.36.

Table 3.35 Meteorological data of Tirana region on 1976-1985 (source:http://www.gaisma.com/en/dir/al-country.html), and http://webworld.unesco.org/water/ihp/db/shiklomanov/part'4/EUROPA/europa.html)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation Mm	164	144	121	98	78	62	28	40	62	115	179	164
Snow area %	0	0	0								0	0
Temperature °C	-0.3	1.1	5.1	10.0	15.6	19.6	22.6	22.6	17.7	12.1	5.7	0.6
Radiation w/m²/day	1820	2450	3580	4350	5660	6640	6870	6030	4350	2900	1870	1510

Table 3.37 Ndroq observed discharge flows on 1976-1985 (source:http://www.gaisma.com/en/dir/al-country.html), and http://webworld.unesco.org/water/ihp/db/shiklomanov/part'4/EUROPA/europa.html)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Q flow ref m3/s	5.9	16.8	26.1	20.3	24.6	21.8	16.7	13.9	7.6	3.9	3.1	4.4

The results of the module (output data) are shown in Table 3.38, as follows:

Table 3.38 DFEM discharge flow at Ndroq site on 1976-1985

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m³/s	9.7	16.0	25.7	23.1	23.1	20.0	16.8	13.9	11.5	9.7	6.0	7.3	15.2
q specific l/s/km²	0.024	0.030	0.040	0.037	0.037	0.034	0.031	0.028	0.025	0.024	0.020	0.022	0.029
Qs flow m³/s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Runoff Mm	51	94	147	134	134	118	99	80	64	51	23	33	1029

Precipitation (P)	1257	mm
Deficit (D)	228	mm
Runoff (R)	1029	mm
Rain event	3.5	mm/event
Length (L)	13	km
Slope (S)	0.038	%
Runoff area (Ar)	512	km²
Co	0.82	
Cinf	0.22	
TC	7	days
CN	86	
K	1.3	

The goodness on fit tests to examine the efficiency and the performance of the module are shown in Table 3.39:

Table 3.39 Discharge flow and the goodness on fit data for Ndroq site on 1976-1985

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	9.7	5.9	-64	0.8	0
Nov	16.0	16.8	5	0.9	0
Dec	25.7	26.1	2	1.0	0
Jan	23.1	20.3	-14	0.8	0
Feb	23.1	24.6	6	1.0	0
Mar	20.0	21.8	8	0.9	0
Apr	16.8	16.7	-1	1.0	0
May	13.9	13.9	0	1.0	0
Jun	11.5	7.6	-51	0.6	0
Jul	9.7	3.9	-148	0.7	0
Aug	6.0	3.1	-93	0.9	0
Sep	7.3	4.4	-67	0.9	0
Mean	15.2	13.8	-11	0.9	0

The linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.95 and it is demonstrated in Figure 3.24.

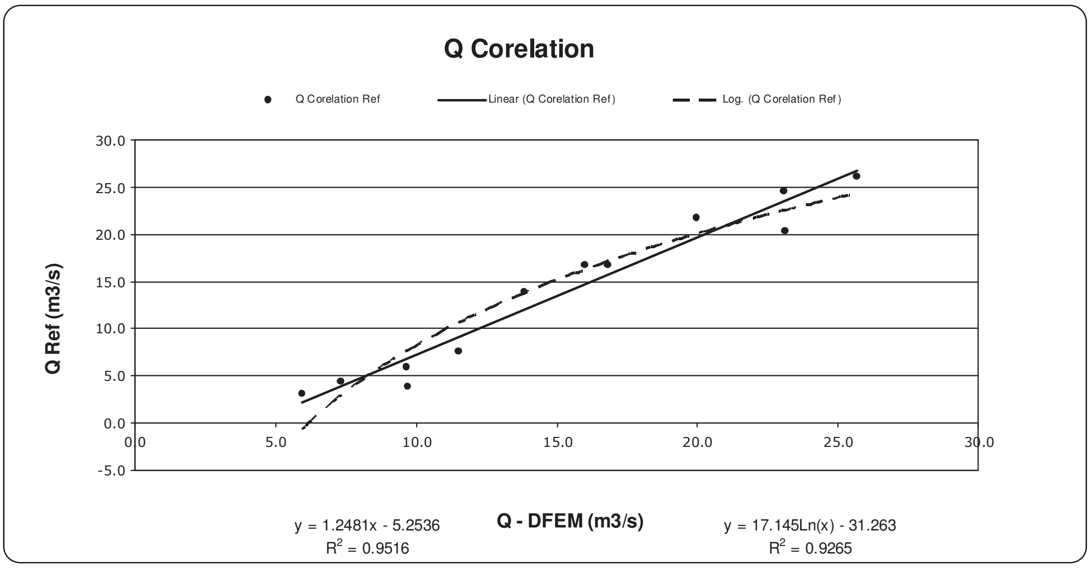

Figure 3.24- The correlation R^2 observed and Q-DFEM discharge flows on 1976-1985

The observed and DFEM discharge flows on 1976-1985, are shown in Figure 3.25.

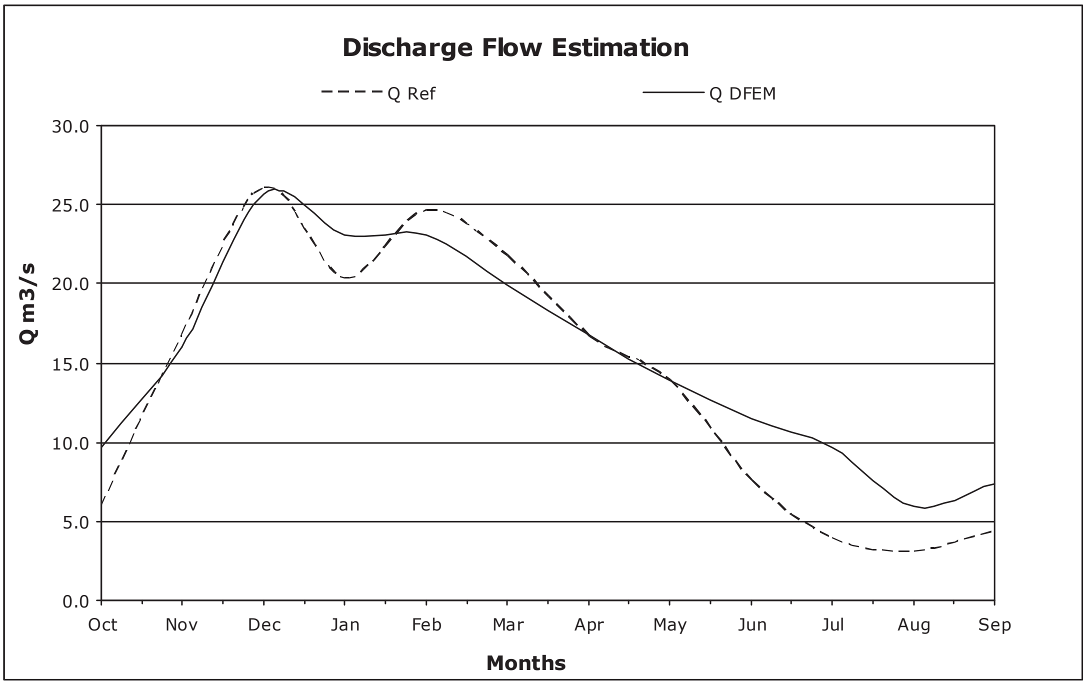

Figure 3.25- The observed and Q-DFEM discharge flows on 1976-1985

The monthly calibration constants C_m for calibration of 1960-1975 are in Table 3.40.

Table 3.40 Calibration constants C_m for Ndroq site on 1960-1975

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Calibration C	0.62	0.92	0.81	1.17	1.08	1.16	1.10	1.05	0.68	0.39	0.44	0.53

Applying the calibrattion constants C_m in Q-DFEM module with input data on 1976-1985, the results and goodness on fit tests are shown in Table 3.41.

Table 3.41 Discharge flow and the goodness on fit data for Ndroq site on 1976-1985

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	6.2	6.6	7	1.0	0
Nov	15.3	15.7	2	0.9	0
Dec	21.6	22.1	2	1.0	0
Jan	28.0	27.1	-3	1.0	0
Feb	25.8	25.8	0	1.0	0
Mar	24.0	24.5	2	1.0	0
Apr	19.2	19.1	0	1.0	0
May	15.1	14.6	-3	0.0	0
Jun	8.0	8	-1	1.0	0

Jul	3.9	3.7	-5	1.0	0
Aug	2.7	2.7	1	1.0	0
Sep	4.0	4.2	5	1.0	0
Mean	14.5	14.5	0	0.9	0

The linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.99 and it is demonstrated in Figure 3.26.

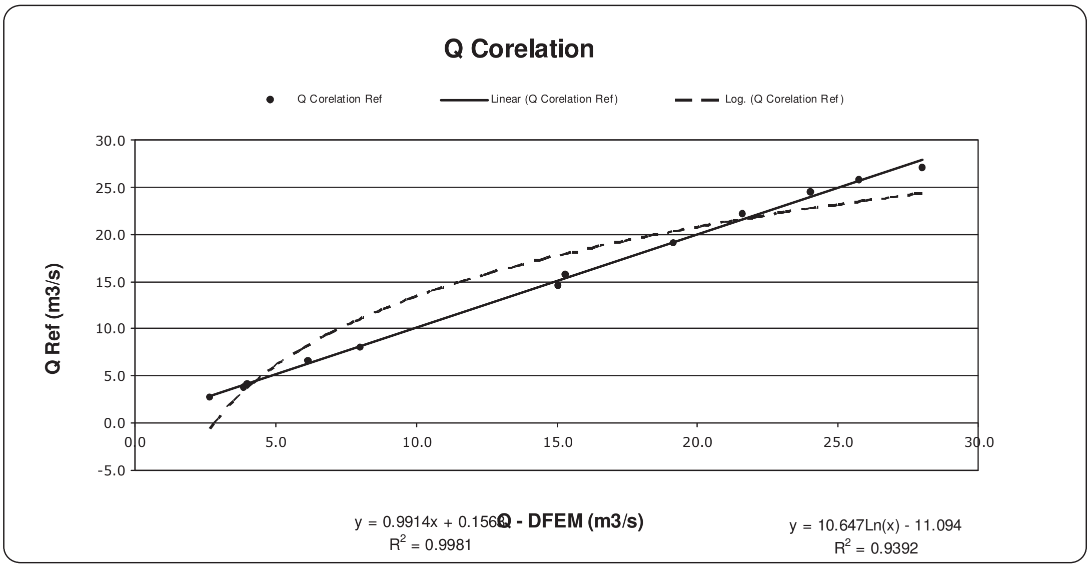

Figure 3.26- The correlation R^2 between observed and validated Q-DFEM discharge flows on 1976-1985.

As above, it is assumed:

(i)- for each period, the monthly discharge water flows are within the goodness on fit criteria and they are evaluated good (Tables 2.35 & 39). The linear correlation R^2 is more than 0.95;

(ii)- calibrating the discharge module on 1960-1975 and validating it on 1976-1985, results that the validated monthly discharge flows are within the goodness on fit criteria and they are evaluated very good (Table 3.41). The linear correlation R^2 is 0.99.

(iii)- DFEM modeling should apply to the other catchments rivers in Albania.

The observed and DFEM discharge flows on 1976-1985, are shown in Figure 3.27.

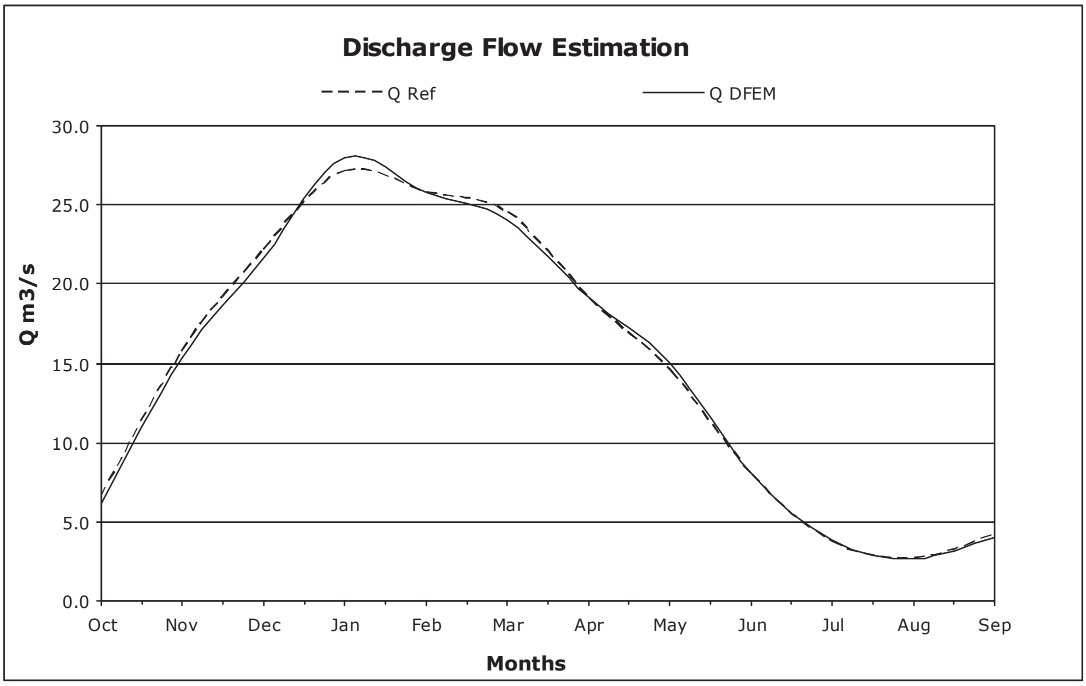

Figure 3.27- Ndroq observed and validated Q- DFEM discharge flows on 1976-1985

In Annex 10.3 is shown Ndroq site at Erzen river using like the input data from the project study “Les resources en eau de l’Albanie” by Selenica A. and Morell M. on December 2000, (the part of MEDHYCOS Project).

4 Vjosa river assessment

Vjosa is an important river in Albania (the second river) with a catchment area of 6710km^2, where 4365km2 are in Albania and 2154km^2 in Greece territory. The origine source is from the Northern Pindos Mountain and it is 260km long (where 70km are crossing through Greece) with direction from SE to NW. The mean slope of the river basin is 28% and the mean altitude is 855m, whereas 75% of the area reaches 420-2400m. From geological point of view, the calcareous rocks are also dominant with quaternary alluvial. The vegetation are bushes (800-900m), the oak trees (800-1200m) and mediterranean coniferous trees.

Vjosa river hydrographical network comprises: Sarantaporos (870km^2) and Voidomatis (384km^2) rivers that are in Greek territory, Drinos river (1320km^2) and Shushica river (587km^2).

Average discharge flow of the river on the border with Greece is 52m^3/s and in Mifol Bridge site (near spilling in the Adriatic Sea) is 195m^3/s. The specific discharge module is q_o=29l/s/km^2, which varies according to the area of the catchments and the topographic conditions of relief. The annual volume of water that spill into the sea Adriatk is 6.2 billion m^3. The maximum discharge flow is Q_{max}= 4670m^3/s within 6 days (for each 100year). The minimum discharge flow is 49.8m^3/s. (Pano N. 2008).

The basin has Mediterranean climate, with monthly average air temperature 20-24°C and precipitation of 20-24mm during the summer. In the winter the monthly average of air temperature is 6-9°C and the precipitation is 150-250mm.

The average atmospheric precipitation vary according to the catchment areas. In the upper part of the river the average precipitation ranges 1210-1320mm, in the middle where is joined with Drino river the precipitation is 1950 mm and at the lower part it ranges 1510 – 1570mm. (Hydro Meteorology Institute 1984 - Hydrology of Albania). The snowfalls are scarce and generally are merged with the rain. (Institute of Enegy, Water and Environment of Albania - Meeting on May 12, 2011). The regional deficit is between 200-400m. (Merkoci Laska et all, 2010).

The basin is distinguished for a number of groundwater sources (47) and three main aquafers. The measurements have shown that the chemical compositions of the river waters is very good. There are about 300.000 inhabitants that live in this region and the main cities are: Permet, Tepelena, Memaliaj, Gjirokaster.

The Vjosa river basin, as a part of Albanian basins, is shown in Figure 4.1.

Figure 4.1 – Albanian rivers basins (source: AKBN)

Even this river is the second in Albania (after Drin river in North), there is no any hydropower plant built in, except Kalivaci HPP that has started the civil works only. So far there have been some studies, where the most important are:

(i) - the study prepared by Design Institute of Tirana, which foreseen the Vjosa river cascade with medium/high dams, reservoirs, total power capacity 495MW and power generation 2.150 GWh/year. (Figure A10.6.1 - Vjosa river power capacity & generation by HMI 1990).

(ii) - the study of Sogreah Consultant 2008 which uses the same philosophy with medium or hight dams and reservoirs, but exploiting also the potential of Shushica and Drinos rivers. There are some plants incompatibilities in the upper of the river scheme (Carshova, Zhepa, Pellumbari or Kaludh). The cascade power capacity is estimated 482MW and the electricity production 1.933GWh/year (Figure A10.6.2 - Vjosa river cascade by SOGREAH 2008).

In both studies, it is included the construction of Kalivaci HPP with a power capacity of 90MW and the annual generation 400GWh. This is a concessionaire contract between Albanian Government and Italian company – Begetti Investment Group since 2001, but it has not commissioned yet because of the proprietary problems with owners as a result of the terrain floods from the reservoir and finantial crisis. The terrain floods are not approved by a lot of NGOs or local civil organisations that consider like an negative impact of the environment. (Vjosa river – Environmental (hydro) Catalism - http://vjosa-river.blogspot.com.)

4.1 Potential hydropower plants

In this study is proposed a new configuration of Vjosa river cascade with runoff scheme and low dams (10-30m). In the longitudinal profile of the river, there are two considerations:

1- new Dorza hydropower plant (instead of the existing Kalivaci HPP project) with headrace level to 100m and tailrace 60m (H_{gross} 40m).

2- in the upper of Vjosa river (from EL.265m asl up to El.180m asl) is developed the idea and it is proposed to Albanian Power Corporation (KESH sha) to build nine straflomatrix hydropower plants with a total capacity of 65-70MW, but this idea is not yet in practice (E.Cuci et all 2008). This profile is considered as a part of the cascade with a power capacity 67.6MW (Vjosa 10.2MW, Vjosa 32.8MW and Vjosa 24.6MW) and electricity generation 336GWh, but without any intervention comments on it.

In Memaliaj location should be proposed to construct a new wind power plant Tepelena-10MW which would connected to Memaliaj Substation 110kV. The wind plant should be controlled by the new hydropower plants regulation group and connected to the new grid network 110kV. Albanian Transmission System Operator (TSO) has planned to invest the refurbishment of 110kV line and 110kV Substations in Permet, Kelcyre and Memaliaj during the next three years. The line track is near the new proposed hydropower plants.

In this session is described the assessment of the potencial hydro energetic of Vjosa river with runoff scheme and low dams of the hydropower plants, without any negativ impact of the environment and social development of the Vjosa basin. The dams will use the relief profile and the plants should install the convecional (Kaplan, bulb) or straflomatrix (propeller) turbines technologies. Based on the site surveys and inspections in the longitudinal profile of Vjosa river, the sites' definitions and the localisation of the potential hydropower plants are shown in Figure 4.2.

Figure 4.2- Vjosa river potential hydropower plants

The observed discharge data recorded during the period 1948-1985 (source: AKBN 2011) correspond to the river site locations as below:

- upstream at Kaludh (Table A.10.4.19)
- midstream at Dragot (Table A.10.4.20)
- downstream at Dorza (Table A.10.4.21)

In the tables above of Annex A.10.4, there are the recording time serie data period on 1948-1985 and the precipitation data are available from Institute of Energy, Water and Environment of Albania as below:

Table 4.1 – *Dorza* observed precipitation (mm) during on 1950 – 1985
(source: Institute of Energy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
173	164	98	72	74	41	30	30	56	122	195	197	1254

Table 4.2 – *Dorza* observed discharge flow m^3/s during on 1950 – 1985
(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
66.3	158.8	270.1	257.4	257.7	221.6	213.4	159.5	89.3	52.0	38.0	36.0	151.7

Table 4.3 - *Kaludh* observed precipitation (mm) during on 1950 – 1985
(source: Institute of Energy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
160	138	88	86	82	49	28	25	53	121	188	191	1208

Table 4.4 – *Kaludh* observed discharge flow m^3/s during on 1950 – 1985
(source: Institute of Energy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
33.0	75.0	100.0	99.0	97.0	91.0	94.0	74.0	43.0	26.0	18.0	19.0	64.1

Table 4.5 - *Dragot* observed precipitation (mm) during on 1950 – 1985
(source: Institute of Energy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
160	138	88	86	82	49	28	25	53	121	188	191	1208

Table 4.6 – *Dragot* observed discharge flow m^3/s during on 1950 – 1985
(source: Institute of Energy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
45.0	111.0	162.0	151.0	151.0	137.0	144.0	116.0	65.0	38.0	26.0	26.0	97.7

Table 4.7 – *Drino Ura Leklit* observed precipitation (mm) during on 1960 – 1985
(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
245	204	136	92	83	42	23	21	78	134	270	250	1579

Table 4.8 – *Drino Ura Leklit* observed discharge flow m^3/s during on 1960 – 1985

(source: Institute of Energy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
13.1	44.9	76.3	84.6	82.5	61.2	44.2	26.1	13.8	8.8	6.2	6.1	39.0

The observed discharge water flow data of Drino river (Ura Leklit) are refered to Table A.10.4.14 of Annex A.10.4.

Using the same method, there are calculated, calibrated and validated the discharge water flows at Kaludh, Dragot, Dorza sites in Vjosa river and Ura Leklit site in Drino river. Hereafter, it is calculated the mean and design discharge water flows (Q_{mean} and Q_{design}) for each ungauged sites, which are classified in Figure 4.3 – Sites classification:

- Upperstream: Pellumbari, Kaludh, Vjosa 10.2MW, 32.8MW, 24.6MW
- Middle stream: Dragot, Memaliaj, Kalivac bis
- Downstream: Dorza, Drizar I & II, Gjonca
- Drinostream: Drino - Ura Leklit

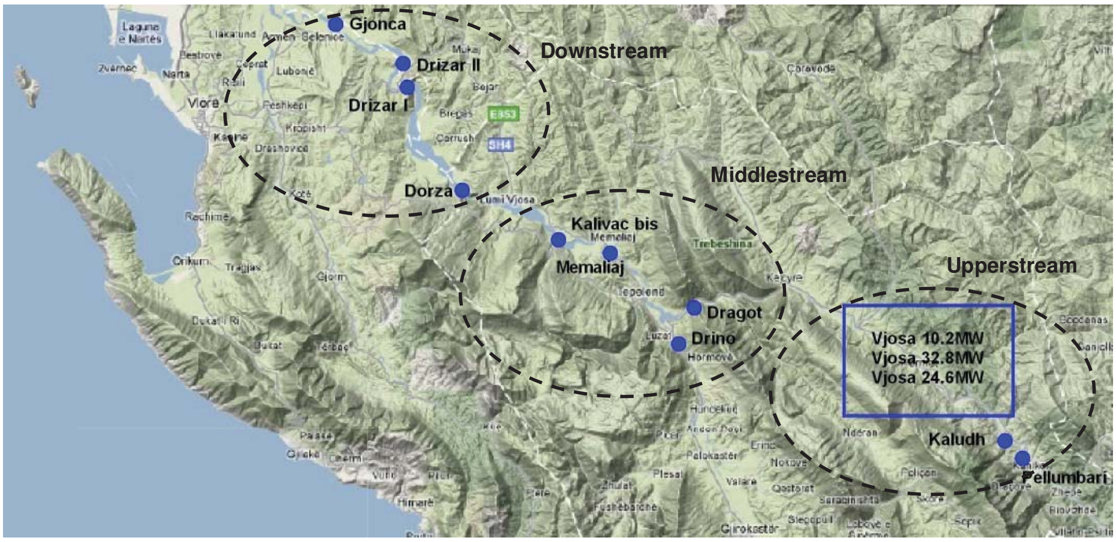

Figure 4.3 – Sites classification: upperstream, middlestream and downstream areas

Vjosa Upperstream

This upperstream area covers the sites of Pellumbari, Kaludh and Vjosa group with a capacity of 67.6MW (Vjosa I 10.2MW, Vjosa II 32.8MW and Vjosa III 24.6MW). This group has the ungauged discharge water flows sites at Petran, Badelonje, Permet and Kosina. (It is not included in the study). Using the meteorological data (precipitation, air temperature, solar radiation) from actual measurement given by GAISMA (www.gaisma.com/en/dir/al-country.html) in Table A.10.4.16, and the curve number CN values (normal, dry & wet), the results are given in Table 4.9.

Table 4.9 – Vjosa Upperstream results

a. Pellumbari (40°09'30N / 20°28'54E) with A_c = 2250 km^2 CN(II) = 83

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	36.3	75.0	95.4	96.8	84.5	84.0	107.8	70.4	38.2	23.1	18.3	22.2	62.7
q specific l/s/km^2	0.023	0.029	0.036	0.037	0.031	0.029	0.027	0.025	0.024	0.021	0.020	0.020	0.027

CN(I) = 67 (dry)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	34.8	68.7	83.7	84.4	76.3	76.5	100.0	66.3	36.2	22.4	17.9	21.7	57.4
q specific l/s/km^2	0.022	0.026	0.032	0.032	0.028	0.027	0.025	0.023	0.023	0.021	0.020	0.020	0.025

CN(III) = 91 (wet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	37.2	78.6	102.4	104.2	89.3	88.3	112.2	72.6	39.2	23.5	18.5	22.5	65.7
q specific l/s/km^2	0.023	0.030	0.039	0.040	0.033	0.031	0.028	0.025	0.024	0.021	0.020	0.021	0.028

b. Kaludh (40°10'31N / 20°27'06E) with A_c = 2300 km^2 CN(II) = 83

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	37.1	76.7	97.7	99.1	86.5	85.9	110.2	71.9	39.0	23.6	18.7	22.7	64.1
q specific l/s/km^2	0.023	0.029	0.036	0.037	0.031	0.029	0.027	0.025	0.024	0.021	0.020	0.020	0.027

CN(I) = 67 (dry)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	35.5	70.2	85.7	86.4	78.1	78.3	102.2	67.7	37.0	22.9	18.3	22.1	58.7
q specific l/s/km^2	0.022	0.026	0.032	0.032	0.028	0.027	0.025	0.023	0.023	0.021	0.020	0.020	0.025

CN(III) = 91 (wet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	38.0	80.4	104.9	106.7	91.4	90.4	114.8	74.2	40.1	24.0	18.9	23.0	67.2
q specific l/s/km^2	0.023	0.030	0.039	0.040	0.033	0.031	0.028	0.025	0.024	0.021	0.020	0.021	0.028

Vjosa Middlestream

The middlestream area covers the sites of Dragot, Memaliaj, Kalivaci bis and Drino. Using the meteorological data (precipitation, temperature, radiation) from actual measurement given by GAISMA (www.gaisma.com/en/dir/al-country.html) in Table A.10.4.15, 16 and 17 the results are given in Table 4.10.

Table 4.10 – Vjosa Middlestream results

a. Dragot (40°17'20N / 20°04'19E) with A_c = 3400 km^2 CN(II) = 82

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	53.8	125.5	182.9	174.6	153.6	144.3	185.2	116.6	56.3	32.4	25.5	31.8	106.9
q specific $l/s/km^2$	0.024	0.032	0.042	0.043	0.035	0.033	0.029	0.026	0.024	0.021	0.020	0.021	0.029

CN(I) = 66 (dry)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	50.9	112.3	154.8	146.9	134.6	128.2	168.5	108.6	53.1	31.3	25.0	30.9	95.4
q specific $l/s/km^2$	0.022	0.028	0.035	0.036	0.031	0.029	0.026	0.024	0.023	0.021	0.020	0.020	0.026

CN(III) = 91 (wet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	55.4	133.1	199.7	191.2	164.7	153.6	194.7	121.1	58.0	32.9	25.8	32.2	113.5
q specific $l/s/km^2$	0.024	0.033	0.046	0.047	0.038	0.035	0.030	0.027	0.025	0.022	0.020	0.021	0.031

b. Memaliaj (40°19'39N / 20°00'06E) with A_c = 4800 km^2 CN(II) = 82

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	69.8	167.9	249.1	238.1	207.1	193.6	246.0	153.1	73.2	41.0	31.8	40.0	142.6
q specific $l/s/km^2$	0.024	0.032	0.042	0.043	0.035	0.033	0.029	0.026	0.024	0.021	0.020	0.021	0.029

CN(I) = 66 (dry)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	66.0	150.2	210.8	200.4	181.4	171.9	223.9	142.5	69.0	39.7	31.1	38.9	127.2
q specific $l/s/km^2$	0.022	0.028	0.035	0.036	0.031	0.029	0.026	0.024	0.023	0.021	0.020	0.020	0.026

CN(III) = 91 (wet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	71.8	178.1	272.0	260.8	222.0	206.1	258.5	159.0	75.4	41.8	32.2	40.6	151.5
q specific $l/s/km^2$	0.024	0.033	0.046	0.047	0.038	0.035	0.030	0.027	0.025	0.022	0.020	0.021	0.031

c. Kalivac bis (40°21'06N / 19°55'18E) with A_c = 5000 km^2 CN(II) = 82

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	72.5	175.2	260.5	249.0	216.2	202.0	256.3	159.3	76.0	42.5	32.9	41.4	148.6
q specific $l/s/km^2$	0.024	0.032	0.042	0.043	0.035	0.033	0.029	0.026	0.024	0.021	0.020	0.021	0.029

CN(I) = 66 (dry)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	68.6	156.7	220.4	209.6	189.4	179.4	233.3	148.2	71.7	41.1	32.2	40.2	132.6
q specific $l/s/km^2$	0.022	0.028	0.035	0.036	0.031	0.029	0.026	0.024	0.023	0.021	0.020	0.020	0.026

CN(III) = 91 (wet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	74.6	185.7	284.4	272.7	231.8	215.0	269.4	165.4	78.4	43.2	33.3	42.0	158.0
q specific $l/s/km^2$	0.024	0.033	0.046	0.047	0.038	0.035	0.030	0.027	0.025	0.022	0.020	0.021	0.031

d. Drino (40°15'07N / 20°03'43E) with A_c = 1300 km^2 CN(II) = 82

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	13.1	54.3	67.1	87.4	62.9	52.1	44.5	28.2	13.3	9.0	7.0	8.2	37.3
q specific $l/s/km^2$	0.024	0.032	0.042	0.044	0.035	0.033	0.029	0.026	0.024	0.021	0.020	0.021	0.029

CN(I) = 66 (dry)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	12.5	48.6	56.8	73.4	55.1	46.2	40.5	26.3	12.6	8.7	6.8	8.0	33.0
q specific $l/s/km^2$	0.022	0.028	0.036	0.037	0.031	0.029	0.026	0.024	0.022	0.020	0.020	0.020	0.026

CN(III) = 91 (wet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	13.5	57.7	73.5	96.0	67.6	55.6	46.8	29.3	13.7	9.1	7.1	8.3	39.9
q specific $l/s/km^2$	0.024	0.034	0.046	0.048	0.038	0.035	0.030	0.027	0.024	0.021	0.020	0.021	0.031

Vjosa Downstream

The downstream area covers the sites of Dorze, Drizar I, Drizar II and Gjonca. Using the meteorological data (precipitation, temperature, radiation) from actual measurement given by GAISMA (www.gaisma.com/en/dir/al-country.html) in Table A.10.4.15, 16 and 17, the results are given in Table 4.11.

Table 4.11 – Vjosa Downstream area results

a. Dorza (40°23'53N / 19°48'06E) with A_c = 5420 km^2 CN(II) = 82

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	74.9	170.5	268.3	263.3	219.5	177.1	243.2	185.7	82.4	49.8	34.8	39.0	150.7
q specific $l/s/km^2$	0.024	0.032	0.042	0.043	0.035	0.033	0.029	0.026	0.024	0.021	0.020	0.021	0.029

CN(I) = 66 (dry)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	70.9	152.6	227.1	221.6	192.3	157.3	221.3	172.8	77.8	48.2	34.0	37.9	134.5
q specific $l/s/km^2$	0.022	0.028	0.035	0.036	0.031	0.029	0.026	0.024	0.023	0.021	0.020	0.020	0.026

CN(III) = 91 (wet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	77.1	180.8	293.0	288.4	235.3	188.5	255.6	192.8	85.0	50.6	35.2	39.6	160.2
q specific $l/s/km^2$	0.024	0.033	0.046	0.047	0.038	0.035	0.030	0.027	0.025	0.022	0.020	0.021	0.031

b. Drizar I (40°29’32N / 19°43’35E) with A_c = 5500 km² CN(II) = 82

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	74.7	174.4	278.6	273.7	225.9	181.6	247.3	187.0	82.4	48.7	33.6	38.0	153.8
q specific $l/s/km^2$	0.024	0.032	0.042	0.043	0.035	0.033	0.029	0.026	0.024	0.021	0.020	0.021	0.029

CN(I) = 66 (dry)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	70.7	156.1	235.8	230.4	198.0	161.3	225.1	174.0	77.7	47.1	32.8	36.9	137.2
q specific $l/s/km^2$	0.022	0.028	0.035	0.036	0.031	0.029	0.026	0.024	0.023	0.021	0.020	0.020	0.026

CN(III) = 91 (wet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	76.9	185.0	304.2	299.8	242.3	193.3	259.9	194.2	84.9	49.6	34.0	38.5	163.5
q specific $l/s/km^2$	0.024	0.033	0.046	0.047	0.038	0.035	0.030	0.027	0.025	0.022	0.020	0.021	0.031

c. Drizar II (40°30’53N / 19°43’44E) with A_c = 5520 km² CN(II) = 82

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	74.9	175.1	279.7	274.8	226.8	182.3	248.2	187.6	82.6	48.9	33.7	38.1	154.4
q specific $l/s/km^2$	0.024	0.032	0.042	0.043	0.035	0.033	0.029	0.026	0.024	0.021	0.020	0.021	0.029

CN(I) = 66 (dry)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	70.9	156.7	236.7	231.3	198.7	161.9	225.9	174.6	78.0	47.3	32.9	37.0	137.7
q specific $l/s/km^2$	0.022	0.028	0.035	0.036	0.031	0.029	0.026	0.024	0.023	0.021	0.020	0.020	0.026

CN(III) = 91 (wet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	77.1	185.7	305.4	301.0	243.2	194.0	260.9	194.8	85.2	49.7	34.1	38.7	164.2
q specific $l/s/km^2$	0.024	0.033	0.046	0.047	0.038	0.035	0.030	0.027	0.025	0.022	0.020	0.021	0.031

d. Gjonca (40°33’23N / 19°38’11E) with A_c = 5640 km² CN(II) = 82

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	76.4	179.1	286.4	281.5	232.1	186.5	253.7	191.5	84.3	49.8	34.3	38.8	157.9
q specific $l/s/km^2$	0.024	0.032	0.042	0.043	0.035	0.033	0.029	0.026	0.024	0.021	0.020	0.021	0.029

CN(I) = 66 (dry)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	72.4	160.2	242.4	236.9	203.3	165.6	230.9	178.3	79.5	48.1	33.5	37.7	140.7
q specific $l/s/km^2$	0.022	0.028	0.035	0.036	0.031	0.029	0.026	0.024	0.023	0.021	0.020	0.020	0.026

CN(III) = 91 (wet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	78.7	189.9	312.8	308.3	248.8	198.5	266.6	198.9	86.9	50.6	34.7	39.3	167.8

q specific l/s/km^2	0.024	0.033	0.046	0.047	0.038	0.035	0.030	0.027	0.025	0.022	0.020	0.021	0.031

The average annual discharge water flows in Vjosa river cascade are shown in Table 4.12, where are included the discharge water flows (at Petran, Badelonja, Permet and Kosina) of the Vjosa group (10.2MW, 32.8MW and 24.6MW), in the upperstream of the river.

In the tables of Annex 10.8 are shown the "goodness on fit" discharge water flows compared with the data of the discharge water flow reference (Q Ref) at Kaludh, Dragot and Dorza sites. (Tables A.10.4.19, 20 and 21).

Table 4.12 – Average annual discharge flow in Vjosa river sites

Ac km^2	2250	2300	2420	2720	2730	2800	3400	4800	5000	5420	5500	5520	5640	1300
Site	Pellumbari	Kaludh	Petran	Badelonja	Permeti	Kosina	Dragot	Memaliaj	Kalivac bis	Dorze	Drizar I	Drizar II	Gjonca	Drino
Oct	36.3	37.1	38.9	43.4	43.5	44.6	53.8	69.8	72.5	74.9	74.7	74.9	78.7	13.1
Nov	75.0	76.7	80.8	91.1	91.5	93.9	125.5	167.9	175.2	170.5	174.4	175.1	189.9	54.3
Dec	95.4	97.7	103.2	117.2	117.6	120.9	182.9	249.1	260.5	268.3	278.6	279.7	312.8	67.1
Jan	96.8	99.1	104.7	118.9	119.4	122.7	174.6	238.1	249.0	263.3	273.7	274.8	308.3	87.4
Feb	84.5	86.5	91.2	103.1	103.5	106.3	153.6	207.1	216.2	219.5	225.9	226.8	248.8	62.9
Mar	84.0	85.9	90.6	102.2	102.6	105.4	144.3	193.6	202.0	177.1	181.6	182.3	198.5	52.1
Apr	107.8	110.2	116.0	130.5	131.0	134.3	185.2	246.0	256.3	243.2	247.3	248.2	266.6	44.5
May	70.4	71.9	75.5	84.6	84.9	87.1	116.6	153.1	159.3	185.7	187.0	187.6	198.9	28.2
Jun	38.2	39.0	40.9	45.8	45.9	47.1	56.3	73.2	76.0	82.4	82.4	82.6	86.9	13.3
Jul	23.1	23.6	24.7	27.3	27.4	28.0	32.4	41.0	42.5	49.8	48.7	48.9	50.6	9.0
Aug	18.3	18.7	19.5	21.5	21.5	22.0	25.5	31.8	32.9	34.8	33.6	33.7	34.7	7.0
Sep	22.2	22.7	23.7	26.2	26.2	26.8	31.8	40.0	41.4	39.0	38.0	38.1	39.3	8.2
Q_{mean} m^3/s	62.7	64.1	67.5	76.0	76.3	78.3	106.9	142.6	148.6	150.7	153.8	154.4	167.8	37.3
H (m)	25	20	9 + 5	4 x 10		3 x 10	30	15	5	40	16	16	15	30

In Annex 10.7 are shown the flow duration curves FDC. The discharge flow design Q_{design} is defined where the curve cuts the y-axis.

The convecional plants like Pellumbari (25m), Kaludh (20m), Dragot (30m), Drino (30m) and Dorza (40m) should have the low dams without any reservoir or river deviation. In Dorza site, the plant is concepted with H=40m, considering the headrace level El.100m asl, (it not affect the floods of the territorry). Between Memaliaj and Dorza plants, is concepted a new runoff plant named Kalivaci bis with H=5m (El.105 - 100m asl).

4.2 Power generation

During the operation of the hydropower plant, it is necessary to estimate the monthly power capacity in operation and the annual electricity generation. This is done based on the simple method as follows:

- For each site, it is considered the monthly discharge water flows (as shown in Table 4.13) and the rated head (H_{gross}).

- Estimate the power produced by $1m^3/s$ or the efficiency. This is calculated using the formula:

$$e_{ff} = 9.8 * \eta * 1m^3/s * H \qquad (kW)$$

- The monthly power capacity under operation is calculated by:

$$P_m = e_{ff} * Q_m \qquad (kW)$$

  where the maximum of P_m, defines the power capacity of the plant

- The monthly electricity generation is:

$$E_m = P_m * 30day * 24hrs \qquad (kWh)$$

- The total electricity generation is

$$E = \sum E_m \qquad (m = 1,2,\ldots 12)$$

Thus, it is considered the relation between the discharge water flow and the power capacity and generation or Q=f(P,E) as well as under the effect of future climate change factors. In the next tables, there are presented the results for each plant.

Table 4.13 Pellumbari hydropower plant 22MW

Pellumbari	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	36.3	25	0.055	7,177	5,167,666
Nov	75.0	25	0.055	14,811	10,664,114
Dec	95.4	25	0.055	18,847	13,569,970
Jan	96.8	25	0.055	19,115	13,762,588
Feb	84.5	25	0.055	16,697	12,021,594
Mar	84.0	25	0.055	16,592	11,946,399
Apr	**107.8**	25	0.055	**21,290**	15,328,691
May	70.4	25	0.055	13,894	10,003,804
Jun	38.2	25	0.055	7,537	5,426,881
Jul	23.1	25	0.055	4,564	3,285,815
Aug	18.3	25	0.055	3,616	2,603,586
Sep	22.2	25	0.055	4,394	3,163,687
Total generation					106,944,794

Table 4.14 Kaludhi hydropower plant 18MW

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	37.1	20	0.044	5,861	4,220,181
Nov	76.7	20	0.044	12,120	8,726,093
Dec	97.7	20	0.044	15,440	11,116,531
Jan	99.1	20	0.044	15,660	11,275,537
Feb	86.5	20	0.044	13,668	9,841,133
Mar	85.9	20	0.044	13,579	9,776,900
Apr	**110.2**	20	0.044	**17,413**	12,537,254
May	71.9	20	0.044	11,356	8,176,514
Jun	39.0	20	0.044	6,158	4,433,965
Jul	23.6	20	0.044	3,723	2,680,511
Aug	18.7	20	0.044	2,947	2,121,718
Sep	22.7	20	0.044	3,582	2,579,107
Total generation					87,485,445

Table 4.15 Dragot hydropower plant 44MW

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	53.8	30	0.066	12,748	9,178,423
Nov	125.5	30	0.066	29,749	21,419,384
Dec	182.9	30	0.066	43,352	31,213,731
Jan	174.6	30	0.066	41,379	29,792,646
Feb	153.6	30	0.066	36,404	26,211,042
Mar	144.3	30	0.066	34,198	24,622,876
Apr	**185.2**	30	0.066	**43,896**	31,604,879
May	116.6	30	0.066	27,645	19,904,428
Jun	56.3	30	0.066	13,338	9,603,211
Jul	32.4	30	0.066	7,668	5,521,260
Aug	25.5	30	0.066	6,049	4,355,349
Sep	31.8	30	0.066	7,528	5,419,973
Total generation					218,847,204

Table 4.16 Drino hydropower plant 15MW

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	13.1	30	0.066	3,116	2,243,293
Nov	54.3	30	0.066	12,871	9,267,179
Dec	67.1	30	0.066	15,903	11,450,505
Jan	87.4	30	0.066	15,000	10,800,000
Feb	**62.9**	30	0.066	**14,911**	10,736,249
Mar	52.1	30	0.066	12,350	8,892,047
Apr	44.5	30	0.066	10,538	7,587,606
May	28.2	30	0.066	6,694	4,819,907
Jun	13.3	30	0.066	3,148	2,266,867
Jul	9.0	30	0.066	2,132	1,535,176
Aug	7.0	30	0.066	1,654	1,191,027
Sep	8.2	30	0.066	1,947	1,401,704
Total generation					72,191,561

Table 4.17 Memaliaj hydropower plant 29.5MW

	Q (m^3/s)	H (m)	eff = kW/m^3/s	kW	kWh
Oct	69.8	15	0.033	8,266	5,951,704
Nov	167.9	15	0.033	19,899	14,327,357
Dec	**249.1**	15	0.033	**29,519**	21,253,517
Jan	238.1	15	0.033	28,216	20,315,518
Feb	207.1	15	0.033	24,536	17,665,766
Mar	193.6	15	0.033	22,939	16,515,880
Apr	246.0	15	0.033	29,150	20,987,838
May	153.1	15	0.033	18,139	13,060,238
Jun	73.2	15	0.033	8,671	6,242,792
Jul	41.0	15	0.033	4,863	3,501,636
Aug	31.8	15	0.033	3,773	2,716,370
Sep	40.0	15	0.033	4,741	3,413,619
Total generation					145,952,234

Table 4.18 Kalivac bis hydropower plant 10.2MW

	Q (m^3/s)	H (m)	eff = kW/m^3/s	kW	kWh
Oct	72.5	5	0.011	2,862	2,060,651
Nov	175.2	5	0.011	6,919	4,981,502
Dec	260.5	5	0.011	10,288	7,407,541
Jan	249.0	5	0.011	9,836	7,082,021
Feb	216.2	5	0.011	8,540	6,148,558
Mar	202.0	5	0.011	7,979	5,744,595
Apr	**256.3**	5	0.011	**10,125**	7,290,122
May	159.3	5	0.011	6,290	4,529,085
Jun	76.0	5	0.011	3,003	2,162,170
Jul	42.5	5	0.011	1,679	1,208,718
Aug	32.9	5	0.011	1,299	935,527
Sep	41.4	5	0.011	1,635	1,177,226
Total generation					50,727,717

Table 4.19 Dorza hydropower plant 85MW

	Q (m^3/s)	H (m)	eff = kW/m^3/s	kW	kWh
Oct	74.9	40	0.088	23,665	17,038,871
Nov	170.5	40	0.088	53,880	38,793,451
Dec	**268.3**	40	0.088	**84,791**	61,049,525
Jan	263.3	40	0.088	83,213	59,913,341
Feb	219.5	40	0.088	69,351	49,932,970
Mar	177.1	40	0.088	55,963	40,293,561
Apr	243.2	40	0.088	76,845	55,328,544
May	185.7	40	0.088	58,666	42,239,835
Jun	82.4	40	0.088	26,041	18,749,360
Jul	49.8	40	0.088	15,728	11,324,038
Aug	34.8	40	0.088	10,994	7,915,745
Sep	39.0	40	0.088	12,326	8,875,017
Total generation					411,454,258

Table 4.20 Drizar I hydropower plant 36MW

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	74.7	16	0.035	9,440	6,796,786
Nov	174.4	16	0.035	22,050	15,876,199
Dec	**278.6**	16	0.035	**35,214**	25,353,859
Jan	273.7	16	0.035	34,600	24,911,972
Feb	225.9	16	0.035	28,560	20,563,114
Mar	181.6	16	0.035	22,955	16,527,871
Apr	247.3	16	0.035	31,262	22,508,286
May	187.0	16	0.035	23,631	17,014,357
Jun	82.4	16	0.035	10,409	7,494,588
Jul	48.7	16	0.035	6,160	4,435,179
Aug	33.6	16	0.035	4,247	3,057,784
Sep	38.0	16	0.035	4,800	3,456,144
Total generation					167,996,139

Table 4.21 Drizar II hydropower plant 36MW

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	74.9	16	0.035	9,472	6,820,003
Nov	175.1	16	0.035	22,133	15,935,582
Dec	**279.7**	16	0.035	**35,352**	25,453,406
Jan	274.8	16	0.035	34,736	25,010,163
Feb	226.8	16	0.035	28,669	20,641,655
Mar	182.3	16	0.035	23,042	16,590,169
Apr	248.2	16	0.035	31,376	22,590,771
May	187.6	16	0.035	23,715	17,074,575
Jun	82.6	16	0.035	10,445	7,520,385
Jul	48.9	16	0.035	6,180	4,449,300
Aug	33.7	16	0.035	4,260	3,066,985
Sep	38.1	16	0.035	4,815	3,466,898
Total generation					168,619,893

Table 4.22 Gjonca hydropower plant 37.1MW

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	78.7	15	0.033	9,322	6,712,182
Nov	189.9	15	0.033	22,500	16,200,144
Dec	**312.8**	15	0.033	**37,065**	26,686,527
Jan	308.3	15	0.033	36,532	26,303,213
Feb	248.8	15	0.033	29,488	21,231,233
Mar	198.5	15	0.033	23,520	16,934,240
Apr	266.6	15	0.033	31,594	22,747,693
May	198.9	15	0.033	23,573	16,972,392
Jun	86.9	15	0.033	10,300	7,415,672
Jul	50.6	15	0.033	6,001	4,320,799
Aug	34.7	15	0.033	4,108	2,957,766
Sep	39.3	15	0.033	4,661	3,356,204
Total generation					171,838,066

Considering the results in the Tables 4.13 up to 4.22, Table 4.12 and the discharge flow design (Q_{design}) in the figures of Annex 10.8 – Flow duration curve, it is appreciated the plants power capacities (Table 4.23).

Table 4.23 – Vjosa river cascade hydropower plants capacities

Site	A_c km^2	H_c m	Q_{mean} M^3/s	Q_{design} m^3/s	MW	H_{gross} m	Elevation m asl
Pellumbari	2250	1190	62.7	110	22	25	310 – 285
Kaludh	2300	1190	64.1	110	18	20	285 – 265
Dragot	3400	1090	106.9	190	44	30	155 – 125
Drino	1300	748	37.3	63	15	30	155 – 125
Memaliaj	4800	980	142.6	250	29.5	15	125 – 110
Kalivac bis	5000	970	148.6	260	10.2	5	105 - 100
Dorza	5420	963	150.7	270	85	40	100 – 60
Drizar I	5500	618	153.8	280	36	16	60 – 44
Drizar II	5520	618	154.4	280	36	16	44 – 28
Gjonca	5640	610	167.8	315	37.1	15	28 – 15
Vjosa I,II,III	2800	1180	74.5	115	67.6	84	265 - 180

Vjosa I, II, II should have the total capacity 67.6MW and annual power generation 336GWh:

- Vjosa I - 10.2 MW, (H=9 + 5m, from El.265 – 251m asl)
- Vjosa II - 32.8 MW, (H=4x10m, from El.250 – 210m asl)
- Vjosa II - 24.6 MW, (H=3x10m, from El.210 – 180m asl)

The following Table 4.24 shows the average annual power generation in normal (CN 82), dry (CN 66) and wet (CN 91) conditions, as well as the total power generation. The uncertain between normal - dry and normal - wet conditions are estimated -13% and +9%.

Table 4.24 Annual power generation in different conditions (normal, dry, wet)

Site	Condition (kWh)		
	Dry	Normal	Wet
Pellumbari	97,958,995	106,944,794	112,159,091
Kaludh	100,166,535	109,359,342	114,693,882
Vjosa I	47,000,000	49,000,000	51,000,000
Vjosa II	132,000,000	164,000,000	196,000,000
Vjosa III	72,000,000	123,000,000	174,000,000
Dragot	195,396,950	218,847,204	232,503,679
Drino	65,766,123	76,300,065	76,030,660
Memaliaj	130,193,878	145,952,234	155,133,334
Kalivac bis	45,245,127	50,727,717	53,922,163

Dorza	367,148,305	411,454,258	437,275,663
Drizar I	149,790,816	167,996,139	178,610,143
Drizar II	150,345,526	168,619,893	179,274,200
Gjonca	144,092,051	161,197,341	171,838,066
Total Generation	1,697,104,306	1,953,398,987	2,132,440,883
%	-13	0	+9

In summary, in normal condition, the potential hydro energetic of Vjosa river cascade, (configured with runoff hydropower plants and low dams), is assessed with a total capacity of 400.4MW and the average annual power generation of 1,953GWh. The operation time is assumed 4500 hours (or 50% of certain).

The uncertainty bound scenarios of the power generation are:

a- pesimist scenario of power generation (in dry condition) is 1,697,104,306 kWh that means 95% certain

b- optimist scenario of power generation (in wet condition) is 2,132,440,883 kWh with 5% certain.

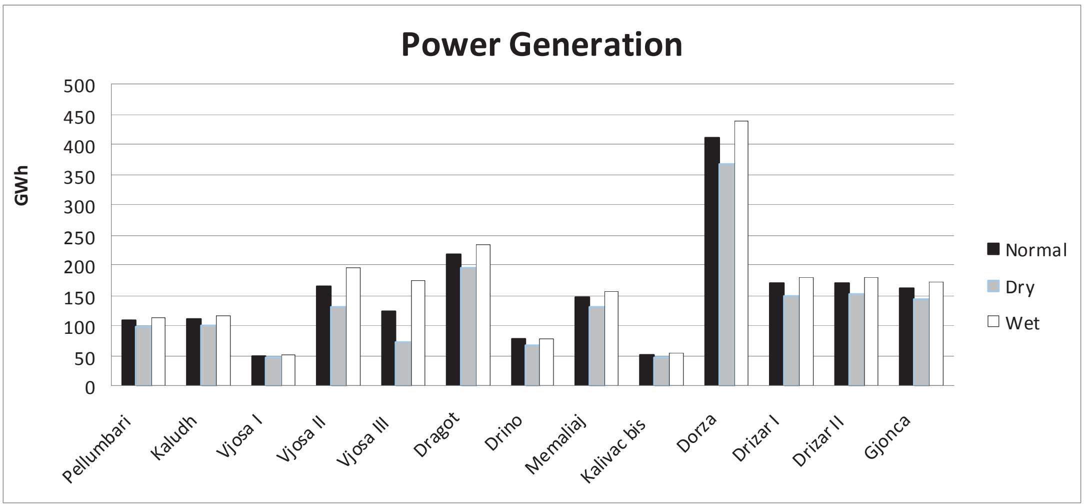

Figure 4.4 – Annual power generation in normal, dry and wet conditions

Using Palisade @Risk Industrial 5.7 software (an evaluation version), a simple Montecarlo simulation is done giving the results as are shown in Figure 4.5. (See Annex 10.12 also). Comparing with 2011-year results as above, the uncertainty bounds (pesimist and optimist scenarios) are estimated approx. in the same ranges.

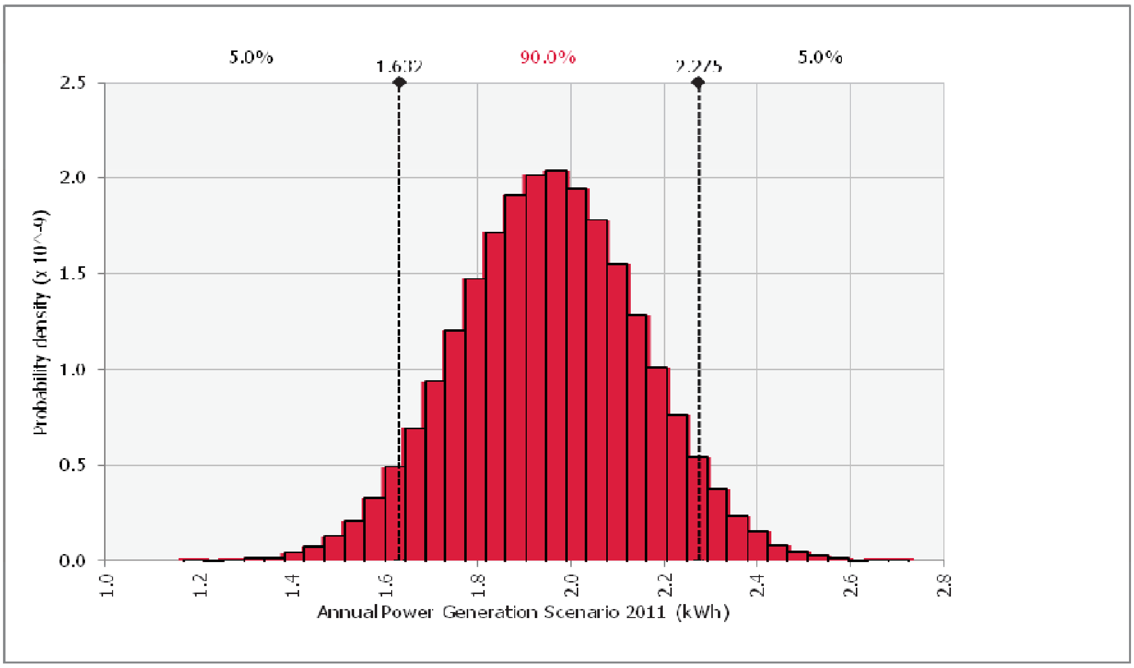

Figure 4.5 – Monte carlo simulation of the power generation scenario on 2011

4.3 Financial analysis

The financial analysis is done considering positive the economic efficiency of the project (Present value W>0), based on the following parameters: (Drobir H. 2010 - "Hydraulic design of small hydroelectric power plants" Lecture of MSc Program Renewable Energy in Central and Eastern Europe).

- plant power capacity (P)
- the specific investment cost (i) with 3000 euro/kW, (refer to Ashta hydropower plants in Albania investment publication data),
- Investment cost (I = P * i)
- power generation (E)
- the selling price (S) with 65 euro/MWh (ERE – Energy Regulatory Entity data)
- annual profit (A = E * S)
- operational & maintenance cost (K) with 3% of the total investment,
- lifetime is (T) 35 years (approx. up to 2050),
- interest rate p=7%, (q=1.07%),

The present value is defined by: $W = - I + T * (A - K) / q > 0$ (a)

Refer to Tables 4.23 and 4.14, the financial results of Vjosa river cascade (including Vjosa I, II, III) are shown in the following tables:

Table 4.25 Vjosa river cascade financial results in Normal condition

	Power	Power generation	Specific investment	Investment	Profit	O&M	Lifetime	Interest	NPV	Payback	Electricity cost	Selling price
Site	kW	kWh	Eur/kW	eur	eur/year	eur/year	year	%	eur	year	eur/ kWh	eur/ kWh
Pellumbari	22,000	106,944,794	3,000	66,000,000	6,951,412	1,980,000	35	7	96,616,268	13.3	0.036	0.065
Kaludh	18,000	109,359,342	3,000	54,000,000	7,108,357	1,620,000	35	7	125,525,703	9.8	0.028	0.065
Vjosa I	10,200	49,000,000	3,000	30,600,000	3,185,000	918,000	35	7	43,554,206	13.5	0.039	0.065
Vjosa II	32,800	164,000,000	3,000	98,400,000	10,660,000	2,952,000	35	7	153,730,841	12.8	0.038	0.065
Vjosa III	24,600	123,000,000	3,000	73,800,000	7,995,000	2,214,000	35	7	115,298,131	12.8	0.038	0.065
Dragot	44,000	218,847,204	3,000	132,000,000	14,225,068	3,960,000	35	7	203,773,261	12.9	0.035	0.065
Drino	15,000	76,300,065	3,000	45,000,000	4,959,504	1,350,000	35	7	73,067,896	12.5	0.034	0.065
Memaliaj	29,500	145,952,234	3,000	88,500,000	9,486,895	2,655,000	35	7	134,973,208	13.0	0.036	0.065
Kalivac bis	10,200	50,727,717	3,000	30,600,000	3,297,302	918,000	35	7	47,227,623	12.9	0.035	0.065
Dorza	85,000	411,454,258	3,000	255,000,000	26,744,527	7,650,000	35	7	369,587,323	13.4	0.036	0.065
Drizar I	36,000	167,996,139	3,000	108,000,000	10,919,749	3,240,000	35	7	143,206,745	14.1	0.038	0.065
Drizar II	36,000	168,619,893	3,000	108,000,000	10,960,293	3,240,000	35	7	144,532,950	14.0	0.041	0.065
Gjonca	37,100	161,197,341	3,000	111,300,000	10,477,827	3,339,000	35	7	122,213,039	15.6	0.037	0.065
Total	400,400	1,953,398,987	3,000	1,201,200,000	126,970,934	36,036,000	35	7	1,773,307,191	13.2	0.036	0.065

Table 4.26 Vjosa river cascade financial results in Dry condition

	Power	Power generation	Specific investment	Investment	Profit	O&M	Lifetime	Interest	NPV	Payback	Electricity cost	Selling price
Site	kW	kWh	Eur/kW	eur	eur/year	eur/year	year	%	eur	year	eur/ kWh	eur/ kWh
Pellumbari	22,000	97,958,995	3,000	66,000,000	6,367,335	1,980,000	35	7	77,510,947	15.0	0.039	0.065
Kaludh	18,000	100,166,535	3,000	54,000,000	6,510,825	1,620,000	35	7	105,980,250	11.0	0.031	0.065
Vjosa I	10,200	47,000,000	3,000	30,600,000	3,055,000	918,000	35	7	39,301,869	14.3	0.042	0.065
Vjosa II	32,800	132,000,000	3,000	98,400,000	8,580,000	2,952,000	35	7	85,693,458	17.5	0.047	0.065
Vjosa III	24,600	72,000,000	3,000	73,800,000	4,680,000	2,214,000	35	7	6,863,551	29.9	0.065	0.065
Dragot	44,000	195,396,950	3,000	132,000,000	12,700,802	3,960,000	35	7	153,914,076	15.1	0.039	0.065
Drino	15,000	65,766,123	3,000	45,000,000	4,274,798	1,350,000	35	7	50,670,962	15.4	0.040	0.065
Memaliaj	29,500	130,193,878	3,000	88,500,000	8,462,602	2,655,000	35	7	101,468,292	15.2	0.039	0.065
Kalivac bis	10,200	45,245,127	3,000	30,600,000	2,940,933	918,000	35	7	35,570,714	15.1	0.039	0.065
Dorza	85,000	367,148,305	3,000	255,000,000	23,864,640	7,650,000	35	7	275,385,416	15.7	0.040	0.065
Drizar I	36,000	149,790,816	3,000	108,000,000	9,736,403	3,240,000	35	7	104,499,164	16.6	0.042	0.065
Drizar II	36,000	150,345,526	3,000	108,000,000	9,772,459	3,240,000	35	7	105,678,571	16.5	0.047	0.065
Gjonca	37,100	144,092,051	3,000	111,300,000	9,365,983	3,339,000	35	7	85,844,313	18.5	0.042	0.065
Total	400,400	1,697,104,306	3,000	1,201,200,000	110,311,780	36,036,000	35	7	1,228,381,585	16.2	0.042	0.065

Table 4.27 Vjosa river cascade financial results in Wet condition

	Power	Power generation	Specific investment	Investment	Profit	O&M	Lifetime	Interest	NPV	Payback	Electricity cost	Selling price
Site	kW	kWh	eur/kW	eur	eur/year	eur/year	Year	%	eur	year	eur/ kWh	eur/ kWh
Pellumbari	22,000	112,159,091	3,000	66,000,000	7,290,341	1,980,000	35	7	107,702,740	12.4	0.034	0.065
Kaludh	18,000	114,693,882	3,000	54,000,000	7,455,102	1,620,000	35	7	136,867,833	9.3	0.027	0.065
Vjosa I	10,200	51,000,000	3,000	30,600,000	3,315,000	918,000	35	7	47,806,542	12.8	0.038	0.065
Vjosa II	32,800	196,000,000	3,000	98,400,000	12,740,000	2,952,000	35	7	221,768,224	10.1	0.032	0.065
Vjosa III	24,600	174,000,000	3,000	73,800,000	11,310,000	2,214,000	35	7	223,732,710	8.1	0.027	0.065
Dragot	44,000	232,503,679	3,000	132,000,000	15,112,739	3,960,000	35	7	232,809,224	11.8	0.033	0.065
Drino	15,000	76,030,660	3,000	45,000,000	4,941,993	1,350,000	35	7	72,495,095	12.5	0.034	0.065
Memaliaj	29,500	155,133,334	3,000	88,500,000	10,083,667	2,655,000	35	7	154,493,771	11.9	0.033	0.065
Kalivac bis	10,200	53,922,163	3,000	30,600,000	3,504,941	918,000	35	7	54,019,553	11.8	0.033	0.065
Dorza	85,000	437,275,663	3,000	255,000,000	28,422,918	7,650,000	35	7	424,487,976	12.3	0.034	0.065
Drizar I	36,000	178,610,143	3,000	108,000,000	11,609,659	3,240,000	35	7	165,773,902	12.9	0.035	0.065
Drizar II	36,000	179,274,200	3,000	108,000,000	11,652,823	3,240,000	35	7	167,185,799	12.8	0.039	0.065
Gjonca	37,100	171,838,066	3,000	111,300,000	11,169,474	3,339,000	35	7	144,837,011	14.2	0.035	0.065
Total	400,400	2,132,440,883	3,000	1,201,200,000	138,608,657	36,036,000	35	7	2,153,980,381	11.7	0.033	0.065

Using Retscreen Clean Energy Project Analysis Software, it is calculated the electricity production cost and IRR for each plant. The cashflow and NPV risk analysis are shown in the figures of Annex 10.10.- Cashflow and NPV risk analysis.

5 Climate change impacts

On the effect of future climate change factors it is determined the impacts in the discharge water flows and the power generation of the proposed hydropower plants in Vjosa river on 2050 year.

5.1 Climate change factors

To estimate of the discharge water flows on 2050 (i.e. in the end of plants lifetimes) is proceeded as follow:

- for each site, the module is validated using the hydrology and meteorology data from the actual measurement issued by GAISMA website source and the average observed data of Kaludh, Dragot and Dorza gauged sites (during the period 1950-1985) issued by AKBN (or Pano N. 2008).

- based on the data issued by GAISMA (Annex 10.4), it is processed to decrease the precipitation by 40%, to increase the air temperature by 2^{o}C and the solar radiation by 20%.

As a result, the uncertain input data of the clime changes scenario are in the below tables:

Table 5.1 - Permet observed meteorological data (2011)
(source: www.gaisma.com/en/dir/al-country.html)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation mm	142	129	104	82	72	42	29	33	61	122	182	189
Temperature ^{o}C	2.62	3.53	6.81	11.37	16.95	21.17	24.32	24.23	19.59	14.36	8.38	3.62
Radiation w/m^2/day	1950	2570	3650	4470	5740	6720	6940	6070	4450	3020	1960	1580

Table 5.2 - Permet estimated uncertain meteorological data (2050)
(source: www.gaisma.com/en/dir/al-country.html)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation mm	85.2	77.4	62.4	49.2	43.2	25.2	17.4	19.8	36.6	73.2	109.2	113.4
Temperature °C	4.62	5.53	8.81	13.37	18.95	23.17	26.32	26.23	21.59	16.36	10.38	5.62
Radiation w/m^2/day	2340	3084	4380	5364	6888	8064	8328	7284	5340	3624	2352	1896

Table 5.3 - Tepelene observed meteorological data (2011)

(source: www.gaisma.com/en/dir/al-country.html)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation mm	164	147	117	89	72	41	28	35	68	138	207	214
Temperature °C	2.62	3.53	6.81	11.37	16.95	21.17	24.32	24.23	19.59	14.36	8.38	3.62
Radiation w/m^2/day	1950	2570	3650	4470	5740	6720	6940	6070	4450	3020	1960	1580

Table 5.4 - Tepelene estimated uncertain meteorological data (2050)

(source: www.gaisma.com/en/dir/al-country.html)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation mm	98.4	88.2	70.2	53.4	43.2	24.6	16.8	21.0	40.8	82.8	124.2	128.4
Temperature °C	4.62	5.53	8.81	13.37	18.95	23.17	26.32	26.23	21.59	16.36	10.38	5.62
Radiation w/m^2/day	2340	3084	4380	5364	6888	8064	8328	7284	5340	3624	2352	1896

Table 5.5 - Gjirokaster observed meteorological data (2011)

(source: www.gaisma.com/en/dir/al-country.html)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation mm	172	155	121	90	70	39	26	34	70	144	216	225
Temperature °C	2.62	3.53	6.81	11.37	16.95	21.17	24.32	24.23	19.59	14.36	8.38	3.62
Radiation w/m^2/day	1950	2570	3650	4470	5740	6720	6940	6070	4450	3020	1960	1580

Table 5.6 - Gjirokaster estimated uncertain meteorological data (2050)

(source: www.gaisma.com/en/dir/al-country.html)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation mm	103	93	73	54	42	23	16	20	42	86	130	135
Temperature °C	4.62	5.53	8.81	13.37	18.95	23.17	26.32	26.23	21.59	16.36	10.38	5.62
Radiation w/m^2/day	2340	3084	4380	5364	6888	8064	8328	7284	5340	3624	2352	1896

The observed discharge flows at Kaludh, Dragot and Dorza sites (Tables 4.2, 4.4, 4.6, 4.8) are used as the reference discharge water flows (Q Ref).

5.2 Discharge flows

The discharge water flows are calculated using the validated models of the sites with the input data that are impacted by the climate change factors: i.e the precipitation decreased by 40%, the air temperature increased by 2^{o}C and the solar radiation increased by 20%. The 2050 scenario of the potential discharge flows in Vjosa river that are impacted by the climate change factors, is shown in Table 5.7.

Table 5.7 – Uncertain average annual discharge flow in Vjosa river sites on 2050

Ac km^2	2250	2300	2420	2720	2730	2800	3400	4800	5000	5420	5500	5520	5640	1300
Site	Pellumbari	Kaludh	Petran	Badelonja	Permeti	Kosina	Dragot	Memaliaj	Kalivac bis	Dorze	Drizar I	Drizar II	Gjonca	Drino
Oct	22.1	22.6	23.6	26.3	26.4	27.0	31.4	40.6	42.1	43.5	43.2	43.3	44.2	7.8
Nov	48.5	49.6	52.3	59.0	59.2	60.8	74.5	99.9	104.2	101.5	104.0	104.4	106.8	32.0
Dec	63.2	64.7	68.4	77.9	78.2	80.4	106.2	145.5	152.3	157.2	164.0	164.6	168.7	38.2
Jan	64.2	65.8	69.6	79.2	79.5	81.8	101.1	138.7	145.2	153.8	160.7	161.4	165.4	49.4
Feb	55.2	56.5	59.7	67.5	67.8	69.6	90.6	122.6	128.1	130.2	134.5	135.0	138.2	36.6
Mar	54.5	55.8	58.8	66.5	66.7	68.5	85.5	115.0	120.0	105.3	108.3	108.7	111.2	30.6
Apr	68.9	70.4	74.1	68.3	83.7	85.8	110.0	146.2	152.4	144.6	147.1	147.7	150.9	26.4
May	44.0	45.0	47.2	52.9	53.1	54.4	69.0	90.3	93.9	109.4	110.0	110.4	112.7	16.8
Jun	23.6	24.1	25.3	28.2	28.3	29.0	33.0	42.7	44.3	48.0	47.8	48.0	48.9	7.9
Jul	13.5	13.8	14.4	15.9	15.9	16.3	18.2	22.9	23.7	27.7	26.9	27.0	27.5	5.2
Aug	10.3	10.4	10.9	11.9	12.0	12.2	13.9	17.1	17.7	18.6	17.8	17.8	18.1	3.9
Sep	12.7	12.9	13.4	14.8	14.8	15.1	17.7	22.0	22.7	21.4	20.6	20.7	21.0	4.7
Q_{mean} m^3/s	40.1	41.0	43.1	47.4	48.8	50.1	62.6	83.6	87.2	88.4	90.4	90.7	92.8	21.6
H (m)	25	20	9 + 5	4 x 10		3 x 10	30	15	5	40	16	16	15	30

Comparing these results with discharge water flows data in Table 4.12, it is found the reduction of the flows in percent (%). This is shown in Table 5.8.

Table 5.8 – Uncertain reduction of discharge flow in Vjosa river sites on 2050 (%)

Ac km^2	2250	2300	2420	2720	2730	2800	3400	4800	5000	5420	5500	5520	5640	1300
Site	Pellumbari	Kaludh	Petran	Badelonja	Permeti	Kosina	Dragot	Memaliaj	Kalivac bis	Dorze	Drizar I	Drizar II	Gjonca	Drino
Oct	39	39	39	39	39	39	42	42	42	42	42	42	44	41
Nov	35	35	35	35	35	35	41	41	41	40	40	40	44	41
Dec	34	34	34	34	34	34	42	42	42	41	41	41	46	43
Jan	34	34	34	33	33	33	42	42	42	42	41	41	46	43
Feb	35	35	35	35	35	35	41	41	41	41	40	40	44	42
Mar	35	35	35	35	35	35	41	41	41	41	40	40	44	41
Apr	36	36	36	48	36	36	41	41	41	41	41	41	43	41
May	37	37	37	37	37	38	41	41	41	41	41	41	43	40
Jun	38	38	38	38	38	38	41	42	42	42	42	42	44	41
Jul	42	42	42	42	42	42	44	44	44	44	45	45	46	42
Aug	44	44	44	44	44	44	46	46	46	46	47	47	48	44
Sep	43	43	43	43	44	44	44	45	45	45	46	46	47	43
Q_{mean} m^3/s	**36**	**38**	**38**	**39**	**38**	**38**	**42**	**42**	**42**	**42**	**42**	**42**	**45**	**42**

5.3 Power generation

The following Table 5.9 shows the uncertain average annual power generation (assuming the operation time 4500 hrs/year or 50% certain) on 2050 year with the reduction of the discharge water flow by the climate changes as well as the difference in percent.

Table 5.9 Uncertain annual power generation 2050

Site	2011	2050	Difference %
Pellumbari	106,944,794	68,341,705	36
Kaludh	109,359,342	69,894,498	36
Vjosa I	49,000,000	42,145,000	14
Vjosa II	164,000,000	134,209,000	18
Vjosa III	123,000,000	104,845,000	15
Dragot	218,847,204	128,173,010	41
Drino	76,300,065	44,278,079	42
Memaliaj	145,952,234	85,630,513	41
Kalivac bis	50,727,717	29,769,622	41
Dorza	411,454,258	241,439,363	41
Drizar I	167,996,139	98,736,482	41
Drizar II	168,619,893	99,105,159	41
Gjonca	161,197,341	95,006,898	41
Total	1,953,398,987	1,241,574,328	36

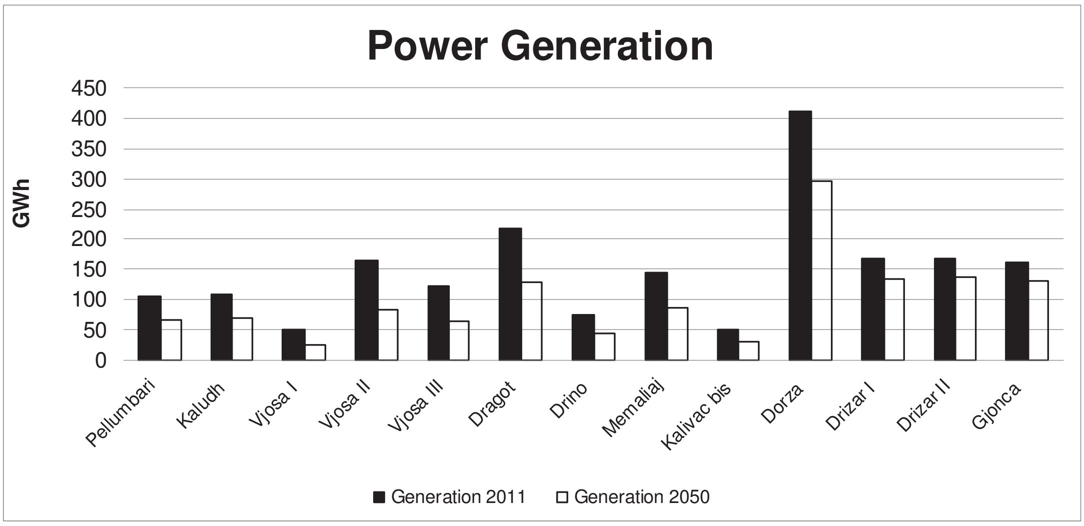

Figure 5.1 – Annual power generation scenarion on 2011 and 2050

The power generation scenario on 2011 and 2050 are shown in Figure 5.1.

Using Palisade @Risk Industrial 5.7 software (evaluation version), a simple Montecarlo simulation result is shown in Figure 5.2. The uncertainty bounds of the power generation on 2050 (with operation time 4500 hrs/year) are: 1,037,000,000 kWh (or 95% certain) and 1,446,000,000 kWh (or 5% certain). The upper bound is near the lower one of the power generation predicted on 2011 year scenario.

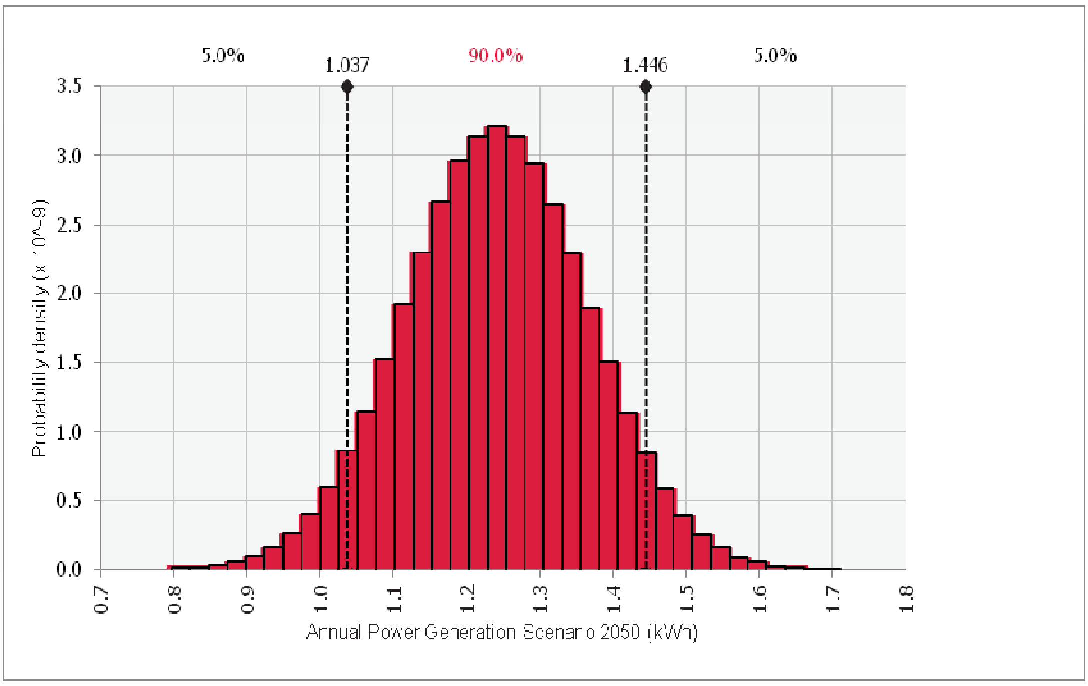

Figure 5.2 - Montecarlo simulation of the power generation scenario on 2050

6 Results and discussions

This study contains the assessment of the potential hydro energetic of the river in Albania with the discharge flow estimation module (DFEM). The module simulates the monthly discharge water flows in a catchment outlet using the monthly meteorological data and the other catchment quantities as the input data.

The module is a lumped and deterministic rainfall - runoff model that is developed based on the water balance equations. The input data (or variables) of the model are: the monthly precipitation P_m, the air temperature T_a and the real solar radiation R_a, 10year/24h return period, (events -e_m and intensity -i are calculated by IMP 5.0 software), the catchment area A_c and its altitude H (m), ^oC/100m temperature lapse rate, q_{ref} specific discharge flow (in l/s/km^2), the constant coefficient n = 0.55, the snow coverage altitude h_s (m) and the snow coverage area S_m(%) (for five months: November, December, January, February and March).

The data output from the model are: the simulated monthly discharge water flow at the catchment outlet (Q_m), the monthly specific discharge (q_m), the annual precipitation (P), the annual deficit (D), the annual runoff (R), the runoff area (A_r), the length (L), the slope (S), the curve number (CN) with Antecedent Moisture Condition Class II, the runoff coefficient (C_o) infiltration coefficient (C_{inf}), the time concentration (T_c) and $Q_{max} = C_o * A_r * i_{max}$ (not in the scope of the study).

The monthly runoff discharge flow Q_{rm} is the function of the monthly effective rainfall R_m. The effective rainfall is a product of the monthly precipitation P_m with the constant propocionality e_m/E (the ration of monthy event quantity e_m with the total annual event quantity E) and it presents the sum of the surface and groundwater at the outlet of the catchment area:

$$Q_{rm} = A_m * R_m^{k_m}$$

where the parameter A_m presents physically the discharge flow per day at the outlet of the catchment and it is calculated by $A_m = (A_r * q_m) / T_c$.

There are some pre-conditions:

- the catchment area is approximated like a circle and the river length (L km) presents the its radius i.e. L=SQRT(A_r/3.14).
- In CN formula calculation, the retention S value (mm) is considered the double quantity of the October deficit (D_m). The deficit is calculated as the product of the monthly actual evapotranspiration ET_o with the constant propocionality e_m/E (the ration of monthy event quantity e_m with the total annual event quantity E).
- k_m constant (recession coefficient in snowmelting formula) should be a constant value (0.5-0.8) or the ratio of $\log A_m/\log R_{annual}$

The snowmelting is considering by the second term:

$$Q_{sm} = 1.1 * a * (T - T_o) * A_s * (1 - k) + Q_{sm}-1 * k * 1000/86400$$

The total discharge flow with snowmelt in the outlet is the sum of:

$$Q = Q_{rm} + Q_{sm}$$

Based on the above structure, the procedural DFEM module is built in MS Excel format, very simple and popular for the users. DFEM User interface and the module intermediate variables data are shown in Annex 10.1.

For the module application is chosen Dorza catchment area (N40°23’53”, E19°48’06”) at the downstream of Vjosa river, where ten years data (1965-1975) are used for model calibration and ten years data (1976-1986) for its validation. A continuous observed records of discharge water flows from 1948-1990 (Tables A.10.4.1 and A.10.4.21) are available fo this site and issued by AKBN.

The meteorological data of Tepelena region are issued by Institute of Energy, Water and Environment of Albania (IEWE). The air temperature data are issued by GAISMA website considering the fact that during on 1965-1975 the temperature is decreased by 0.6°C and after 1975 it is increased by 1.2°C. So, the value of 1.8°C is substracted from the available data issued by this website. The solar radiation data are issued by GAISMA website data also.

The DFEM module is applied only for the ten years period on 1965-1975, where the discharge water flows and goodness on fit resuts are given in the Table 3.4. The correlation coefficient between the simulated and the observed data is on the range of R^2=79%. Also, the module is applied for the ten years period of 1976-1986, where the results are in Table 3.8 and the correlation coefficient R^2=85%.

In the next steps, the module application on 1965-1975 is calibrated with the observed discharge flows using the Goal Seek tool in MS Excel. The monthly calibration constants C_m are calculated (Table 3.9) and they are applied to the module for the period on 1976-1986. The results are given in Table 3.10 and the mean discharge flow is 116.2m^3/s (compared to 129.5m^3/s of the observed data) with the Mass error 10%, Nash efficiency 0.8, Shulz criteria 0 and the linear correlation coefficient R^2 = 92%. The module has calculated the curve number CN (Table 3.11) in normal (83), dry (67) and wet (91) conditions.

But, in the above applications, it is not considered the snowfalls because there are not available in the observed snowdepth or snow coverage area data. In this condition, the module with snowmelt is applied for each of mentioned periods filling the input data cells of the coverage area as below:

- 1965-1975 Nov 10%; Dec 20%; Jan 30%; Feb 30%; Mar 20%.
- 1976-1986 Nov 10%; Dec 20%; Jan 30%; Feb 30%; Mar 20%.

The results data are given in Tables 3.12 and 3.13.

For discussion, April and May snow coverage data cells (%) should be included also in the module input data/

After the calibration of the module with the snow coverage data of 1965-1975, there are calculated the monthly calibration constants C_m (Table 3.14) and are applied to the validation period on 1976-1986. The results are shown in Table 3.15, and the mean discharge flow is estimated 118.3m^3/s (compared to 129.5m^3/s of the observed data), the Mass error 9%, Nash efficiency 0.8, Shulz criteria 0 and the linear correlation coefficient R^2 = 93%.

To predict the discharge water flows on 2011 year, the DFEM module is applied for the long time period 1960-1990. The meteorological input data and the observed discharge water flows during on 1960-1990, are issued by Institute of Energy, Water and Environment of Albania and GAISMA website (http://www.gaisma.com/en/dir/al-country.html).

Also, the project study with title “Les resources en eau de l’Albanie” prepared and published by Selenica A. and Morell M. on December 2000, (part of MEDHYCOS Project), has covered the long time period on 1960-2000 of Dorza hydro meteorological data. The module application with the input data of this study is explained in detail in Annex 10.2 – Dorza site.

After the calibration with the data of time period 1960-1990, the module is validated on 2011 year and it is calculated the predicted discharge water flows using GAISMA website input data (Table 3.24). The “goodness on fit” tests are very good and the linear correlation coefficient between the observed and simulated discharge flows is calculated $R^2 = 0.94$. (Figure 3.16).

Further, the module is applied for the long term on 2050 year to predict the uncertain discharge water flows (Table 3.28) when the precipitation should be decrease 40%, air temperature should be increase 2°C and the real solar radiation should be increased 20% of the actual meteorological values issued by GAISMA (http://www.gaisma.com). The “goodness on fit” tests are good and the linear correlation coefficient between the observed and simulated discharge water flows is calculated $R^2=0.99$. (Figure 3.18). It is shown the reduction of the uncertain discharge flows on 2050 is estimated 42% i.e. the discharge water flows reduction is proportionally with the reduction of the precipitation.

A simple method is applied for the calculation and the preparation of the flow duration curve FDC. It is considered the predicted discharge flows on 2011 year, where the monthly discharge water flow module is validated (Table 3.24). The discharge design (Q_{design}) is defined where the curve cuts the Y-axis (Figure 3.21). The X-axis presents the month-days (in percent) i.e 0% presents 30 days of year, 10% presents 60days, etc.

Finally, to demostrate the module application in the other river catchment areas in Albania, the DFEM module is applied in Ndroq site catchment area (N40°23’53”, E19°48’06”) at Erzeni river, in the Middle of Albania territory. The hydro meteorological data are issued by Institute of Energy, Water and Environment and the websites of GAISMA and UNESCO. The module is applied for the periods:

- fifteen years period on 1960-1975, where the mean discharge flow is 15.8m^3/s (compared to 14.5m^3/s of the observed data), the Mass error 9%, Nash efficiency 0.7, Shulz criteria 0 (Table 3.35) and the linear correlation coefficient R^2=89%. (Figure 3.23).

- ten years period of 1976-1985, where the mean discharge flow is 15.2m^3/s (compared to 13.8m^3/s of the observed data), the Mass error 11%, Nash efficiency 0.9, Shulz criteria 0 (Table 3.39) and the linear correlation coefficient R^2=95%. (Figure 3.24).

Using the period on 1960-1975, the module is calibrated (Table 3.40) and it is applied for validation on 1976-1985, where the mean discharge water flow is 14.5m^3/s (compared to 14.5m^3/s of the observed data), the Mass error 0%, Nash efficiency 0.9, Shulz criteria 0 (Table 3.41) and the linear correlation coefficient R^2=99%. (Figure 3.26).

In Annex 10.3 - Ndroq site, it is described the module application with the data from the study study “Les resources en eau de l’Albanie” by Selenica A. and Morell M. on December 2000, (part of MEDHYCOS Project) where the prediction of the discharge water flows on 2011 year, is shown in Table A.10.3.9. In this case, the “goodess on fit” test are good and the module is performed very well.

The DFEM module application is chosen for the assessment of the potential hydro energetic of a river in Albania such as Vjosa river that is the second after Drin river, but it is not generate the electricity yet. The building of the new hydropower plants in cascade shall increase the renewable energy production and the reduction of the import of the electricity. It shall increase the sustainability of the Albanian Electricity Energy System reducing of the electricity transmission and distribution losses. In the past, there are some studies for the assessment of the potential hydro energetic of Vjosa river, but their conceptual designs were based on the hydropower plants with reservoirs scheme and high dams, causing impacts in the environment and the social effects.

In this study, Vjosa river assessment is done determining the hydropower plants capacities and the electricity generations in Vjosa river longitudinal profiles based on the discharge water flows, calculated by DFEM module at the gauged or ungauged outlets of the sites catchment areas. The long time data issued by Institute of Energy, Water and Environment of Albania and AKBN (the observed discharge flows, the precipitation, the air temperature and the solar radiation), are used for the calibration of the module during on 1950-1985 at the gauged reference sites: at upperstream (Kaludh), at middlestream (Dragot) and at downstream (Dorza). Considering the actual measure meteorological data issued by GAISMA websites, it is calculated the monthly discharge water flows for each proposed sites. The results are given in the Table 4.12.

For the calculation of the monthly power generation for each plant, it is estimated the power produced by $1m^3/s$ (or the efficiency) using the formula:

$$e_{ff} = 9.8 * \eta * 1m^3/s * H \qquad (kW)$$

The monthly power capacity under operation is calculated by:

$$P_m = e_{ff} * Q_m \qquad (kW)$$

and the monthly power generation is:

$$E_m = P_m * 30day * 24hrs \qquad (kWh)$$

where it is defined the design flows and the power capacity.

The power generation is calculated for normal, dry and wet conditions based on the curve number CN values estimated by module. In Table 4.23 and 4.24 are shown Vjosa river cascade hydropower plants capacities and their power generations.

The object for discussion is the detemination of the monthly rainfall events and the estimation of the curve number using the other metodology or input data.

The financial analysis is done for the performance and the feasibility of the proposed plants, the paybacks and the electricity production costs. The economic efficiency (W) is estimated by: $W = - I + T * (A – K) / q > 0$

Vjosa river cascade financial results (in normal condition) are given in Table 4.25.

Financially, the estimated results show that all the plants are efficient (NPV >0), the average payback is 13.5 years with IRR 7%, the total investment of the cascade is 1,2 mld euro, the total annual profit is 110 - 140 mln euro/year, O&M cost is around 36 mln euro and the cascade electricity production cost is 36 euro/MWh.

Finally, the effect of future climate change factors to the discharge water flows on 2050 year (i.e. the end of plants lifetimes) is estimated for each site, where the DFEM module is validated using the hydrology and the meteorology data from the actual measurement issued by GAISMA website source (Annex 10.4) and the observed data of Kaludh, Dragot and Dorza gauged sites during on 1950-1985 (AKBN source). Further, these data issued by GAISMA are processed decreasing the precipitation by 40%, increasing the air temperature by 2^{o}C and the solar radiation by 20%.

As result, the uncertain average annual discharge water flows of Vjosa river cascade on 2050 year, under the climate change scenarios (Tables from 5.1-5.6), are given in the Table 5.7. The cascade power generation on 2050 is shown in Table 5.9. It seems that under the discharge flows changes, the plants with high dams (Dragot 30m or Dorza 40m) are more sensitive than the low dams.

The DFEM module application should be applied with the hydro meteorological data published by FAO (using the new tool of LocClim 1.0 software) or SamSamWater website (www.samsamwater.com). In both cases, there are availabe to get the long term of the monthly precipitation and the potential evapotraspiration data during 1960-1990.

The DFEM module user interface (Figure A.10.13.2 in Annex 10.13) should be addopted to the monthly evapotranspiration input data instead of the temperature and solar radiation data (that need to calculate the actual evapotranspiration Eto). In this case, the monthly actual evapotranspiration is calculated:

$Eto = Kc * Etp$ Kc – crop coefficient with value of 0.5

The curve number (CN II) is defined:

$CN = 25400/(D_{oct}+254)$ D_{oct} is the deficit (mm) during October

The DFEM module user interface, FAO LocClim software and SamSamWater website are shown in Annex 10.13, where Kaludh, Dragot and Dorza discharge water flows (on 2011) are calculated also. The results shown that the “goodness of fit” tests are estimated as good.

For discussion, DFEM module should be tested for the river catchment area less than 500km^2.

The configuration with the power capacity and the power generation of Vjosa river cascade is shown in the schematic diagram of the Figure 5.2- Vjosa river cascade potential hydroenergetic assessment.

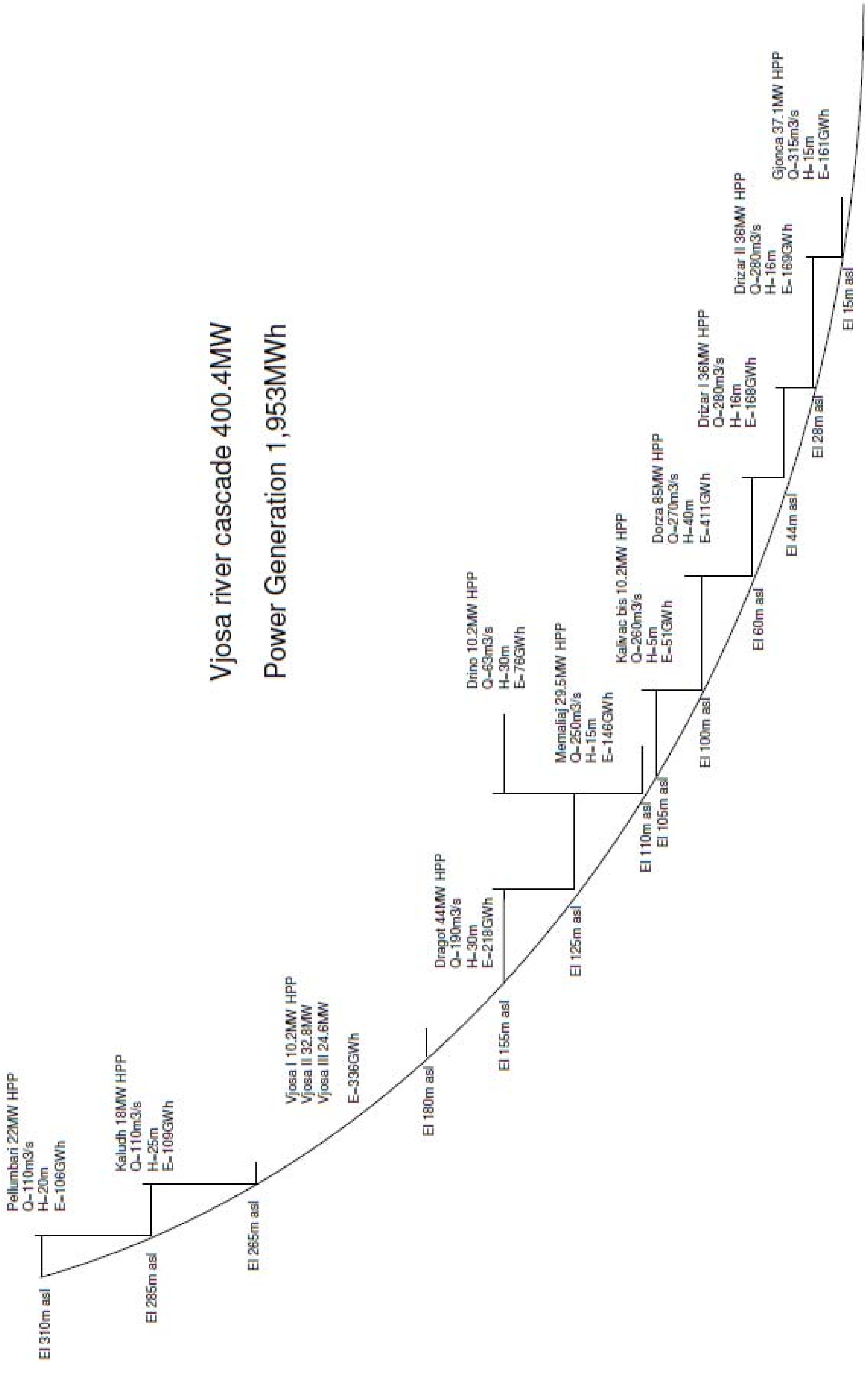

Figure 5.2- Vjosa river cascade potential hydroenergetic assessment

7 Conclusions

Considering the results of this study, it is concluded as follows:

- A discharge flow estimation module has been designed which is user friendly and it has the moderate quantity of the input data (or parameters) to be calculated or estimated. The module has a good performance over the catchments areas located in Albania (Vjosa and Erzeni rivers in this study) and under the climatic change factors.

- The rainfall-runoff modeling of the module is lumped and deterministic type with a good efficiency compared with the observed data at the chosen sites. A tipical parameter is introduced in the study: the discharge flow per day at the outlet of the catchment area.

- The methodology and the module structure are performed well in the chosen catchment areas. Using the long term of the observed data for the calibration and the validation of DFEM module, the statistical measures data have good peformance. The modeling structure and the DFEM module should be used for the others rivers catchments areas in Albania.

- In normal condition, the potential hydro energetic of Vjosa river cascade, with runoff hydropower plants and low dams, is assessed with a total capacity of 400.4MW and the annual power generation of 1,953GWh assumed the operation time 4500 hours (or 50% of the certain). The uncertainty bounds of the power generation on 2011 are: 1,697,104,306 kWh in dry condition (or 95% certain) and 2,132,440,883 kWh in wet condition (or 5% certain).

- The reduction of the discharge flows, as a result of the effect of future climate change factors (precipitation decrease 40%, temperature increase 2^{o}C and radiation increase 20%), is from 36% in upperstream area (hillslope catchment) up to 45% in the downstream are (footslope catchment). The uncertain average annual power generation on 2050 year is estimated

1,241,574,328 kWh or the reduction is about 36% compared with power production on 2011 year. The uncertainty bounds on 2050 year (operation time 4500 hrs/year) are: in dry condition 1,037,000,000 kWh (or 95% certain) and in wet condition 1,446,000,000 kWh (or 5% certain). The upper bound of the uncertanty is near the lower limit one of the power generation predicted on 2011 scenario.

- The building and the implementation of the hydropower plants with low dams (≤30m) installing the distributed TG units (the installation of the defined numbers of the TG units with small capacity) should be considered an advantage.

- The DFEM module should be applied to predict the discharge water flow at a specific river's site using the hydro and meteorological databases prepared by the international institutions and organizations (FAO website et all) reducing the time and the cost of the feasibility study and the potential hydro energetic assessment of the river in the different catchment area in Albania.

8 Acknowledgements

I would like to express my gratitude to the committee Univ.Prof.Dipl.Ing.Dr. Mr. Reinhard Haas, Dipl.Ing. Mrs Andreas Würz and Dipl.Ing. Mr. Ralph Roggenbauer, who created the opportunity to realize my graduation in the renewable energy sources and the energy efficiency programs of Vienna University of Technology. Also, I would like to express my high appreciation to Univ.Prof.Dipl.Ing.Dr.techn. Mr. Günter Blöschl for the consulting and the successful cooperation during the preparation and the realization of this MSc Thesis. Of course, a very special thank you to my daughter Anja and my wife Doli that supported and encouraged me all the time.

Sincerely, Thank You All.

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10 Annexes

10.1 DFEM User interface

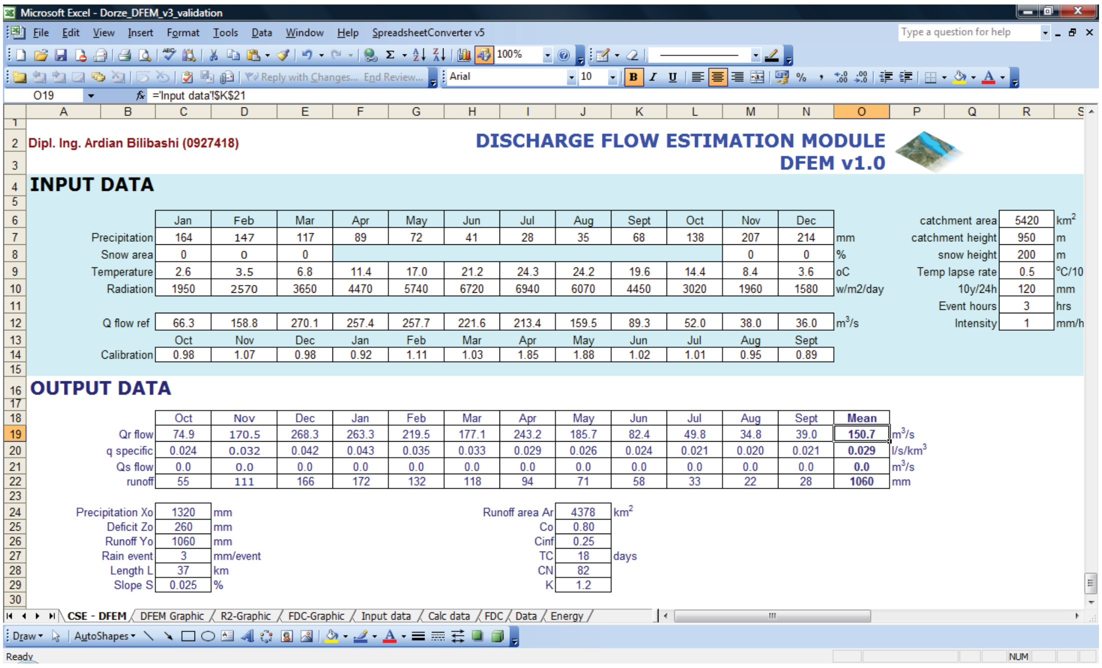


Figure A.10.1- DFEM User interface with Dorza discharge flows on 2011

Table A.10.1- Q-DFEM module variables data for Dorza site validation on 2011

Runoff mm / Tc - 30days			q	b	A	K	Cal	Q
Oct	55	111	0.024	-0.005	5.9202	0.64	0.98	74.9
Nov	111	166	0.032	-0.010	7.8640	0.64	1.07	170.5
Dec	166	172	0.042	-0.016	10.4038	0.64	0.98	268.3
Jan	172	132	0.043	-0.016	10.7034	0.64	0.92	263.3
Feb	132	118	0.035	-0.012	8.7387	0.64	1.11	219.5
Mar	118	94	0.033	-0.011	8.1564	0.64	1.03	177.1
Apr	94	71	0.029	-0.009	7.2219	0.64	1.85	243.2
May	71	58	0.026	-0.007	6.4466	0.64	1.88	185.7
Jun	58	33	0.024	-0.005	6.0171	0.64	1.02	82.4
Jul	33	22	0.021	-0.003	5.3061	0.64	1.01	49.8
Aug	22	28	0.020	-0.002	5.0336	0.64	0.95	34.8
Sep	28	55	0.021	-0.003	5.1785	0.64	0.89	39.0
Mean	1060	1060	0.029	-0.01	7.2492	0.64	1.14	150.7

10.2 Dorza site

The study “Les resources en eau de l’Albanie” by Selenica A. and Morell M. on December 2000, (part of MEDHYCOS Project), has covered the entire time period 1960-2000 of Dorza hydro meteorological data.

The meteorological input data and the observed discharge water flows on 1950-2000, are given Tables A.10.2.1 and A.10.2.2.

Table A.10.2.1 Meteorological data of Tepelena region during the period 1950-2000 (source; Selenica A. Morell M. 2000, “Les resources en eau de l’Albanie” “)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation Mm	189	156	115	91	82	40	34	27	77	128	220	199
Snow area %	0	0	0								0	0
Temperature °C	6.3	7.6	9.9	13.3	17.5	21.5	24.1	24.3	21.1	16.2	11.4	7.8
Radiation w/m²/day	1950	2570	3650	4470	5740	6720	6940	6070	4450	3020	1960	1580

Table A.10.2.2 Dorza observed discharge flows during the period 1950-2000 (source; Selenica A. Morell M. 2000, “Les resources en eau de l’Albanie” “)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Q flow ref m3/s	65	170	285	280	259	223	224	167	92	54	38	37

The module results (output data) are shown in Table A. 10.2.3, as follows:

Table A.10.2.3 DFEM discharge flow at Dorza site on 1950-2000

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m³/s	82.1	138.7	281.3	243.0	226.0	175.6	123.1	96.5	87.2	46.8	41.2	34.6	131.3
q specific l/s/km²	0.024	0.030	0.043	0.039	0.038	0.033	0.028	0.026	0.025	0.021	0.021	0.020	0.029
Qs flow m³/s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Runoff Mm	61	101	174	157	149	123	91	72	65	32	27	21	1072

Precipitation (P)	1358	mm
Deficit (D)	286	mm
Runoff (R)	1072	mm
Rain event	3	mm/event
Length (L)	37	km
Slope (S)	0.026	%
Runoff area (Ar)	4298	km²
Co	0.79	

Cinf	0.27	
TC	17	days
CN	83	
K	1.3	

The goodness on fit tests to examine the efficiency and the performance of the module are shown in Table A. 10.2.4:

Table A.10.2.4 Discharge flow and the goodness on fit data for Dorza site on 1950-2000

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	82.1	65	-26	1.0	0
Nov	138.7	170	18	0.0	0
Dec	281.3	285	1	1.0	0
Jan	243.0	280	13	0.9	0
Feb	226.0	259	13	0.9	0
Mar	175.6	223	21	0.5	0
Apr	123.1	224	45	0.0	0
May	96.5	167	42	0.0	0
Jun	87.2	92	5	1.0	0
Jul	46.8	54	13	1.0	0
Aug	41.2	38	-8	1.0	0
Sep	34.6	37	6	1.0	0
Mean	131.3	157.8	17	0.7	0

The observed and DFEM discharge water flows at Dorza site on 1950-2000, are presented in Figure A.10.2.1.

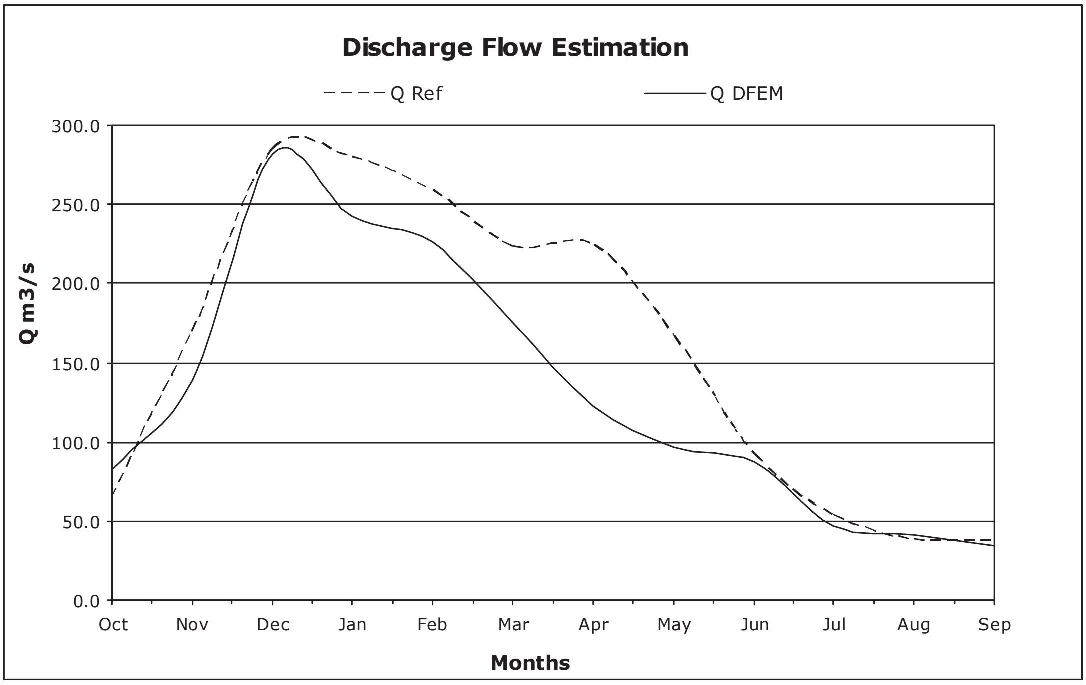


Figure A.10.2.1- Dorza observed and Q-DFEM discharge flows on 1950-2000

The linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.88 and it is demonstrated in Figure A.10.2.2.

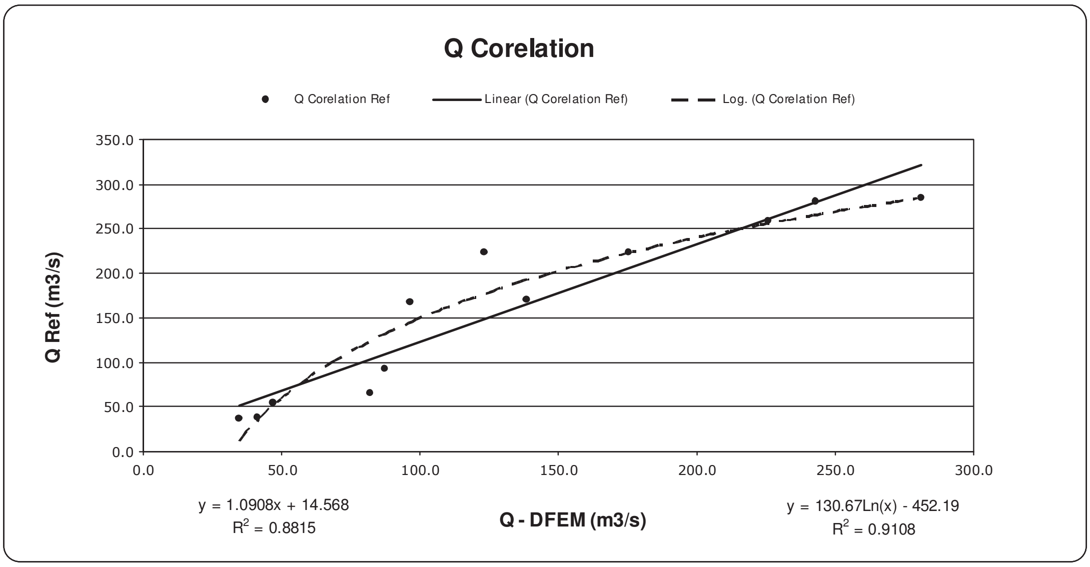


Figure A.10.2.2- The correlation R^2 between the observed and Q-DFEM discharge flows on 1950-2000

The monthly calibration constants C_m is in Table A.10.2.5.

Table A.10.2.5 Calibration constant C for Dorza site on 1950-2000

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Calibration C	0.79	1.23	1.01	1.15	1.15	1.27	1.82	1.73	1.06	1.15	0.92	1.07

The validation is made applying the calibration constants C_m in Q-DFEM module with the input data issued by GAISMA website (Table A.10.4.15).

Table A.10.2.6 Meteorological data of Tepelena region 2011
(source: http://www.gaisma.com/en/dir/al-country.html)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation mm	164	147	117	89	72	41	28	35	68	138	207	214
Snow area %	0	0	0								0	0
Temperature °C	2.6	3.5	6.8	11.4	17.0	21.2	24.3	24.2	19.6	14.4	8.4	3.6
Radiation w/m²/day	1950	2570	3650	4470	5740	6720	6940	6070	4450	3020	1960	1580

Table A.10.2.7 Dorza observed discharge flows during the period 1950-2000
(source: Selenica A. Morell M. 2000 “Les resources en eau de l’Albanie”)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Q flow ref M3/s	65	170	285	280	259	223	224	167	92	54	38	37

The results of the module (output data) are shown in Table A.10.2.8, as follows:

Table A.10.2.8 DFEM discharge flow at Dorza site on 2011

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	59.4	191.8	271.4	324.5	222.3	214.5	235.4	167.9	83.5	56.2	33.4	45.9	158.8
q specific $l/s/km^2$	0.024	0.032	0.042	0.043	0.035	0.033	0.029	0.026	0.024	0.021	0.020	0.021	0.029
Qs flow m^3/s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Runoff Mm	55	111	166	172	132	118	94	71	58	33	22	28	1060

The results data and goodness on fit tests are shown in Table A.10.2.9.

Table A.10.2.9 Discharge flow and the goodness on fit data for Dorza site on 2011

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	59.4	65	9	1.0	0
Nov	191.8	170	-13	0.0	0
Dec	271.4	285	5	1.0	0

Jan	324.5	280	-16	0.9	0
Feb	222.3	259	14	0.9	0
Mar	214.5	223	4	1.0	0
Apr	235.4	224	-5	1.0	0
May	167.9	167	-1	1.0	0
Jun	83.5	92	9	1.0	0
Are Jul	56.2	54	-4	1.0	0
Aug	33.4	38	12	1.0	0
Sep	45.9	37	-24	1.0	0
Mean	**158.8**	**157.8**	**-1**	**0.9**	**0**

The performance and the efficiency are within the goodness on fit criteria.

The DFEM module and the observed discharge flows are shown in Figure A.10.2.3

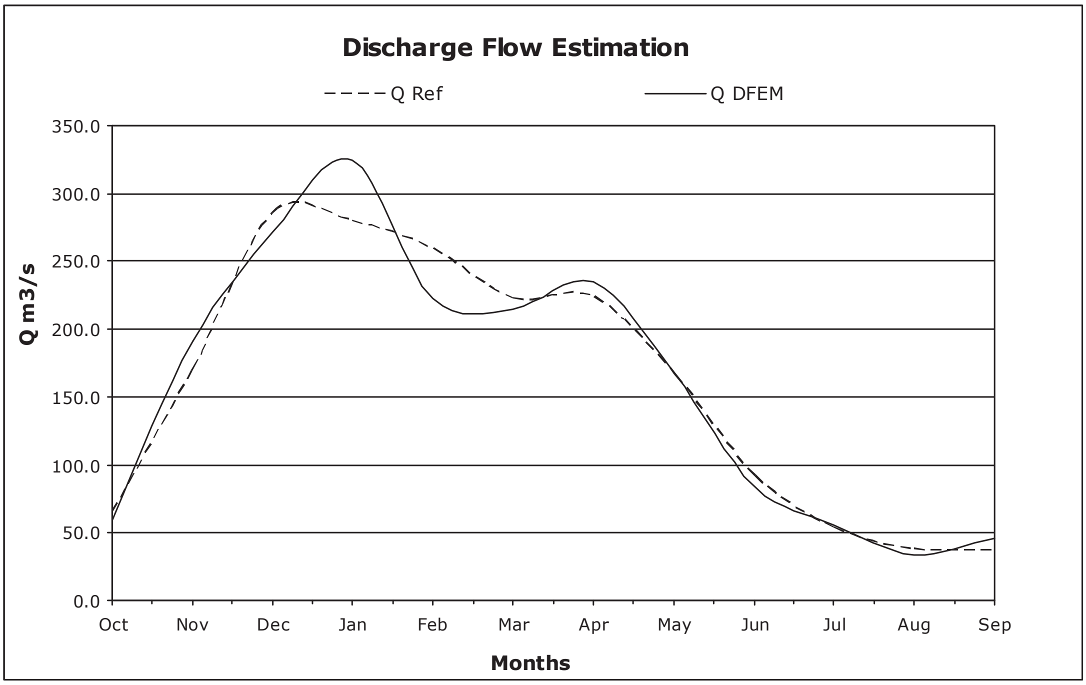


Figure A.10.2.3- Dorza observed and predicted Q-DFEM discharge flows on 2011

The module output data are:

Precipitation (P)	1320	mm
Deficit (D)	260	mm
Runoff (R)	1060	mm
Rain event	3	mm/event
Length (L)	37	km
Slope (S)	0.026	%

Runoff area (Ar)	4298	km^2
Co	0.80	
Cinf	0.25	
TC	17	days
CN	82	
K	1.3	

The linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.95 and it is demonstrated in Figure A.10.2.4.

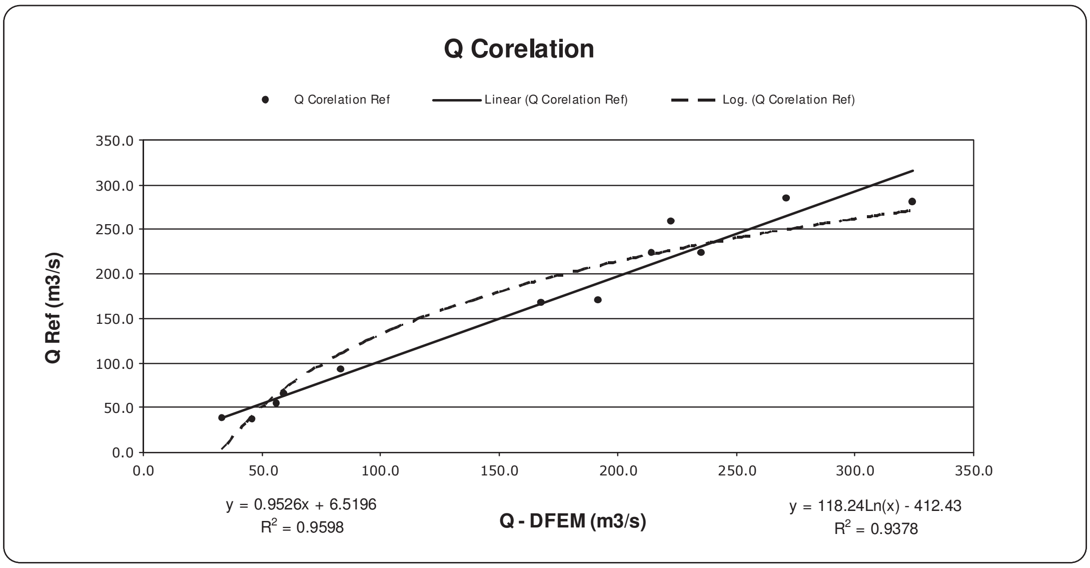


Figure A.10.2.4- The correlation R^2 between observed and validated Q-DFEM discharge flows during 2011.

10.3 Ndroq site

Another application is at Ndroq site of Erzeni river for the period 1950-2000, using the data from the study "Les resources en eau de l'Albanie" by Selenica A. and Morell M. on December 2000, (part of MEDHYCOS Project).

The meteorological input data and observed discharge water flows on 1950-2000, are given Tables A.10.3.1 and A. 10.3.2.

Table A.10.3.1– Meteorological data of Tirana region on 1950-2000
(source: Selenica A. Morell M. 2000 "Les resources en eau de l'Albanie")

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation Mm	143	132	115	105	104	67	42	49	78	116	174	148
Snow area %	0	0	0								0	0
Temperature °C	6.7	7.9	9.9	13.3	17.7	21.6	23.8	23.8	20.6	16.1	11.8	8.2
Radiation $w/m^2/day$	1820	2450	3580	4350	5660	6640	6870	6030	4350	2900	1870	1510

Table A.10.3.2 Ndroq observed discharge flows on 1950-2000
(source: Selenica A. Morell M. 2000 "Les resources en eau de l'Albanie")

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Q flow ref m3/s	6.5	16.8	21.8	25.4	25.3	22.5	18.2	14.2	7.6	3.5	2.6	4.1

The results of the module (output data) are shown in Table A.10.3.3, as follows:

Table A.10.3.3 DFEM discharge flow at Ndroq site on 1950-2000

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	11.4	15.9	24.3	20.3	19.6	18.0	15.8	14.6	14.4	10.2	7.5	8.3	15.0
q specific $l/s/km^2$	0.025	0.029	0.038	0.034	0.033	0.032	0.029	0.028	0.028	0.024	0.022	0.022	0.029
Qs flow m^3/s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Runoff Mm	61	90	135	115	111	103	89	82	81	52	33	38	990

Precipitation (P)	1273	mm
Deficit (D)	283	mm
Runoff (R)	990	mm
Rain event	4.55	mm/event

Length (L)	13	km
Slope (S)	0.037	%
Runoff area (Ar)	521	km^2
Co	0.78	
Cinf	0.29	
TC	7	days
CN	83	
K	1.3	

The goodness on fit tests to examine the efficiency and the performance of the module are shown in Table A.10.3.4:

Table A.10.3.4 Discharge flow and the goodness on fit data for Ndroq site on 1950-2000

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	11.4	6.5	-76	0.6	0
Nov	15.9	16.8	5	0.9	0
Dec	24.3	21.8	-11	0.9	0
Jan	20.3	25.4	20	0.8	0
Feb	19.6	25.3	23	0.7	0
Mar	18.0	22.5	20	0.7	0
Apr	15.8	18.2	13	0.7	0
May	14.6	14.2	-3	0.0	0
Jun	14.4	7.6	-90	0.0	0
Jul	10.2	3.5	-192	0.6	0
Aug	7.5	2.6	-189	0.8	0
Sep	8.3	4.1	-102	0.8	0
Mean	15.0	14.0	-7	0.6	0

The linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.83 and it is demonstrated in Figure A.10.3.2.

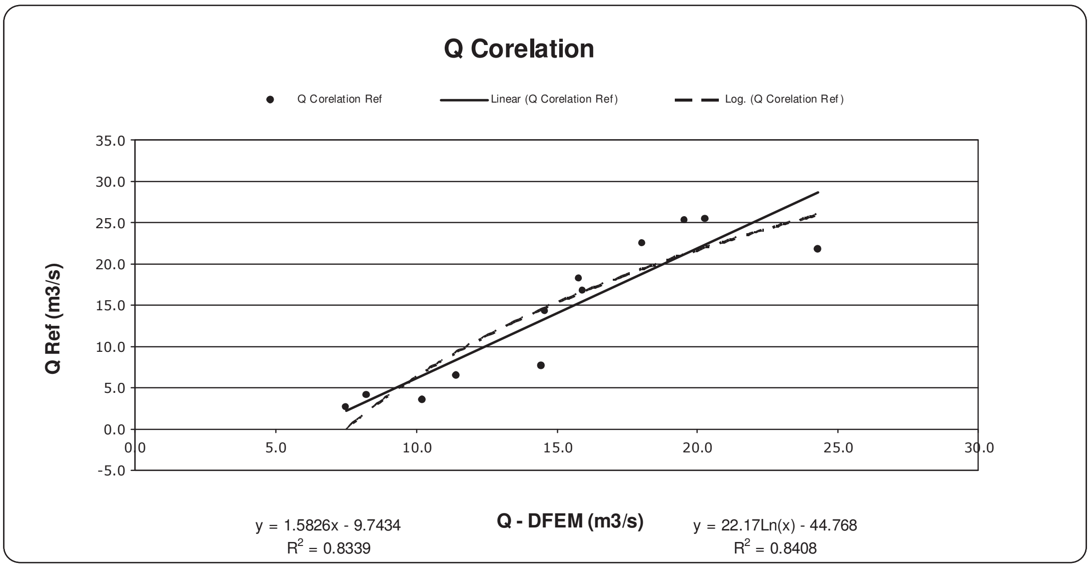


Figure A.10.3.2- The correlation R^2 between observed and Q-DFEM discharge flows during 1950-2000

The observed and DFEM discharge water flows during the period 1950-2000, are presented in Figure A.10.3.1.

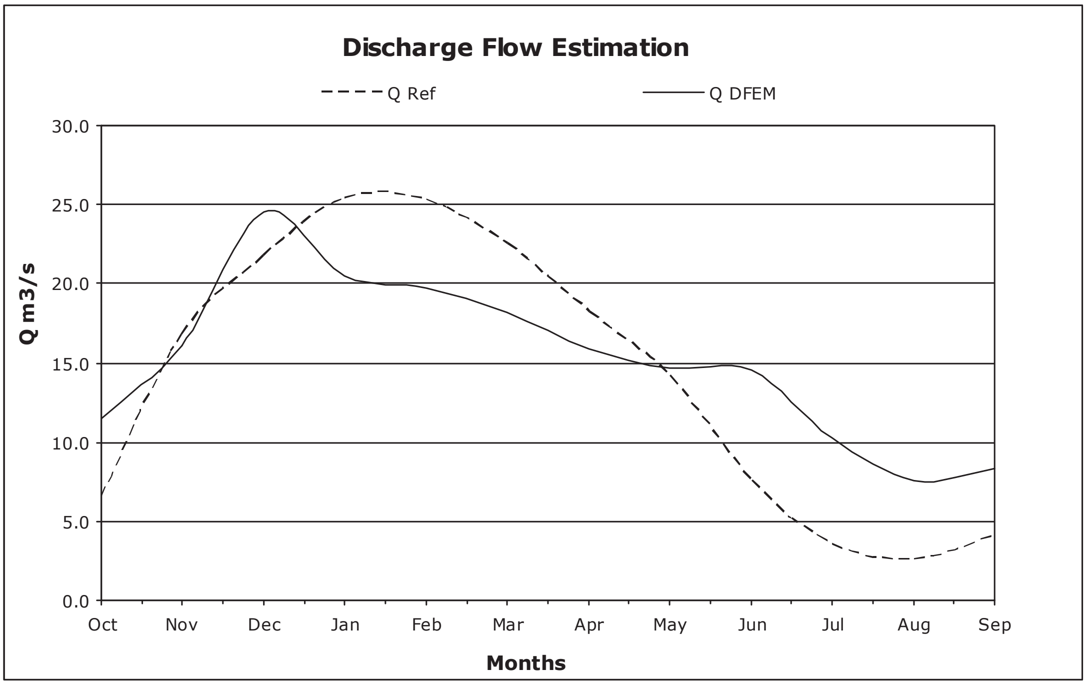


Figure A.10.3.1- Ndroq observed and Q-DFEM discharge flows on 1950-2000

The monthly calibration constants C_m is in Table A.10.3.5.

Table A.10.3.5 Calibration constant C for Ndroq site on 1950-2000

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Calibration C	0.57	1.05	0.90	1.25	1.29	1.25	1.15	0.97	0.53	0.34	0.35	0.50

The validation is made applying the calibration constants C_m in Q-DFEM module with the input data issued by GAISMA website (Table A.10.4.18).

Table A.10.3.6– Meteorological data of Tirana region predicted on 2011
(source: http://www.gaisma.com/en/dir/al-country.html)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation mm	127	115	109	97	82	59	37	47	78	108	160	143
Snow area %	0	0	0								0	0
Temperature °C	-0.3	1.1	5.1	10.0	15.6	19.6	22.6	22.6	17.7	12.1	5.7	0.6
Radiation w/m^2/day	1820	2450	3580	4350	5660	6640	6870	6030	4350	2900	1870	1510

Table A.10.3.7– Ndroq observed discharge flows on 1950-2000
(source: Selenica A. Morell M. 2000 “Les resources en eau de l’Albanie”)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Q flow ref m3/s	6.5	16.8	21.8	25.4	25.3	22.5	18.2	14.2	7.6	3.5	2.6	4.1

The results of the module (output data) are shown in Table A.10.3.8, as follows:

Table A.10.3.8 DFEM discharge flow at Ndroq site on 2011

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
Qr flow m^3/s	6.7	16.1	20.1	24.9	22.8	20.1	17.7	13.5	6.4	3.3	2.5	4.1	13.2
q specific l/s/km^2	0.025	0.028	0.034	0.032	0.030	0.029	0.028	0.027	0.025	0.023	0.021	0.022	0.027
Qs flow m^3/s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Runoff Mm	63	87	129	115	102	92	88	78	66	47	30	38	934

The results data and goodness on fit tests are shown in Table A.10.3.9.

Table A.10.3.9 Discharge flow and the goodness on fit data for Ndroq site on 2011

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	6.7	6.5	-2	1.0	0
Nov	16.1	16.8	4	0.9	0
Dec	20.1	21.8	8	0.9	0
Jan	24.9	25.4	2	1.0	0
Feb	22.8	25.3	10	1.0	0

Mar	20.1	22.5	11	0.9	0
Apr	17.7	18.2	3	1.0	0
May	13.5	14.2	5	0.0	0
Jun	6.4	7.6	16	1.0	0
Are Jul	3.3	3.5	6	1.0	0
Aug	2.5	2.6	5	1.0	0
Sep	4.1	4.1	0	1.0	0
Mean	13.2	14.0	6	0.9	0

Precipitation (P)	1162	mm
Deficit (D)	228	mm
Runoff (R)	934	mm
Rain event	4.55	mm/event
Length (L)	13	km
Slope (S)	0.037	%
Runoff area (Ar)	521	km^2
Co	0.80	
Cinf	0.24	
TC	7	days
CN	86	
K	1.3	

The performance and the efficiency are within the goodness on fit criteria.
The linear correlation R^2 between the observed and simulated discharge water flows is calculated 0.99 and it is demonstrated in Figure A.10.3.4.

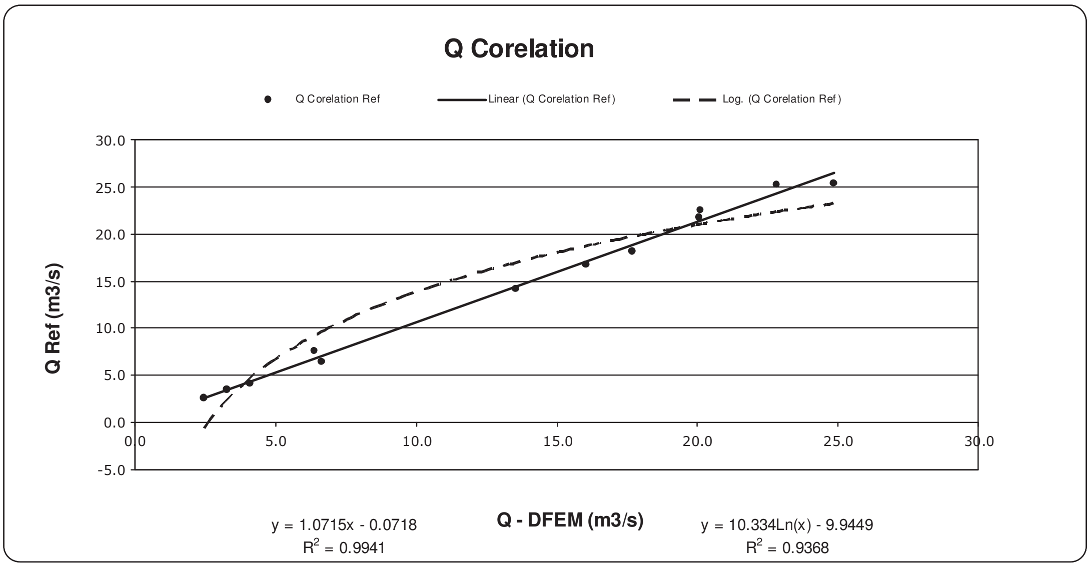


Figure A.10.3.4- The correlation R^2 between observed and validated Q-DFEM discharge flows during 2011.

The observed and DFEM discharge flows on 2011, are shown in Figure A.10.3.3.

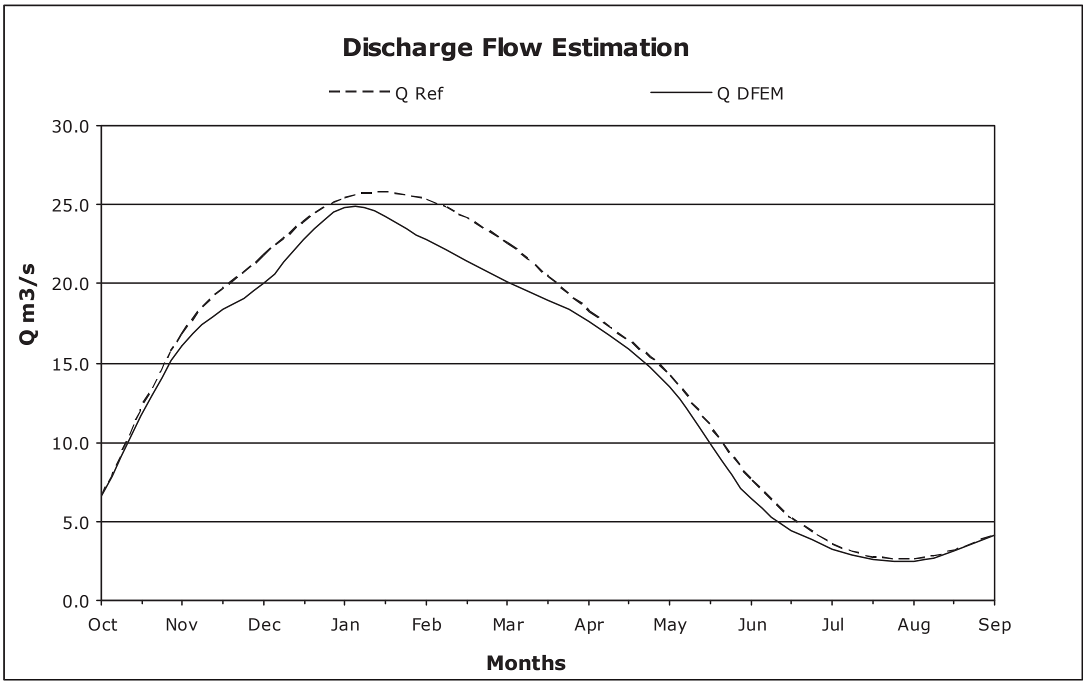


Figure A.10.3.3- Ndroq observed and predicted Q-DFEM discharge flows on 2011

10.4 Hydro meteorology data

Table A.10.4.1 - Observed discharge flows at Dorza 1958 – 1990
(source: Pano N. 2008 " Pasurite Ujore te Shqiperise")

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean
1958	53	208.8	264.3	257.4	165.4	332.3	260.9	191.8	106.7	65	42.4	40.4	165.7
1959	73.6	273.8	461.3	457.1	124.2	135.8	192.6	178.9	98.9	75.1	50.6	50.7	181.1
1960	82.8	155.8	443.5	518.6	383.3	257.2	282	259.2	101.2	62.5	46.8	51.6	220.4
1961	34.5	172.8	173.6	228.9	192.1	129.9	128.4	105.4	60.3	42.1	32.8	28.1	110.7
1962	74.4	466.3	439.6	104.3	151.4	434.2	216.1	100.9	58	43.6	39.6	41.3	180.8
1963	70.5	54.2	396.1	882.8	1035.8	274.9	378.5	371.3	227.8	97	58.1	42.8	324.2
1964	57.8	268.5	474.9	75.6	157	257.9	208.7	89.7	96.9	59.5	40.1	34.5	151.8
1965	30.3	143.5	295.7	251	318	329	382.5	207.7	121.6	69.3	45.8	36.7	185.9
1966	48.9	388.7	494	595.2	283.4	239.9	182.7	147.5	103.5	49.7	28.7	28.6	215.9
1967	36.1	37.2	193	315.6	130.5	124.3	172.2	182.1	100.3	69.6	43.7	46.9	121.0
1968	35.2	51.9	165.4	310.1	255.7	182.7	151.4	117.9	95.6	41.7	35.8	35	123.2
1969	27.3	55.9	469	194.5	391.9	363.9	207.8	200	82.8	52.9	36.1	31.9	176.2
1970	43.3	72.9	117.3	324.7	234.4	235.5	213.6	142.8	91	57.1	38.3	31.5	133.5
1971	38.3	113.4	149.2	359.3	123.2	266.7	231.2	120.7	57.4	35.5	29.2	34.6	129.9
1972	182.7	95.7	86.8	156.6	256.2	218.1	190	142.9	65.4	46	32.2	33.5	125.5
1973	47.6	73.1	341.4	162.4	296.5	249.9	257.5	208.1	83.3	49.8	35.2	37.6	153.5
1974	204	265.9	134.8	151.5	305.5	175.4	268.1	292.1	115.2	67.5	46.6	49	173.0
1975	70.6	117	181.7	80.6	107.2	164.9	161.8	95	52.9	33.2	25.9	21.7	92.7
1976	52	310.5	495.8	84.7	104.7	103.6	121	95	58.9	43.3	29.1	29.8	127.4
1977	34.5	173.5	185	205.6	213.7	109.6	92.4	67.4	41	30.3	27.9	35	101.3
1978	40	51.1	182.5	199.6	360.1	229.9	338.5	191	97.2	55.9	41.2	49	153.0
1979	38	231.3	158.3	482.1	393.6	158.1	373.7	157.2	91.2	54.5	42.2	34.4	184.6
1980	129.2	240	355	280.2	185.6	261	170.8	225.5	144.5	65.9	44.8	34.3	178.1
1981	148.6	86.1	514.6	182.4	281.3	292.6	215.1	191.7	102	59.6	48.9	44.6	180.6
1982	73.4	195.2	405.7	199.1	97.9	156.3	203.1	136.6	77.1	43	36.8	36.9	138.4
1983	32	88.5	223.6	118.9	242.7	152.6	157.4	89.2	74.2	50.5	34.5	38.1	108.5
1984	28	65.7	50.4	274.7	249.7	196.5	189.6	159.2	86	45.9	34.8	34.2	117.9
1985	27.9	269.5	120.9	271.5	154.5	177.4	209.3	149.5	69.7	33.8	22.7	20	127.2
1986	32.2	34.6	51.4	339	384.5	280.7	165.5	147.2	94.1	51.2	39.9	27.9	137.4
1987	59.5	151.9	200.4	183.2	172.4	200.7	197.6	136.2	85	47.5	34.5	30.4	124.9
1988	31.1	119.8	188.5	82.9	142.9	230.2	186.6	113.7	54.8	34	29.9	21.7	103.0
1989	142.8	133.8	110.7	56.3	77.5	154.8	82.9	89.3	54.3	38.8	31	30.2	83.5
1990	36.6	80.5	303.5	49.4	48.6	39.4	66.7	51.5	37	27.7	27.3	28.2	66.4

Table A.10.4.2 – Dorza observed precipitation during on 1965 – 1975
(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
171.2	162.1	100.3	71.7	72.8	42.3	31	30.4	58.2	128.6	198.3	200.5	1267.4

Table A.10.4.3 - Dorza observed precipitation during on 1975 – 1985
(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
171.2	162.1	100.3	71.7	72.8	42.3	31	30.4	58.2	128.6	198.3	200.5	1267.4

Table A.10.4.4 - Permet observed precipitation during on 1965 – 1975
(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
160.3	138.7	87.8	86.4	81.9	49.7	27.6	25.8	52.6	120.5	191.2	194.7	1217.2

Table A.10.4.5 - Permet observed precipitation during on 1975 – 1985
(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
158.7	137.4	88.8	85.4	82.2	47.8	27.7	24.8	53	121.2	184.5	187.9	1199.4

Table A.10.4.6 - Selenica observed precipitation during on 1965 – 1975
(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
128.3	105.4	82.2	63.5	66	27.8	32.1	25.1	41.2	82.3	161.2	138.6	953.7

Table A.10.4.7 - Selenica observed precipitation during on 1975 – 1985
(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
127.9	108.3	80.3	62.8	65.2	28.8	33.1	26.3	40.6	80.9	158.4	137.2	949.8

Table A.10.4.8 – Ura Leklit observed precipitation during on 1965 – 1975
(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
245.3	205.6	138.6	92.7	84.1	41.1	22.3	21.3	78.8	135.3	275.5	255.3	1595.9

Table A.10.4.9 – Ura Leklit observed precipitation during on 1975 – 1985
(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
244.6	202.3	134.3	91.1	82.2	42.2	23	21.6	78.1	132.8	265.2	244.1	1561.5

Table A.10.4.10 - Ndroq observed precipitation during on 1965 – 1975

(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
167	149	123	96	79	59	29	44	69	120	186	162	167

Table A.10.4.11 - Ndroq observed precipitation during on 1975 – 1985

(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
164	144	121	98	78	62	28	40	62	115	179	164	164

Table A.10.4.12 - Ndroq observed discharge flow during on 1965 – 1975

(source: Institute of Enewrgy, Water and Environment of Albania)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
27.1	25.8	24.5	19.1	14.6	8.0	3.7	2.7	4.2	6.6	15.7	22.1	

Table A.10.4.13 - Ndroq observed discharge flow during on 1976 – 1984

(source:UNESCO(http://webworld.unesco.org/water/ihp/db/shiklomanov/part'4/EUROPA/europa.html)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1976	18.0	19.5	8.80	10.0	9.20	12.0	5.80	3.60	3.40	7.00	26.5	40.0	13.6
1977	25.0	33.5	13.0	9.70	5.90	2.10	1.60	1.00	4.40	3.80	12.5	16.0	10.7
1978	22.0	41.5	50.5	39.0	42.5	11.0	3.80	1.80	8.40	4.00	4.20	27.0	21.3
1979	23.0	25.0	22.5	30.5	10.5	7.20	5.10	6.00	4.90	4.60	48.0	31.0	18.2
1980	26.0	14.0	12.0	9.40	25.0	8.80	2.80	1.60	1.80	9.90	28.0	35.0	14.5
1981	15.0	33.0	39.0	12.0	12.0	3.30	2.10	3.30	4.40	13.0	13.5	45.0	16.3
1982	16.0	9.00	11.5	8.50	5.30	4.20	4.10	3.40	2.70	4.40	5.30	27.5	8.49
1983	10.0	23.0	13.0	12.5	7.00	16.5	8.30	4.60	3.20	2.00	8.30	9.40	9.82
1984	27.5	23.5	26.0	18.5	7.40	3.10	1.20	2.80	6.10	4.20	4.90	3.60	

Table A.10.4.14 – Vjosa river observed discharge flows

(source: Institute of Enewrgy, Water and Environment of Albania and Selenica A. Morell M. 2000 "Les resources en eau de l'Albanie" MEDHYCOS project)

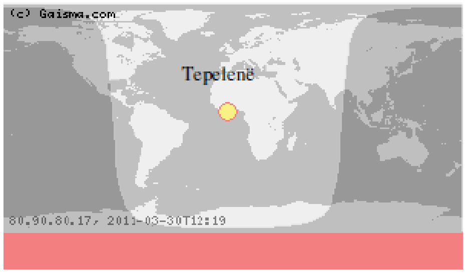
			Biovizhde 1960-1975									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
78.7	78.2	96	91.6	75.1	31	20.2	17.3	17.8	36	40.2	76.7	54.9
			Biovizhde 1960-1990									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
85.4	92.6	82	110	85.3	43.5	22.5	15	15.2	23.1	53.3	86.4	59.5
			Biovizhde 1975-1985									Annual
92.1	107	68	128.4	95.5	56	24.8	12.7	12.6	10.2	66.4	96.1	64.15
			Ura e Leklit 1960-1975									

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
94.4	91.3	66.8	47.5	28.3	14.8	9.4	6.5	6.4	14.7	47.7	82.1	42.5
			Ura e Leklit 1960-1990									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
84.6	82.5	61.2	44.2	26.1	13.8	8.8	6.2	6.1	13.1	44.9	76.3	39.0
			Ura e Leklit 1975-1985									Annual
74.8	73.7	55.6	40.9	23.9	12.8	8.1	5.9	5.8	11.5	42.1	70.5	35.47
			Permet 1960-1975									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
106	119	109	110	90.6	47	30	22.3	21	46.1	81.9	110	74.4
			Permet 1960-1990									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
102	106	104	117	83.5	42.5	22.5	17.2	17.3	31.8	63.4	103	67.5
			Permet 1975-1985									Annual
98	93	99	124	76.4	38	15	12.1	13.6	17.5	44.9	96	60.6
			Dragot 1960-1975									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
117	158	123	117	138	59.2	32.9	23.3	22.6	47.2	130	128	91.4
			Dragot 1960-1990									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
117	158	123	117	138	59.2	32.9	23.3	22.6	47.7	130	128	91.4
			Dragot 1975-1985									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
117	158	123	117	138	59.2	32.9	23.3	22.6	48.2	130	128	91.4
			Petran 1960-1975									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
104	99.5	96.3	94.7	77.2	45	27.3	19.4	19.7	36.2	80.3	103	66.9
			Petran 1960-1999									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
99.3	99.2	94.1	94.3	75.1	40.5	20.5	16.8	16.6	30.4	60.2	100	62.3
			Petran 1975-1985									
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
94.6	98.9	91.9	93.9	73	36	13.7	14.2	13.5	24.6	40.1	97	57.6

Table A.10.4.15 - Tepelena observed meteorological data
(source: www.gaisma.com/en/dir/al-country.html)

Tepelenë, Albania - Basic information

Latitude: +40.3 (40°18'00"N)
Longitude: +20.01 (20°00'36"E)
Time zone: UTC+1 hours
Local time: 14:30:00
Country: Albania
Continent: Europe
Sub-region: Southern Europe
Distance: ~120 km (from your IP)

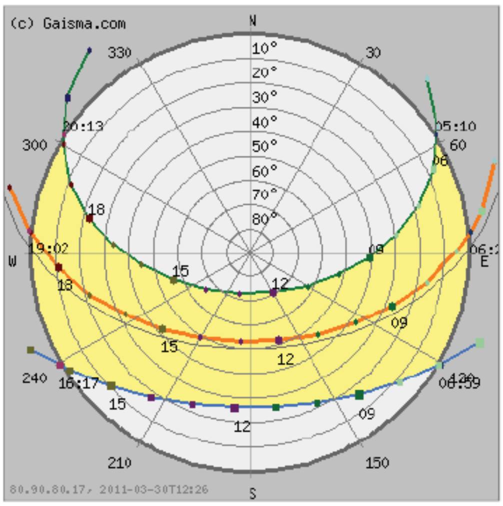


Tepelenë, Albania - Solar energy and surface meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	1.95	2.57	3.65	4.47	5.74	6.72	6.94	6.07	4.45	3.02	1.96	1.58
Clearness, 0 - 1	0.47	0.46	0.48	0.47	0.52	0.58	0.62	0.60	0.53	0.48	0.43	0.42
Temperature, °C	2.62	3.53	6.81	11.37	16.95	21.17	24.32	24.23	19.59	14.36	8.38	3.62
Wind speed, m/s	4.23	4.43	4.19	3.89	3.40	3.36	3.44	3.53	3.43	3.76	4.19	4.50
Precipitation, mm	164	147	117	89	72	41	28	35	68	138	207	214
Wet days, d	13.9	13.1	13.4	13.3	11.0	8.2	5.5	6.2	7.2	10.4	13.8	14.9

These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; New et al. 2002
Notes: Help, Change preferences.

Tepelenë, Albania - Sun path diagram



Sun path
Today
June 21
December 21
Annual variation
Equinox (March and September)
Sunrise/sunset
Sunrise
Sunset
Time
00-02
03-05
06-08
09-11
12-14
15-17
18-20
21-23

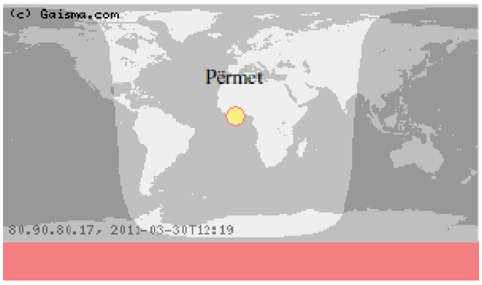
Notes: • = Daylight saving time, * = Next day. How to read this graph? Change preferences.

Table A.10.4.16 - Permet observed meteorological data

(source: www.gaisma.com/en/dir/al-country.html)

Përmet, Albania - Basic information

Latitude: +40.24 (40°14'24"N)
Longitude: +20.35 (20°21'00"E)
Time zone: UTC+1 hours
Local time: 14:30:53
Country: Albania
Continent: Europe
Sub-region: Southern Europe
Distance: ~130 km (from your IP)

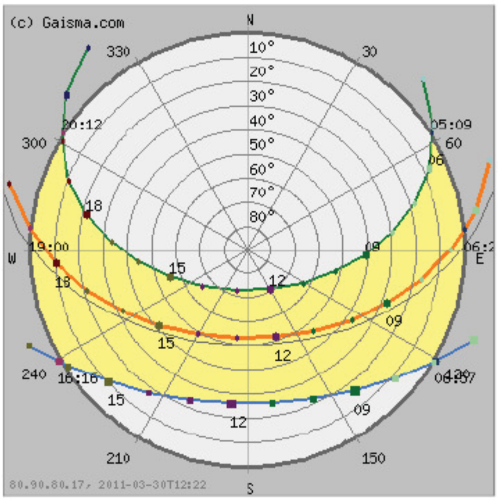


Përmet, Albania - Solar energy and surface meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	1.95	2.57	3.65	4.47	5.74	6.72	6.94	6.07	4.45	3.02	1.96	1.58
Clearness, 0 - 1	0.47	0.46	0.48	0.47	0.52	0.58	0.62	0.60	0.53	0.48	0.43	0.42
Temperature, °C	2.62	3.53	6.81	11.37	16.95	21.17	24.32	24.23	19.59	14.36	8.38	3.62
Wind speed, m/s	4.23	4.43	4.19	3.89	3.40	3.36	3.44	3.53	3.43	3.76	4.19	4.50
Precipitation, mm	142	129	104	82	72	42	29	33	61	122	182	189
Wet days, d	13.5	12.9	13.2	13.2	11.5	8.6	5.8	6.8	7.2	10.3	13.5	14.6

These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; New et al. 2002
Notes: Help. Change preferences.

Përmet, Albania - Sun path diagram



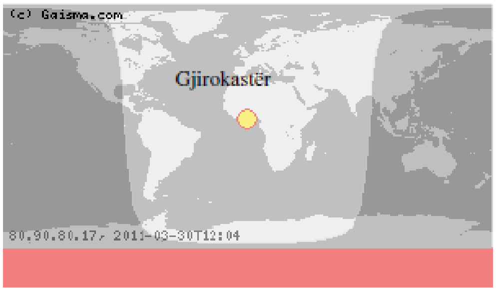
Sun path
Today
June 21
December 21
Annual variation
Equinox (March and September)
Sunrise/sunset
Sunrise
Sunset
Time
00-02
03-05
06-08
09-11
12-14
15-17
18-20
21-23

Notes: • = Daylight saving time, * = Next day. How to read this graph? Change preferences.

Table A.10.4.17 - Gjirokaster observed meteorological data
(source: www.gaisma.com/en/dir/al-country.html)

Gjirokastër, Albania - Basic information

Latitude: +40.08 (40°04'48"N)
Longitude: +20.15 (20°09'00"E)
Time zone: UTC+1 hours
Local time: 14:32:09
Country: Albania
Continent: Europe
Sub-region: Southern Europe
Distance: ~140 km (from your IP)

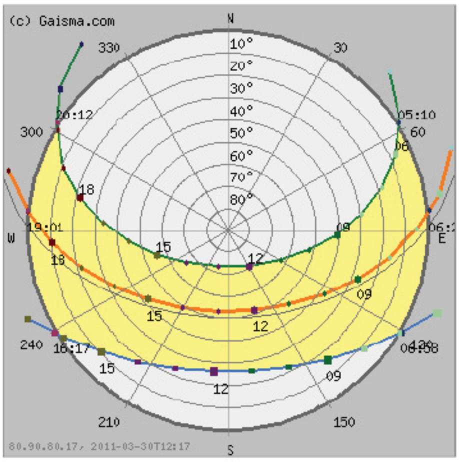


Gjirokastër, Albania - Solar energy and surface meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	1.95	2.57	3.65	4.47	5.74	6.72	6.94	6.07	4.45	3.02	1.96	1.58
Clearness, 0 - 1	0.47	0.46	0.48	0.47	0.52	0.58	0.62	0.60	0.53	0.48	0.43	0.42
Temperature, °C	2.62	3.53	6.81	11.37	16.95	21.17	24.32	24.23	19.59	14.36	8.38	3.62
Wind speed, m/s	4.23	4.43	4.19	3.89	3.40	3.36	3.44	3.53	3.43	3.76	4.19	4.50
Precipitation, mm	172	155	121	90	70	39	26	34	70	144	216	225
Wet days, d	14.0	13.3	13.5	13.3	10.9	8.0	5.3	6.0	7.2	10.6	13.9	15.1

These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; New et al. 2002
Notes: Help. Change preferences.

Gjirokastër, Albania - Sun path diagram



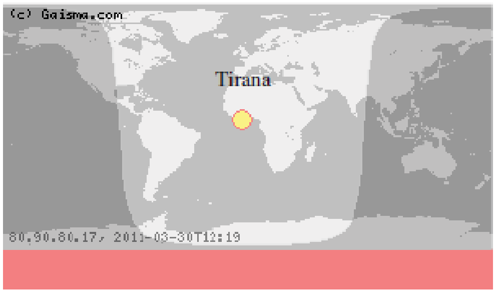
Sun path
Today
June 21
December 21
Annual variation
Equinox (March and September)
Sunrise/sunset
Sunrise
Sunset
Time
00-02
03-05
06-08
09-11
12-14
15-17
18-20
21-23

Notes: • = Daylight saving time, * = Next day. How to read this graph? Change preferences.

Table A.10.4.18 - Tirana observed meteorological data
(source: www.gaisma.com/en/dir/al-country.html)

Tirana, Albania - Basic information

Latitude: +41.33 (41°19'48"N)
Longitude: +19.82 (19°49'12"E)
Time zone: UTC+1 hours
Local time: 14:44:14
Country: Albania
Continent: Europe
Sub-region: Southern Europe
Distance: ~0.3 km (from your IP)

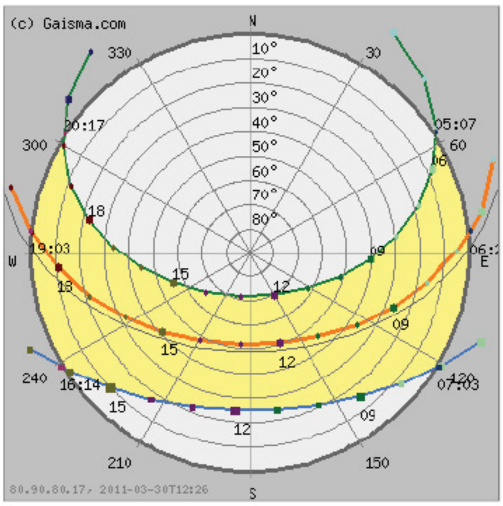


Tirana, Albania - Solar energy and surface meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	1.82	2.45	3.58	4.35	5.66	6.64	6.87	6.03	4.35	2.90	1.87	1.51
Clearness, 0 - 1	0.46	0.45	0.48	0.46	0.52	0.58	0.61	0.60	0.53	0.47	0.42	0.42
Temperature, °C	-0.34	1.08	5.08	9.99	15.56	19.56	22.57	22.57	17.73	12.09	5.68	0.61
Wind speed, m/s	3.94	4.14	3.92	3.73	3.22	3.19	3.25	3.34	3.31	3.64	3.92	4.17
Precipitation, mm	127	115	109	97	82	59	37	47	78	108	160	143
Wet days, d	12.9	12.3	12.8	12.9	9.5	8.0	5.2	5.3	7.3	9.3	13.3	13.7

These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; New et al. 2002
Notes: Help. Change preferences.

Tirana, Albania - Sun path diagram



Sun path
Today
June 21
December 21
Annual variation
Equinox (March and September)
Sunrise/sunset
Sunrise
Sunset
Time
00-02
03-05
06-08
09-11
12-14
15-17
18-20
21-23

Notes: • = Daylight saving time, * = Next day. How to read this graph? Change preferences.

Table A.10.4.19 Vjosa River: Monthly Inflow at Kaludh Reservoir
(source: AKBN – Agjencia Kombetare e Burimeve Natyrore)

Time series natural inflows at KALUDH HPP (in m³/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.	in hm3	in %
1948	119	107	65	68,3	57,8	39,9	26,3	24	23,1	23,3	28,3	21,5	**50**	1 586	78%
1949	28,4	22,2	43,6	41,9	29,8	27,7	20,1	18	20,4	27,3	125	83,8	**41**	1 283	63%
1950	91,2	98,8	61,6	94,5	68,8	32,8	21,3	17,4	26,3	34,3	132	151	**69**	2 181	108%
1951	76,9	59,8	135	72,4	114	95	36,4	20,3	30,1	82,1	141	94,9	**80**	2 517	125%
1952	155	102	77	91,5	53	32,3	20,3	15,2	13,7	20,2	118	175	**73**	2 295	114%
1953	103	103	56,9	90,9	76	73,2	41,2	27,5	23,3	49,1	48,6	23,7	**60**	1 883	93%
1954	47,5	115	125	111	113	71,2	36,4	23,7	18	35,1	79,1	71,2	**71**	2 224	110%
1955	114	116	87,3	58,2	46,2	26,4	33,2	23,6	31,8	73,9	91,3	61,6	**64**	2 006	99%
1956	97,3	134	96,7	123	85,6	54,6	29,5	19,6	17,3	21,4	140	100	**77**	2 415	120%
1957	57,7	71,2	48,5	43,3	46,2	35,2	27,4	17	26,5	44,4	60,2	133	**51**	1 605	79%
1958	104	80,7	153	122	99,3	42,2	25,2	17,1	19	30,8	94,2	104	**74**	2 343	116%
1959	180	49,6	75,1	90,6	81,5	36,4	34,2	30,5	23,3	27	93,7	173	**75**	2 352	116%
1960	201	165	108	124	105	50,9	28,6	13,1	22	50	65,4	143	**90**	2 828	140%
1961	82,6	74,5	71	69,1	50,8	27,8	16	11,5	8,7	26,6	81,2	64,1	**49**	1 534	76%
1962	69	85	173	111	68,9	44,1	25,1	17,5	18,7	46,9	241	208	**92**	2 912	144%
1963	223	271	114	126	110	76,5	42,5	35,7	22,8	39,8	35,4	120	**101**	3 197	158%
1964	25,4	49,3	91,7	86,9	52,9	77,2	37,8	31,3	25,8	37,6	76,9	150	**62**	1 952	97%
1965	94,8	86,5	108	147	105	51,9	41,3	23,9	17,9	12,7	74,1	112	**73**	2 300	114%
1966	179	115	100	94	78,3	53,2	26	17,4	18,2	32,2	145	173	**86**	2 710	134%
1967	118	58,3	68,1	94,4	100	42,3	34,8	21,8	24,7	17,2	18,9	83,6	**57**	1 793	89%
1968	120	138	105	90	73	56	17,8	8,2	7,2	7	21,5	64	**59**	1 860	92%
1969	69,5	119	134	86,9	83,5	25,2	15,3	14,6	16,5	14	23,3	148	**62**	1 970	98%
1970	151	124	117	119	85	55,4	34,9	18	16	34	39,1	60,5	**71**	2 244	111%
1971	164	62,6	114	104	54,2	28,1	18	18	20,7	20	56,2	61,5	**60**	1 896	94%
1972	76,7	125	118	119	83,9	32	23,9	17,5	20,2	105	55,1	41,1	**68**	2 148	106%
1973	52,3	98,4	102	121	92,6	30,5	17,9	12,9	12,4	17	24	130	**59**	1 869	92%
1974	51,4	103	56	83,5	85,3	32,3	18	14,2	17	65	84,9	41,2	**54**	1 713	85%
1975	29,7	35,4	61,2	62,3	42,9	28,4	18,5	14	11,8	27,9	40,1	71,9	**37**	1 167	58%
1976	34,5	36	45,8	58,1	37,2	25	18	12,3	14	19	110	169	**48**	1 521	75%
1977	88,6	105	49,5	43,4	26,5	15,2	12	11,5	16,7	16,4	73	69,2	**44**	1 385	69%
1978	82	162	119	139	93,2	38,9	19	14,8	20	17	24	69,9	**67**	2 099	104%
1979	206	156	77,2	172	76,4	50,2	24,2	17,8	15,5	18,5	89,2	61,6	**80**	2 535	125%
1980	110	74,1	108	78,8	111	57,7	23,5	15,8	13,1	47,3	97	148	**74**	2 324	115%
1981	68,3	123	133	94,4	93,5	39,7	22,9	18,4	16,7	36	24,9	192	**72**	2 267	112%
1982	50,8	27,7	37,8	87,5	54	28,2	45,7	13,8	15,7	26,6	67,7	136	**49**	1 554	77%
1983	45,7	64,1	42,4	47,2	28,7	28,1	21,8	15,5	15,1	23,2	29,4	45,4	**34**	1 069	53%
1984	120	92,7	90,1	97	90,1	36	17	14,6	13,6	11,9	21,9	14,6	**52**	1 628	81%
1985	81,5	68,1	77,2	117	68,9	27	13,8	10	9,6	10,2	86,9	46,8	**51**	1 621	80%
MAX	223	271	173	172	114	95	46	36	32	105	241	208	101	3 197	
MIN	25	22	38	42	27	15	12	8	7	7	19	15	34	1 069	
AVE	**99**	**97**	**91**	**94**	**74**	**43**	**26**	**18**	**19**	**33**	**75**	**100**	**64**	**2 021**	**100%**
S.D	*52*	*47*	*33*	*30*	*25*	*18*	*9*	*6*	*6*	*21*	*47*	*52*	*15*	467	
%	*13*	*13*	*12*	*12*	*10*	*6*	*3*	*2*	*2*	*4*	*10*	*13*	*100*		
in hm3	261	254	238	248	195	112	68	48	49	86	198	264	2 021		

Table A.10.4.20 Vjosa River: Monthly Inflow at Dragot Reservoir (source: AKBN – Agjencia Kombetare e Burimeve Natyrore)

Time series natural inflows at DRAGOTI Reservoir (in m³/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.	in hm3	in %
1 948	192	173	97,5	110	141	91,8	46,6	34,5	31	30,5	43,9	30,5	**85**	2 687	87%
1 949	47,5	25,3	79,6	75,3	68,3	52,8	26,4	22,5	22	29	218	137	**67**	2 112	69%
1 950	127	115	106	155	102	45,5	39,2	34,6	29	41,6	241	311	**112**	3 540	115%
1 951	140	156	259	139	162	100	41,8	29,5	32	116	177	109	**122**	3 840	125%
1 952	288	230	158	187	111	66,6	41,2	31,6	29,5	41,4	214	361	**147**	4 623	150%
1 953	195	213	89,9	156	128	123	54,8	39,4	30,5	50	60	30	**97**	3 074	100%
1 954	73,9	288	235	204	201	88,1	38	25	23,7	53,8	121	109	**122**	3 838	125%
1 955	175	178	134	89,1	70,8	40,4	50,8	36,1	48,7	114	141	95,3	**98**	3 083	100%
1 956	151	207	150	190	132	84,5	45,6	30,3	26,8	32,1	212	151	**118**	3 712	120%
1 957	87	107	73,2	65,5	69,7	53,1	41,3	20	20	41	66	148	**66**	2 081	68%
1 958	116	85	162	178	154	65,6	39	26,4	29,4	37	146	161	**100**	3 152	102%
1 959	278	76,7	100	109	126	56,3	52,9	39	36	47	167	301	**116**	3 650	118%
1 960	250	195	126	164	164	67	39	20,5	34,4	58	98,9	267	**124**	3 899	127%
1 961	125	100	92	97	76,8	42	30	22	17	25	107	105	**70**	2 204	72%
1 962	71	81	265	136	70	39,4	32,4	26,8	28,6	50,8	231	228	**105**	3 311	107%
1 963	356	432	143	201	215	140	67,8	35	28	48,2	36,6	222	**160**	5 058	164%
1 964	38,4	74,6	139	136	66	76	47,2	30,4	25	41	138	272	**90**	2 848	92%
1 965	146	144	177	237	153	80,1	48,7	31,9	27,6	19,6	106	180	**113**	3 550	115%
1 966	286	177	154	145	121	82	38,1	20,8	21,1	37,9	232	278	**133**	4 186	136%
1 967	194	90,4	100	141	155	65,6	54	33,8	38,3	26,2	28,6	127	**88**	2 770	90%
1 968	210	197	144	127	103	75	27	15,4	15	10,6	30,4	117	**89**	2 816	91%
1 969	105	180	202	134	126	46	28,2	22	20,9	21,5	35,9	232	**96**	3 031	98%
1 970	205	145	146	135	107	68,5	41,8	25,7	22,6	41,7	54,4	74	**89**	2 803	91%
1 971	200	78,2	173	158	82,5	42,7	25,4	19,4	22,5	25,5	57,7	93,6	**82**	2 571	83%
1 972	90	167	148	162	114	48,8	34,5	22,7	24,8	129	66,9	58,6	**89**	2 802	91%
1 973	79,7	150	155	184	141	46,5	27,3	19,7	18,9	25,6	36,2	197	**90**	2 841	92%
1 974	77,6	154	84,6	126	130	50,8	27,2	21,4	25,6	95,7	125	60,7	**82**	2 572	83%
1 975	43,8	52,2	90,1	91,7	63,2	41,9	27,3	20,6	17,4	40,2	57,7	103	**54**	1 706	55%
1 976	49,6	51,8	65,9	83,5	53,5	35,7	25,9	17,8	20,2	29,1	168	259	**72**	2 260	73%
1 977	126	156	75,6	66,3	40,5	23,3	18,4	17,6	25,5	22,9	98,4	100	**64**	2 025	66%
1 978	108	248	154	239	147	70	33,8	25,2	31,4	27,2	34,8	125	**104**	3 268	106%
1 979	282	214	96	230	128	61,3	34,4	27,2	24,1	27,4	143	108	**115**	3 615	117%
1 980	183	115	164	114	149	88,9	36,4	23,8	20,7	69,7	141	217	**110**	3 476	113%
1 981	114	184	204	144	128	69,4	35,8	29,8	25,7	98	63,9	341	**120**	3 778	123%
1 982	144	67,8	107	145	99,1	64,5	33,5	27,9	28,8	56	116	222	**93**	2 921	95%
1 983	83	178	114	116	63,7	50,3	39,7	22,8	23,4	21,5	44,7	123	**73**	2 313	75%
1 984	179	148	135	141	131	60,8	31,5	25,5	24,3	20	40,7	27,9	**80**	2 535	82%
1 985	135	111	109	155	118	54,7	23,9	15,1	13,9	13,2	132	90	**81**	2 551	83%
MAX	356	432	265	239	215	140	68	39	49	129	241	361	160	5 058	
MIN	38	25	66	66	41	23	18	15	14	11	29	28	54	1 706	
AVE	**151**	**151**	**137**	**144**	**116**	**65**	**38**	**26**	**26**	**45**	**111**	**162**	**98**	**3 082**	**100%**
S.D	*79*	*76*	*49*	*45*	*40*	*24*	*10*	*6*	*7*	*29*	*66*	*90*	*23*	660	
%	*13*	*13*	*12*	*12*	*10*	*6*	*3*	*2*	*2*	*4*	*9*	*14*	*100*		
in hm3	398	397	360	378	305	170	99	68	68	119	293	427	3 082		

Table A.10.4.21 Vjosa River: Monthly Inflow at Dorza (Kalivaci Reservoir) (source: AKBN – Agjencia Kombetare e Burimeve Natyrore)

Time series natural inflows at KALIVACI HPP (in m³/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.	in hm3	in %
1 948	307	282	159	180	191	116	69	55	43	66	76	57	**133**	4 207	86%
1 949	76	46	123	102	90	75	48	42	42	48	280	202	**98**	3 085	63%
1 950	235	218	140	200	124	64	52	45	43	65	320	470	**165**	5 193	106%
1 951	200	250	360	170	186	120	57	41	46	150	250	150	**165**	5 203	106%
1 952	426	353	198	218	130	80	50	39	37	50	261	525	**197**	6 220	127%
1 953	315	302	120	178	144	141	67,6	45,1	40,3	63	76	48	**128**	4 047	82%
1 954	136	520	320	284	247	115	56	40	34,8	70	190	185	**183**	5 776	118%
1 955	360	400	252	134	100	59	67	48	74	154	225	150	**169**	5 316	108%
1 956	234	425	253	270	179	106	58,5	38,9	34	43,5	339	281	**188**	5 944	121%
1 957	224	188	126	95,7	95,9	70,3	52,7	26,5	29,1	55	94,8	248	**109**	3 432	70%
1 958	257	165	332	261	192	107	65	42,4	40,4	53	209	264	**166**	5 224	106%
1 959	457	124	136	193	179	98,9	75,1	50,6	50,7	73,6	274	449	**180**	5 679	116%
1 960	520	383	257	282	259	101	62,5	46,8	51,6	82,8	156	444	**220**	6 953	142%
1 961	229	192	130	128	105	60,3	42,1	32,8	28,1	34,5	173	174	**111**	3 492	71%
1 962	104	151	434	216	101	58	43,6	39,6	41,3	74,4	465	440	**181**	5 697	116%
1 963	883	1040	272	379	371	228	97	58,1	42,8	70,5	54,2	396	**324**	10 227	208%
1 964	75,6	157	258	210	90	96,9	59,5	40,1	34,5	57,8	269	475	**152**	4 792	98%
1 965	251	318	329	383	208	122	69,3	45,8	36,7	30,3	144	296	**186**	5 869	120%
1 966	595	263	240	183	147	104	49,7	28,7	28,6	48,9	389	494	**214**	6 756	138%
1 967	316	131	124	172	182	100	69,6	43,7	46,9	36,1	37,2	193	**121**	3 815	78%
1 968	310	256	183	151	118	95,6	41,7	35,8	35	35,2	51,9	165	**123**	3 885	79%
1 969	195	392	364	208	200	82,8	52,9	36,1	31,9	27,3	55,9	469	**176**	5 558	113%
1 970	325	234	236	214	143	91	57,1	38,3	31,5	56	72,9	117	**135**	4 246	86%
1 971	359	125	267	231	121	57,4	35,5	29,2	34,6	38,3	102	149	**129**	4 071	83%
1 972	157	256	218	190	143	65,4	46	32,2	33,5	183	95,7	86,8	**126**	3 959	81%
1 973	162	297	250	258	208	83,3	49,8	35,2	37,6	47,6	75,1	341	**154**	4 848	99%
1 974	151	305	175	268	292	115	67,5	46,6	49	204	266	135	**173**	5 451	111%
1 975	80,6	107	165	162	95	52,9	33,2	25,9	21,7	70,6	117	182	**93**	2 925	60%
1 976	84,7	105	104	121	94,9	58,9	43,2	29,1	29,8	52	311	496	**127**	4 020	82%
1 977	206	214	110	92,4	67,4	41	30,3	27,9	35	34,5	174	185	**101**	3 200	65%
1 978	200	360	230	339	191	97,2	55,9	41,2	49,4	40	51,1	182	**153**	4 827	98%
1 979	482	394	158	374	157	91,2	54,5	42,2	34,4	38	231	158	**185**	5 819	119%
1 980	280	186	261	171	226	144	64,4	44,8	34,3	129	240	355	**178**	5 612	114%
1 981	182	281	293	215	192	102	59,6	48,9	44,6	149	86,1	515	**181**	5 698	116%
1 982	199	97,9	156	203	137	77,1	43	36,8	36,9	73,4	195	408	**139**	4 371	89%
1 983	119	243	153	157	89,2	74,4	50,5	34,5	38,1	32	89,5	224	**109**	3 427	70%
1 984	275	250	197	190	159	86,3	46,1	34,8	34,3	28	65,6	50,3	**118**	3 722	76%
1 985	271	155	180	209	149	69,7	33,9	22,7	20	27,9	269	122	**127**	4 019	82%
MAX	883	1040	434	383	371	228	97	58	74	204	465	525	324	10 227	
MIN	76	46	104	92	67	41	30	23	20	27	37	48	93	2 925	
AVE	**269**	**268**	**217**	**210**	**161**	**92**	**55**	**39**	**38**	**68**	**180**	**271**	**156**	**4 910**	**100%**
S.D	*162*	*167*	*82*	*74*	*63*	*33*	*13*	*8*	*9*	*45*	*108*	*151*	*44*	*1034*	
%	*14*	*14*	*12*	*11*	*9*	*5*	*3*	*2*	*2*	*4*	*10*	*14*	*100*		
in hm3	708	703	571	553	422	243	144	103	101	179	472	711	4 910		

10.5 Vjosa river watershed

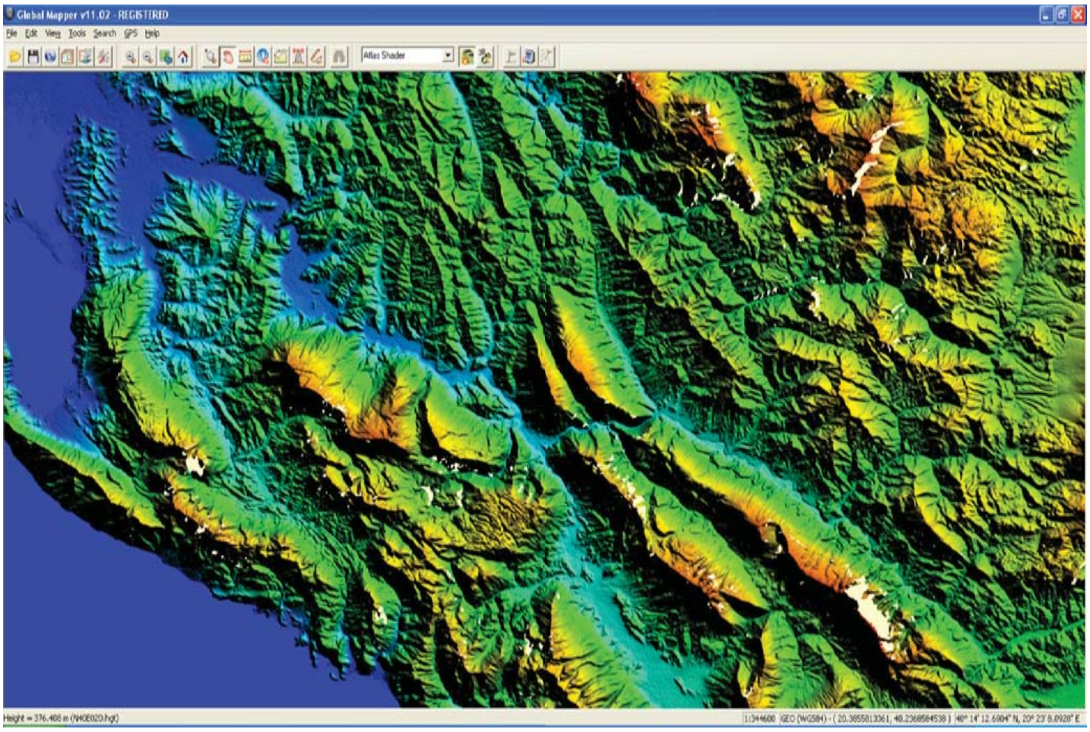


Figure A.10.5.1- Vjosa river basin (source: Global Mapper 11.0)

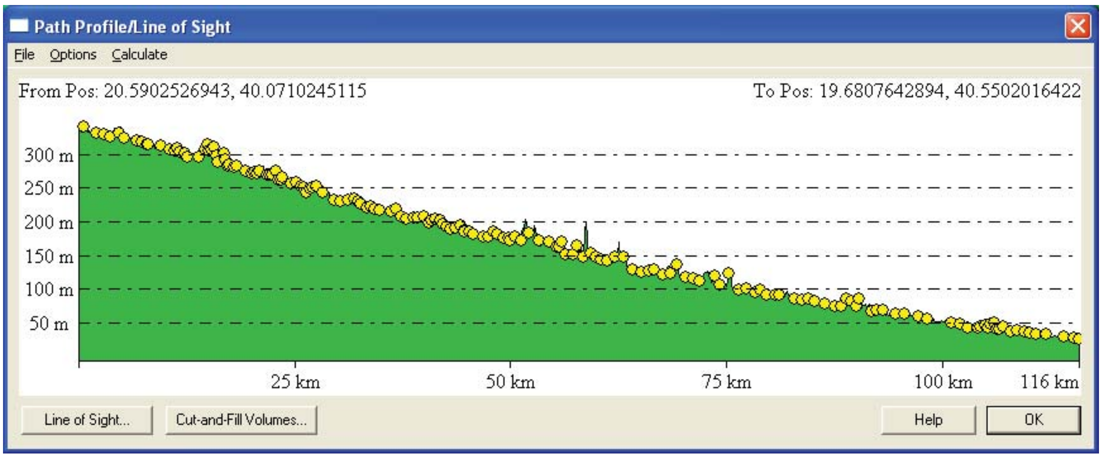


Figure A.10.5.2- Vjosa river longitudinal profile (source: Global Mapper 11.0)

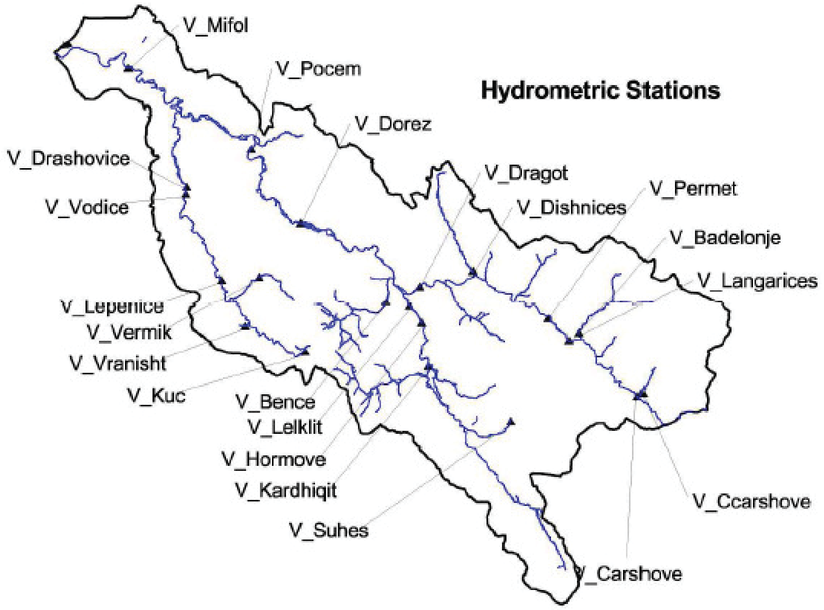


Figure A.10.5.3- Vjosa river hydrostream station (source: Kassomenos P. et all)

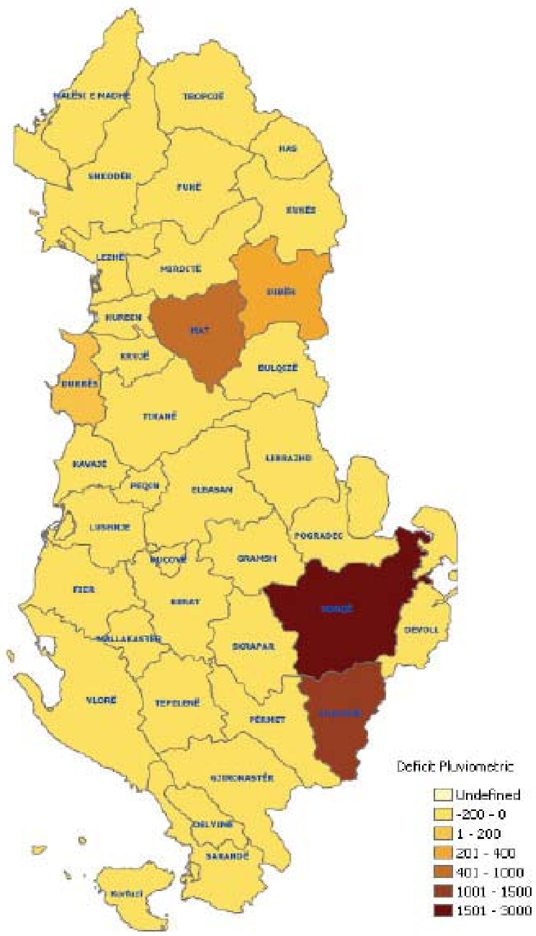


Figure A.10.5.4- Deficit data (source: Laska Merkoci et all 2010)

10.6 Vjosa river previous proposals

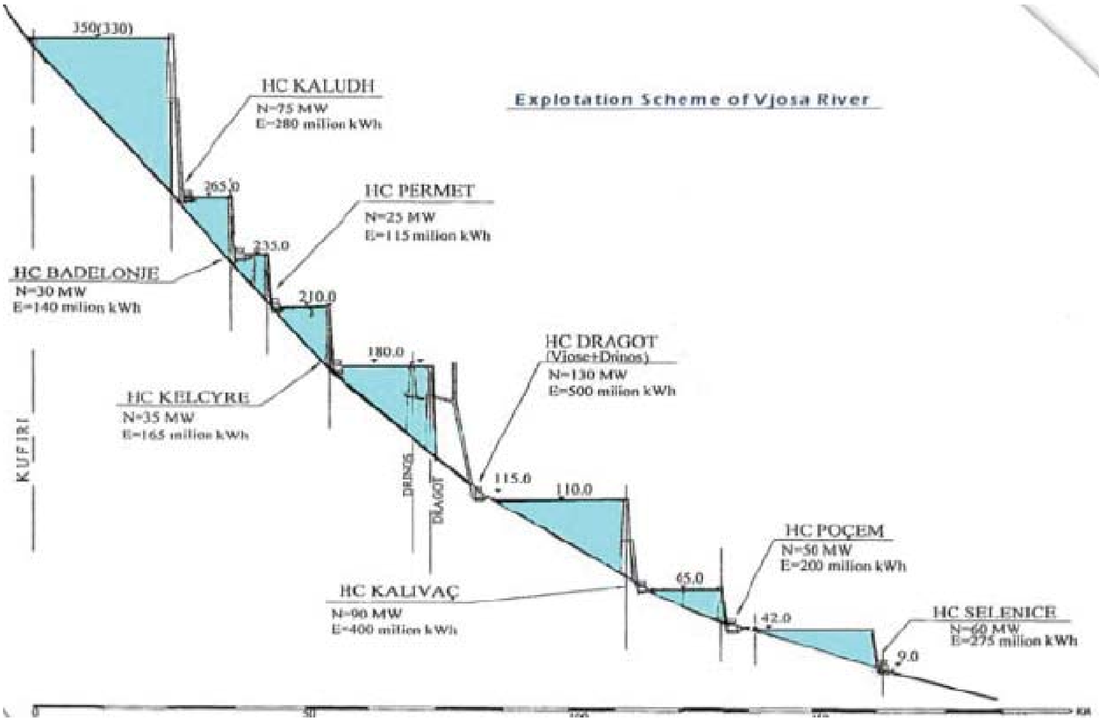


Figure A.10.6.1- Vjosa river power capacity & generation by HMI 1990 (source METE)

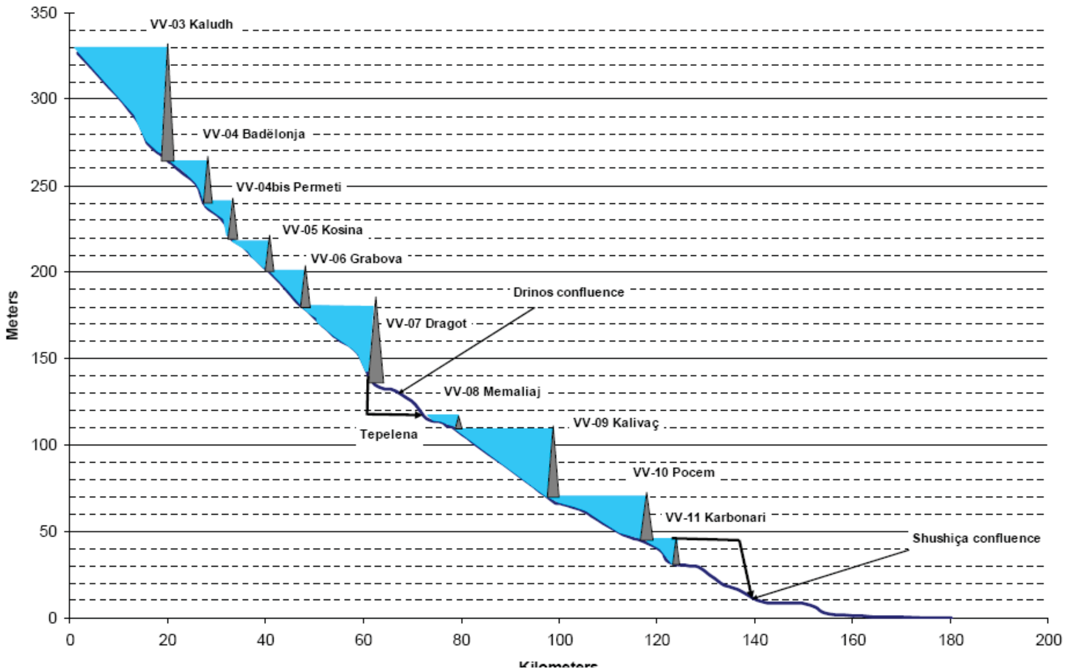


Figure A.10.6.2- Vjosa river power capacity & generation by SOGREAH 2008

10.7 Flow duration curves

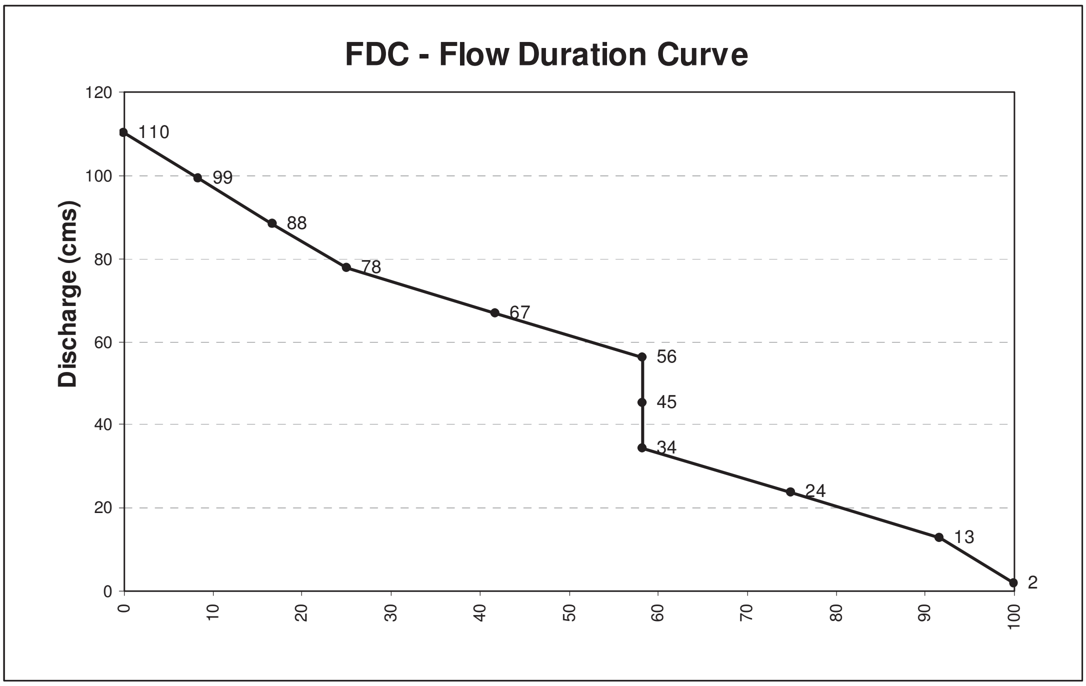


Figure A.10.7.1- Pellumbari FDC – Q_{design} = 110m^3/s

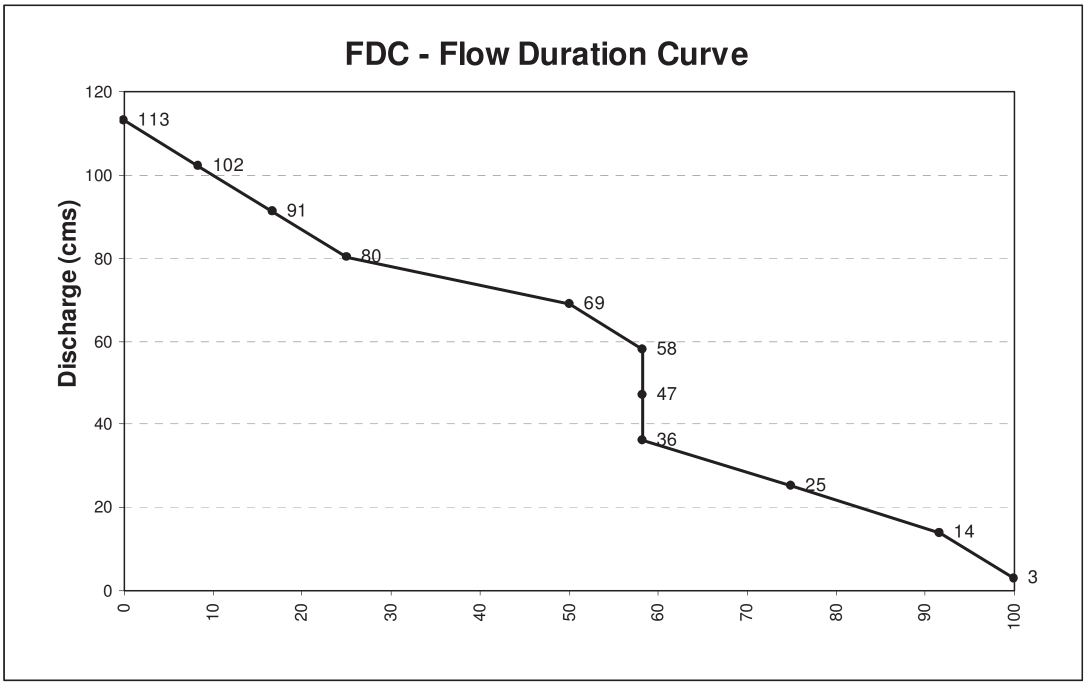


Figure A.10.7.2- Kaludh FDC – Q_{design} = 113m^3/s

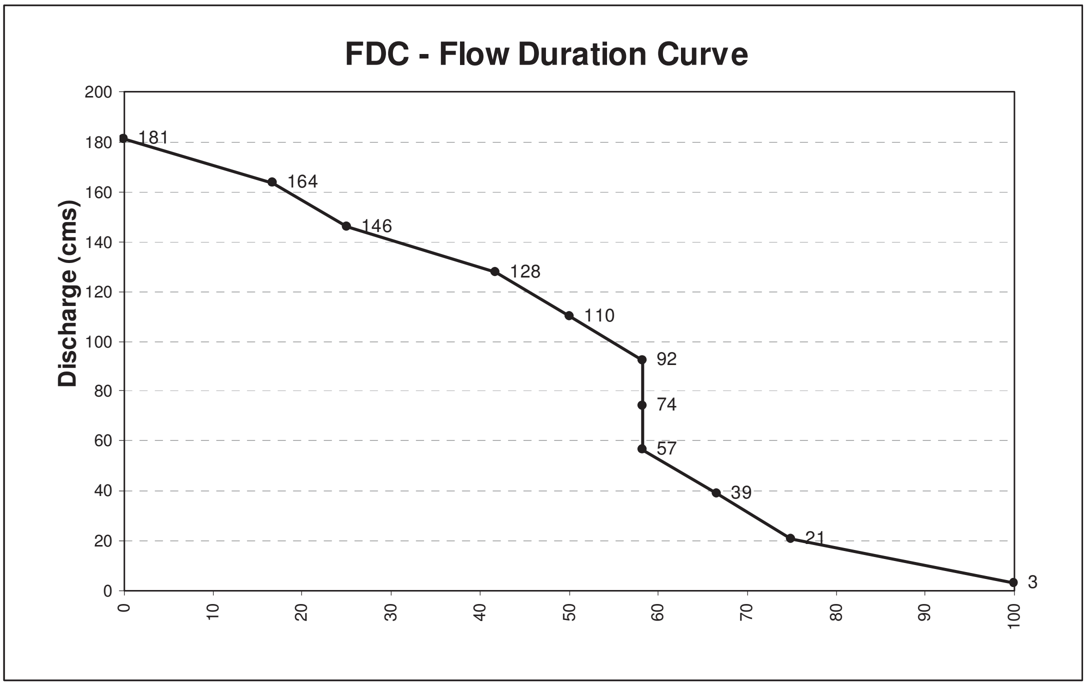


Figure A.10.7.3- Dragot FDC – Q_{design} = 181m^3/s

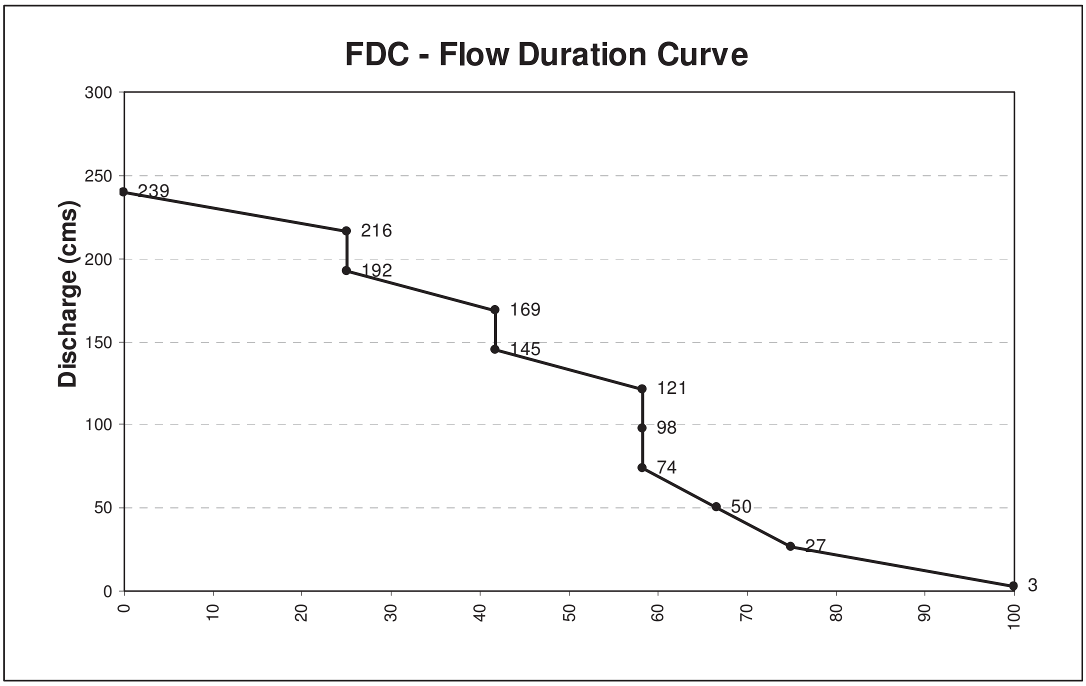


Figure A.10.7.4- Memaliaj FDC – Q_{design} = 239m^3/s

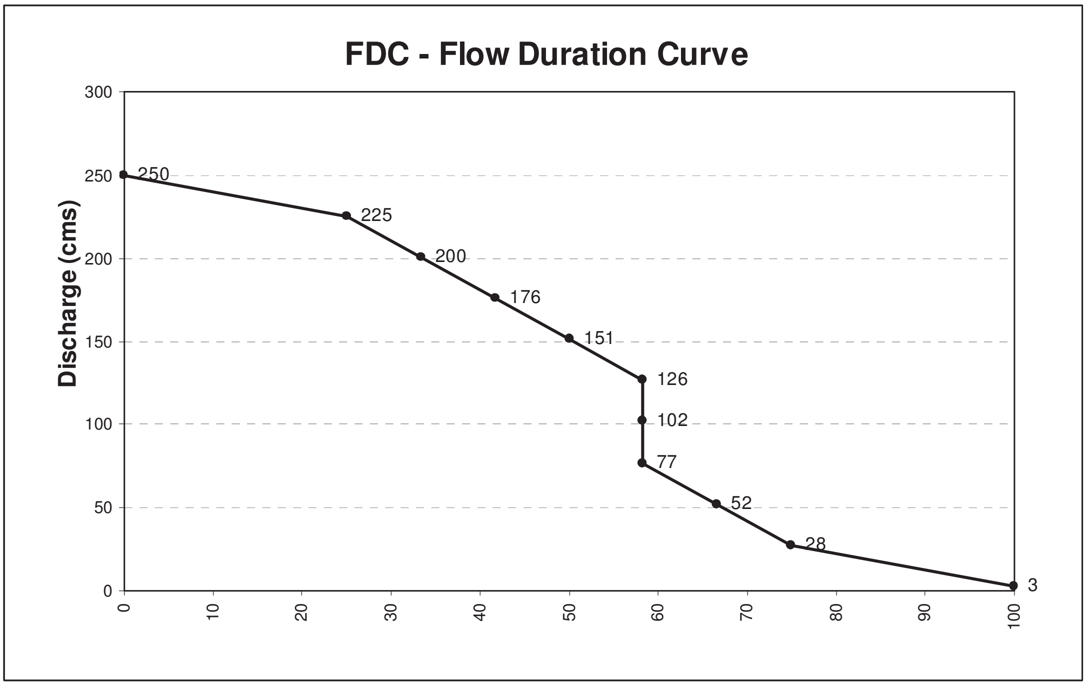


Figure A.10.7.5- Kalivac bis FDC – Q_{design} = 250m^3/s

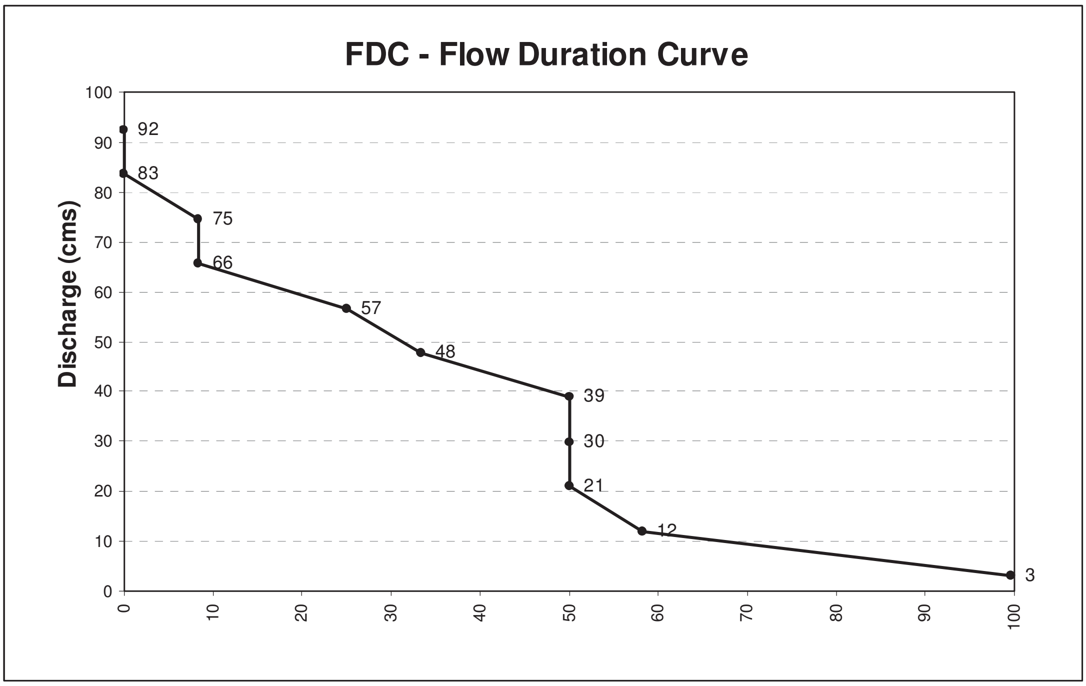


Figure A.10.7.6- Drino FDC – Q_{design} = 83m^3/s

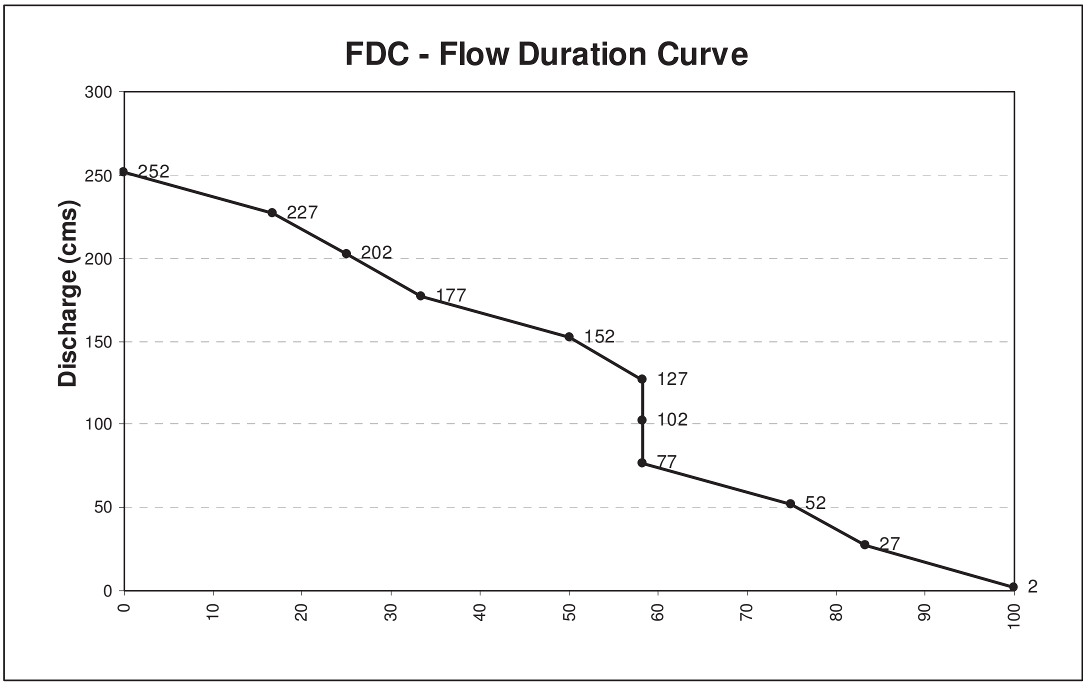


Figure A.10.7.7- Dorza FDC – Q_{design} = 252m^3/s

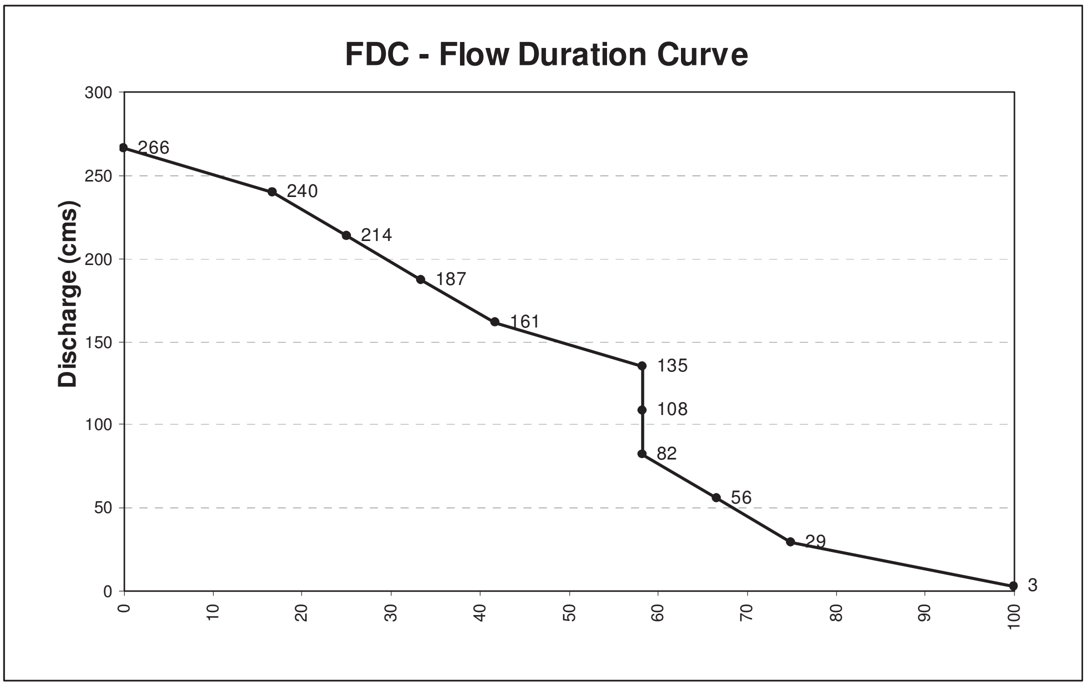


Figure A.10.7.8- Drizar I FDC – Q_{design} = 266m^3/s

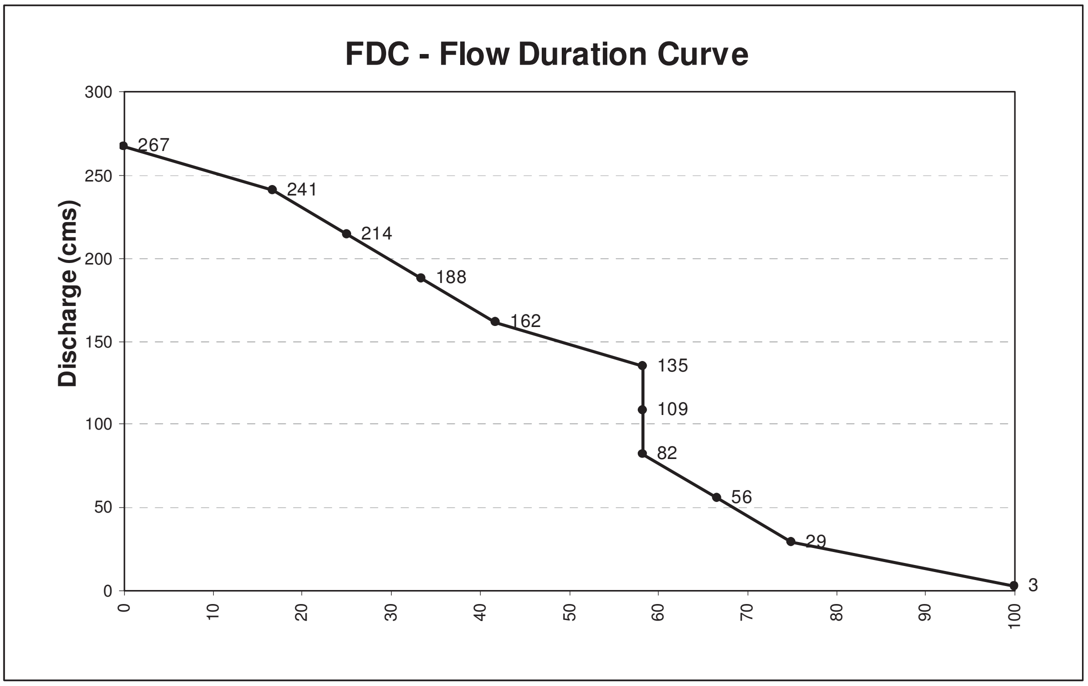


Figure A.10.7.9- Drizar II FDC – Q_{design} = 267m^3/s

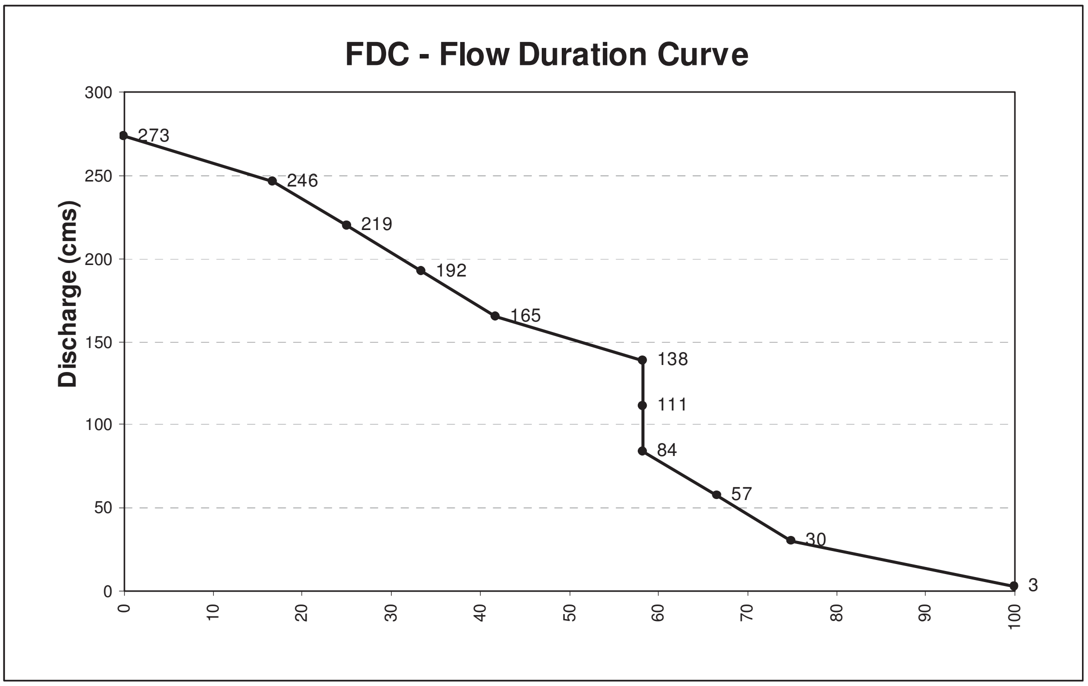


Figure A.10.7.10- Gjonca FDC – Q_{design} = 273m^3/s

10.8 Discharge flow and the goodness on fit data

The "goodness on fit" discharge water flows are compered with Q-Ref of Kaludh, Dragot and Dorza discharge data shown in Tables A.10.4.19, 20 and 21.

Vjosa Upperstream

Table A.10.8.1 Pellumbari goodness on fit discharge flow compared Kaludh Q Ref.

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	36.3	33.0	-10	1.0	0
Nov	75.0	75.0	0	1.0	0
Dec	95.4	100.0	5	1.0	0
Jan	96.8	99.0	2	1.0	0
Feb	84.5	97.0	13	0.9	0
Mar	84.0	91.0	8	0.9	0
Apr	107.8	94.0	-15	0.8	0
May	70.4	74.0	5	0.9	0
Jun	38.2	43.0	11	0.9	0
Jul	23.1	26.0	11	1.0	0
Aug	18.3	18.0	-2	1.0	0
Sep	22.2	19.0	-17	1.0	0
Mean	62.7	64.1	2	0.9	0

Table A.10.8.2 Kaludh goodness on fit discharge flow compared to Kaludh Q Ref

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	37.1	33.0	-12	1.0	0
Nov	76.7	75.0	-2	1.0	0
Dec	97.7	100.0	2	1.0	0
Jan	99.1	99.0	0	1.0	0
Feb	86.5	97.0	11	0.9	0
Mar	85.9	91.0	6	1.0	0
Apr	110.2	94.0	-17	0.7	0
May	71.9	74.0	3	1.0	0
Jun	39.0	43.0	9	1.0	0
Jul	23.6	26.0	9	1.0	0
Aug	18.7	18.0	-4	1.0	0
Sep	22.7	19.0	-19	1.0	0
Mean	64.1	64.1	0	1.0	0

Vjosa Middlestream

Table A.10.8.3 Dragot goodness on fit discharge flow compared to Dragot Q Ref.

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	53.8	45.0	-20	1.0	0
Nov	125.5	111.0	-13	0.0	0
Dec	182.9	162.0	-13	0.9	0
Jan	174.6	151.0	-16	0.8	0
Feb	153.6	151.0	-2	1.0	0
Mar	144.3	137.0	-5	1.0	0
Apr	185.2	144.0	-29	0.2	0
May	116.6	116.0	-1	1.0	0
Jun	56.3	65.0	13	0.9	0
Jul	32.4	38.0	15	1.0	0
Aug	25.5	26.0	2	1.0	0
Sep	31.8	26.0	-22	1.0	0
Mean	106.9	97.7	-9	0.8	0

Table A.10.8.4 Memaliaj goodness on fit discharge flow compared to Dragot Q Ref

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	69.8	66.3	-5	1.0	0
Nov	167.9	158.8	-6	0.0	0
Dec	249.1	270.1	8	1.0	0
Jan	238.1	257.4	7	1.0	0
Feb	207.1	257.7	20	0.8	0
Mar	193.6	221.6	13	0.8	0
Apr	246.0	213.4	-15	0.7	0
May	153.1	159.5	4	0.3	0
Jun	73.2	89.3	18	0.9	0
Jul	41.0	52.0	21	1.0	0
Aug	31.8	38.0	16	1.0	0
Sep	40.0	36.0	-11	1.0	0
Mean	142.6	151.7	6	0.8	0

Table A.10.8.5 Kalivac bis goodness on fit discharge flow compared Dragot Q Ref.

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	72.5	66.3	-9	1.0	0
Nov	175.2	158.8	-10	0.0	0

Dec	260.5	270.1	4	1.0	0
Jan	249.0	257.4	3	1.0	0
Feb	216.2	257.7	16	0.8	0
Mar	202.0	221.6	9	0.9	0
Apr	256.3	213.4	-20	0.5	0
May	159.3	159.5	0	1.0	0
Jun	76.0	89.3	15	1.0	0
Jul	42.5	52.0	18	1.0	0
Aug	32.9	38.0	13	1.0	0
Sep	41.4	36.0	-15	1.0	0
Mean	148.6	151.7	2	0.9	0

Table A.10.8.6 Drino goodness on fit discharge flow compared to Drino Q Ref

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	13.1	13.1	0	1.0	0
Nov	54.3	44.9	-21	0.0	0
Dec	67.1	76.3	12	0.9	0
Jan	87.4	84.6	-3	1.0	0
Feb	62.9	82.5	24	0.8	0
Mar	52.1	61.2	15	0.8	0
Apr	44.5	44.2	-1	1.0	0
May	28.2	26.1	-8	1.0	0
Jun	13.3	13.8	4	1.0	0
Jul	9.0	8.8	-3	1.0	0
Aug	7.0	6.2	-12	1.0	0
Sep	8.2	6.1	-35	1.0	0
Mean	37.3	39.0	4	0.9	0

Vjosa Downstream

Table A.10.8.7 Dorza goodness on fit discharge flow compared to Dorza Q Ref.

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	74.9	66.3	-13	1.0	0
Nov	170.5	158.8	-7	0.0	0
Dec	268.3	270.1	1	1.0	0
Jan	263.3	257.4	-2	1.0	0
Feb	219.5	257.7	15	0.9	0

Mar	177.1	221.6	20	0.6	0
Apr	243.2	213.4	-14	0.8	0
May	185.7	159.5	-16	0.0	0
Jun	82.4	89.3	8	1.0	0
Jul	49.8	52.0	4	1.0	0
Aug	34.8	38.0	8	1.0	0
Sep	39.0	36.0	-8	1.0	0
Mean	150.7	151.7	1	0.8	0

Table A.10.8.8 Drizar I goodness on fit discharge flow compared to Dorza Q Ref

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	74.7	66.3	-13	1.0	0
Nov	174.4	158.8	-10	0.0	0
Dec	278.6	270.1	-3	1.0	0
Jan	273.7	257.4	-6	1.0	0
Feb	225.9	257.7	12	0.9	0
Mar	181.6	221.6	18	0.7	0
Apr	247.3	213.4	-16	0.7	0
May	187.0	159.5	-17	0.0	0
Jun	82.4	89.3	8	1.0	0
Jul	48.7	52.0	6	1.0	0
Aug	33.6	38.0	12	1.0	0
Sep	38.0	36.0	-5	1.0	0
Mean	153.8	151.7	-1	0.8	0

Table A.10.8.9 Drizar II goodness on fit discharge flow compared to Dorza Q Ref.

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	74.9	66.3	-13	1.0	0
Nov	175.1	158.8	-10	0.0	0
Dec	279.7	270.1	-4	1.0	0
Jan	274.8	257.4	-7	1.0	0
Feb	226.8	257.7	12	0.9	0
Mar	182.3	221.6	18	0.7	0
Apr	248.2	213.4	-16	0.7	0
May	187.6	159.5	-18	0.0	0
Jun	82.6	89.3	8	1.0	0

Jul	48.9	52.0	6	1.0	0
Aug	33.7	38.0	11	1.0	0
Sep	38.1	36.0	-6	1.0	0
Mean	154.4	151.7	-2	0.8	0

Table A.10.8.10 Gjonca goodness on fit discharge flow compared to Dorza Q Ref

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter
Oct	76.4	66.3	-15	1.0	0
Nov	179.1	158.8	-13	0.0	0
Dec	286.4	270.1	-6	1.0	0
Jan	281.5	257.4	-9	0.9	0
Feb	232.1	257.7	10	0.9	0
Mar	186.5	221.6	16	0.7	0
Apr	253.7	213.4	-19	0.6	0
May	191.5	159.5	-20	0.0	0
Jun	84.3	89.3	6	1.0	0
Jul	49.8	52.0	4	1.0	0
Aug	34.3	38.0	10	1.0	0
Sep	38.8	36.0	-8	1.0	0
Mean	157.9	151.7	-4	0.8	0

10.9 Power generation in dry / wet conditions

Table A.10.9.1 Pellumbari hydropower plant 22MW (dry)

Pellumbari	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	34.8	25	0.055	6,867	4,944,544
Nov	68.7	25	0.055	13,560	9,763,115
Dec	83.7	25	0.055	16,522	11,895,660
Jan	84.4	25	0.055	16,672	12,003,562
Feb	76.3	25	0.055	15,066	10,847,784
Mar	76.5	25	0.055	15,114	10,881,807
Apr	100.0	25	0.055	19,747	14,217,554
May	66.3	25	0.055	13,094	9,427,534
Jun	36.2	25	0.055	7,155	5,151,403
Jul	22.4	25	0.055	4,427	3,187,464
Aug	17.9	25	0.055	3,541	2,549,524
Sep	21.7	25	0.055	4,290	3,089,042
Total generation					97,958,995

Table A.10.9.2 Kaludhi hydropower plant 18MW (dry)

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	35.5	25	0.055	7,010	5,047,330
Nov	70.2	25	0.055	13,869	9,985,708
Dec	85.7	25	0.055	16,917	12,180,595
Jan	86.4	25	0.055	17,073	12,292,395
Feb	78.1	25	0.055	15,416	11,099,828
Mar	78.3	25	0.055	15,461	11,131,641
Apr	102.2	25	0.055	20,188	14,535,160
May	67.7	25	0.055	13,377	9,631,609
Jun	37.0	25	0.055	7,307	5,260,965
Jul	22.9	25	0.055	4,517	3,252,044
Aug	18.3	25	0.055	3,607	2,597,005
Sep	22.2	25	0.055	4,378	3,152,257
Total generation					100,166,535

Table A.10.9.3 Dragot hydropower plant 44MW (dry)

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	50.9	30	0.066	12,068	8,688,866
Nov	112.3	30	0.066	26,617	19,164,470
Dec	154.8	30	0.066	36,690	26,416,814
Jan	146.9	30	0.066	34,823	25,072,250
Feb	134.6	30	0.066	31,896	22,965,304
Mar	128.2	30	0.066	30,377	21,871,468
Apr	168.5	30	0.066	39,945	28,760,439
May	108.6	30	0.066	25,731	18,526,490
Jun	53.1	30	0.066	12,586	9,061,731
Jul	31.3	30	0.066	7,419	5,341,770
Aug	25.0	30	0.066	5,914	4,258,150
Sep	30.9	30	0.066	7,318	5,269,199
Total generation					195,396,950

Table A.10.9.4 Drino hydropower plant 15MW (dry)

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	12.5	30	0.066	2,951	2,125,074
Nov	48.6	30	0.066	11,515	8,290,491
Dec	56.8	30	0.066	13,457	9,688,883
Jan	73.4	30	0.066	17,399	12,527,379
Feb	55.1	30	0.066	13,054	9,398,976
Mar	46.2	30	0.066	10,955	7,887,507
Apr	40.5	30	0.066	9,597	6,909,758
May	26.3	30	0.066	6,244	4,495,822
Jun	12.6	30	0.066	2,983	2,147,406
Jul	8.7	30	0.066	2,069	1,489,562
Aug	6.8	30	0.066	1,621	1,167,317
Sep	8.0	30	0.066	1,896	1,365,326
Total generation					67,493,501

Table A.10.9.5 Memaliaj hydropower plant 29.5MW (dry)

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	66.0	15	0.033	7,825	5,634,252
Nov	150.2	15	0.033	17,804	12,819,052
Dec	210.8	15	0.033	24,982	17,987,282
Jan	200.4	15	0.033	23,745	17,096,694
Feb	181.4	15	0.033	21,497	15,478,197
Mar	171.9	15	0.033	20,376	14,670,364
Apr	223.9	15	0.033	26,526	19,098,932
May	142.5	15	0.033	16,883	12,156,107
Jun	69.0	15	0.033	8,182	5,890,790
Jul	39.7	15	0.033	4,705	3,387,802
Aug	31.1	15	0.033	3,689	2,655,748
Sep	38.9	15	0.033	4,609	3,318,657
Total generation					130,193,878

Table A.10.9.6 Kalivac bis hydropower plant 10.2MW (dry)

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	68.6	5	0.011	2,709	1,950,740
Nov	156.7	5	0.011	6,190	4,457,077
Dec	220.4	5	0.011	8,707	6,269,152
Jan	209.6	5	0.011	8,278	5,959,934
Feb	189.4	5	0.011	7,482	5,387,176
Mar	179.4	5	0.011	7,087	5,102,683
Apr	233.3	5	0.011	9,214	6,634,011
May	148.2	5	0.011	5,855	4,215,547
Jun	71.7	5	0.011	2,834	2,040,255
Jul	41.1	5	0.011	1,624	1,169,424
Aug	32.2	5	0.011	1,270	914,649
Sep	40.2	5	0.011	1,590	1,144,477
Total generation					45,245,127

Table A.10.9.7 Dorza hydropower plant 85MW (dry)

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	70.9	40	0.088	22,403	16,130,053
Nov	152.6	40	0.088	48,208	34,709,491
Dec	227.1	40	0.088	71,760	51,667,451
Jan	221.6	40	0.088	70,029	50,420,572
Feb	192.3	40	0.088	60,764	43,749,724
Mar	157.3	40	0.088	49,710	35,791,081
Apr	221.3	40	0.088	69,929	50,348,973
May	172.8	40	0.088	54,605	39,315,667
Jun	77.8	40	0.088	24,572	17,692,172
Jul	48.2	40	0.088	15,217	10,955,906
Aug	34.0	40	0.088	10,749	7,739,087
Sep	37.9	40	0.088	11,984	8,628,129
Total generation					367,148,305

Table A.10.9.8 Drizar I hydropower plant 36MW (dry)

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	70.7	16	0.035	8,936	6,434,260
Nov	156.1	16	0.035	19,729	14,204,841
Dec	235.8	16	0.035	29,802	21,457,485
Jan	230.4	16	0.035	29,118	20,964,878
Feb	198.0	16	0.035	25,023	18,016,765
Mar	161.3	16	0.035	20,390	14,681,015
Apr	225.1	16	0.035	28,448	20,482,539
May	174.0	16	0.035	21,995	15,836,492
Jun	77.7	16	0.035	9,822	7,072,003
Jul	47.1	16	0.035	5,960	4,290,996
Aug	32.8	16	0.035	4,152	2,989,542
Sep	36.9	16	0.035	4,667	3,360,000
Total generation					149,790,816

Table A.10.9.9 Drizar II hydropower plant 36MW (dry)

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	70.9	16	0.035	8,967	6,456,239
Nov	156.7	16	0.035	19,803	14,257,972
Dec	236.7	16	0.035	29,919	21,541,733
Jan	231.3	16	0.035	29,233	21,047,512
Feb	198.7	16	0.035	25,119	18,085,580
Mar	161.9	16	0.035	20,467	14,736,352
Apr	225.9	16	0.035	28,552	20,557,601
May	174.6	16	0.035	22,073	15,892,541
Jun	78.0	16	0.035	9,856	7,096,345
Jul	47.3	16	0.035	5,979	4,304,658
Aug	32.9	16	0.035	4,165	2,998,538
Sep	37.0	16	0.035	4,681	3,370,454
Total generation					150,345,526

Table A.10.9.10 Gjonca hydropower plant 37.1MW (dry)

	Q (m^3/s)	H (m)	eff = kW/m^3/s	kW	kWh
Oct	72.4	15	0.033	8,574	6,173,167
Nov	160.2	15	0.033	18,985	13,669,045
Dec	242.4	15	0.033	28,727	20,683,356
Jan	236.9	15	0.033	28,071	20,211,346
Feb	203.3	15	0.033	24,097	17,349,773
Mar	165.6	15	0.033	19,626	14,131,011
Apr	230.9	15	0.033	27,356	19,696,277
May	178.3	15	0.033	21,126	15,211,073
Jun	79.5	15	0.033	9,426	6,786,662
Jul	48.1	15	0.033	5,706	4,108,125
Aug	33.5	15	0.033	3,969	2,857,550
Sep	37.7	15	0.033	4,465	3,214,666
Total generation					144,092,051

Table A.10.9.11 Pellumbari hydropower plant 22MW (wet)

Pellumbari	Q (m^3/s)	H (m)	eff = kW/m^3/s	kW	kWh
Oct	37.2	25	0.055	7,349	5,291,594
Nov	78.6	25	0.055	15,530	11,181,731
Dec	102.4	25	0.055	20,228	14,564,197
Jan	104.2	25	0.055	20,571	14,811,151
Feb	89.3	25	0.055	17,644	12,703,423
Mar	88.3	25	0.055	17,445	12,560,367
Apr	112.2	25	0.055	22,168	15,960,714
May	72.6	25	0.055	14,344	10,327,626
Jun	39.2	25	0.055	7,751	5,580,824
Jul	23.5	25	0.055	4,639	3,339,870
Aug	18.5	25	0.055	3,657	2,633,085
Sep	22.5	25	0.055	4,451	3,204,508
Total generation					112,159,091

Table A.10.9.12 Kaludhi hydropower plant 18MW (wet)

	Q (m^3/s)	H (m)	eff = kW/m^3/s	kW	kWh
Oct	38.0	25	0.055	7,502	5,401,595
Nov	80.4	25	0.055	15,884	11,436,667
Dec	104.9	25	0.055	20,713	14,913,051
Jan	106.7	25	0.055	21,066	15,167,541
Feb	91.4	25	0.055	18,054	12,998,582
Mar	90.4	25	0.055	17,845	12,848,739
Apr	114.7	25	0.055	22,663	16,317,260
May	74.2	25	0.055	14,654	10,551,185
Jun	40.1	25	0.055	7,916	5,699,519
Jul	24.0	25	0.055	4,733	3,407,537
Aug	18.9	25	0.055	3,725	2,682,121
Sep	23.0	25	0.055	4,542	3,270,085
Total generation					114,693,882

Table A.10.9.13 Dragot hydropower plant 44MW (wet)

	Q (m^3/s)	H (m)	eff = kW/m^3/s	kW	kWh
Oct	55.4	30	0.066	13,122	9,447,541
Nov	133.1	30	0.066	31,546	22,713,158
Dec	199.7	30	0.066	47,339	34,084,074
Jan	191.2	30	0.066	45,318	32,629,233
Feb	164.7	30	0.066	39,032	28,103,060
Mar	153.6	30	0.066	36,403	26,210,206
Apr	194.7	30	0.066	46,133	33,216,107
May	121.1	30	0.066	28,711	20,671,708
Jun	58.0	30	0.066	13,752	9,901,602
Jul	32.9	30	0.066	7,803	5,618,308
Aug	25.8	30	0.066	6,122	4,407,486
Sep	32.2	30	0.066	7,641	5,501,196
Total generation					232,503,679

Table A.10.9.14 Drino hydropower plant 15MW (wet)

	Q (m^3/s)	H (m)	eff = kW/m^3/s	kW	kWh
Oct	13.5	30	0.066	3,209	2,310,176
Nov	57.7	30	0.066	13,673	9,844,524
Dec	73.5	30	0.066	17,413	12,537,052
Jan	96.0	30	0.066	22,757	16,384,957
Feb	67.6	30	0.066	16,028	11,539,936
Mar	55.6	30	0.066	13,180	9,489,732
Apr	46.8	30	0.066	11,087	7,982,882
May	29.3	30	0.066	6,952	5,005,450
Jun	13.7	30	0.066	3,242	2,334,453
Jul	9.1	30	0.066	2,167	1,560,511
Aug	7.1	30	0.066	1,672	1,204,095
Sep	8.3	30	0.066	1,975	1,421,849
Total generation					81,615,617

Table A.10.9.15 Memaliaj hydropower plant 29.5MW (wet)

	Q (m^3/s)	H (m)	eff = kW/m^3/s	kW	kWh
Oct	71.8	15	0.033	8,509	6,126,212
Nov	178.1	15	0.033	21,101	15,192,758
Dec	272.0	15	0.033	32,233	23,207,941
Jan	260.8	15	0.033	30,902	22,249,779
Feb	222.0	15	0.033	26,307	18,940,952
Mar	206.1	15	0.033	24,417	17,580,588
Apr	258.5	15	0.033	30,636	22,057,805
May	159.0	15	0.033	18,838	13,563,686
Jun	75.4	15	0.033	8,940	6,436,767
Jul	41.8	15	0.033	4,949	3,563,185
Aug	32.2	15	0.033	3,818	2,748,887
Sep	40.6	15	0.033	4,812	3,464,774
Total generation					155,133,334

Table A.10.9.16 Kalivac bis hydropower plant 10.2MW (wet)

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	74.6	5	0.011	2,946	2,121,071
Nov	185.7	5	0.011	7,337	5,282,395
Dec	284.4	5	0.011	11,234	8,088,721
Jan	272.7	5	0.011	10,773	7,756,307
Feb	231.8	5	0.011	9,156	6,592,386
Mar	215.0	5	0.011	8,493	6,114,924
Apr	269.4	5	0.011	10,641	7,661,775
May	165.4	5	0.011	6,533	4,703,673
Jun	78.4	5	0.011	3,096	2,229,353
Jul	43.2	5	0.011	1,708	1,229,964
Aug	33.3	5	0.011	1,315	946,726
Sep	42.0	5	0.011	1,660	1,194,867
Total generation					53,922,163

Table A.10.9.17 Dorza hydropower plant 85MW (wet)

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	77.1	40	0.088	24,359	17,538,463
Nov	180.8	40	0.088	57,134	41,136,654
Dec	293.0	40	0.088	92,588	66,663,498
Jan	288.4	40	0.088	91,136	65,617,749
Feb	235.3	40	0.088	74,357	53,537,334
Mar	188.5	40	0.088	59,571	42,891,112
Apr	255.6	40	0.088	80,763	58,149,212
May	192.8	40	0.088	60,928	43,868,104
Jun	85.0	40	0.088	26,850	19,331,940
Jul	50.6	40	0.088	16,004	11,523,082
Aug	35.2	40	0.088	11,126	8,010,502
Sep	39.6	40	0.088	12,511	9,008,015
Total generation					437,275,663

Table A.10.9.18 Drizar I hydropower plant 36MW (wet)

	Q (m^3/s)	H (m)	eff = $kW/m^3/s$	kW	kWh
Oct	76.9	16	0.035	9,717	6,996,073
Nov	185.0	16	0.035	23,382	16,835,154
Dec	304.2	16	0.035	38,452	27,685,341
Jan	299.8	16	0.035	37,894	27,283,865
Feb	242.3	16	0.035	30,621	22,047,443
Mar	193.3	16	0.035	24,435	17,593,351
Apr	259.9	16	0.035	32,855	23,655,766
May	194.2	16	0.035	24,542	17,670,230
Jun	84.9	16	0.035	10,733	7,727,459
Jul	49.6	16	0.035	6,268	4,513,137
Aug	34.0	16	0.035	4,298	3,094,387
Sep	38.5	16	0.035	4,872	3,507,937
Total generation					178,610,143

Table A.10.9.19 Drizar II hydropower plant 36MW (wet)

	Q (m^3/s)	H (m)	eff = kW/m^3/s	kW	kWh
Oct	77.1	16	0.035	9,750	7,019,971
Nov	185.7	16	0.035	23,470	16,898,123
Dec	305.4	16	0.035	38,603	27,794,042
Jan	301.0	16	0.035	38,044	27,391,406
Feb	243.2	16	0.035	30,738	22,131,653
Mar	194.0	16	0.035	24,527	17,659,666
Apr	260.9	16	0.035	32,976	23,742,456
May	194.8	16	0.035	24,629	17,732,769
Jun	85.2	16	0.035	10,770	7,754,058
Jul	49.7	16	0.035	6,288	4,527,506
Aug	34.1	16	0.035	4,311	3,103,699
Sep	38.7	16	0.035	4,887	3,518,851
Total generation					179,274,200

Table A.10.9.20 Gjonca hydropower plant 37.1MW (wet)

	Q (m^3/s)	H (m)	eff = kW/m^3/s	kW	kWh
Oct	78.7	15	0.033	9,322	6,712,182
Nov	189.9	15	0.033	22,500	16,200,144
Dec	312.8	15	0.033	37,065	26,686,527
Jan	308.3	15	0.033	36,532	26,303,213
Feb	248.8	15	0.033	29,488	21,231,233
Mar	198.5	15	0.033	23,520	16,934,240
Apr	266.6	15	0.033	31,594	22,747,693
May	198.9	15	0.033	23,573	16,972,392
Jun	86.9	15	0.033	10,300	7,415,672
Jul	50.6	15	0.033	6,001	4,320,799
Aug	34.7	15	0.033	4,108	2,957,766
Sep	39.3	15	0.033	4,661	3,356,204
Total generation					171,838,066

10.10 Cashflow and NPV risk analysis

Pellumbari HPP 22MW

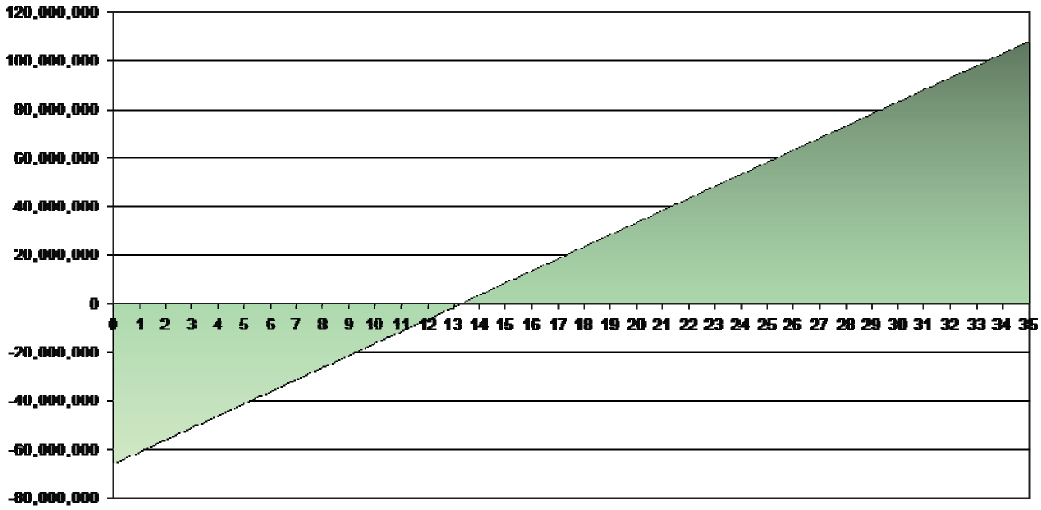


Figure A.10.10.1- Pellumbari HPP - Cashflow

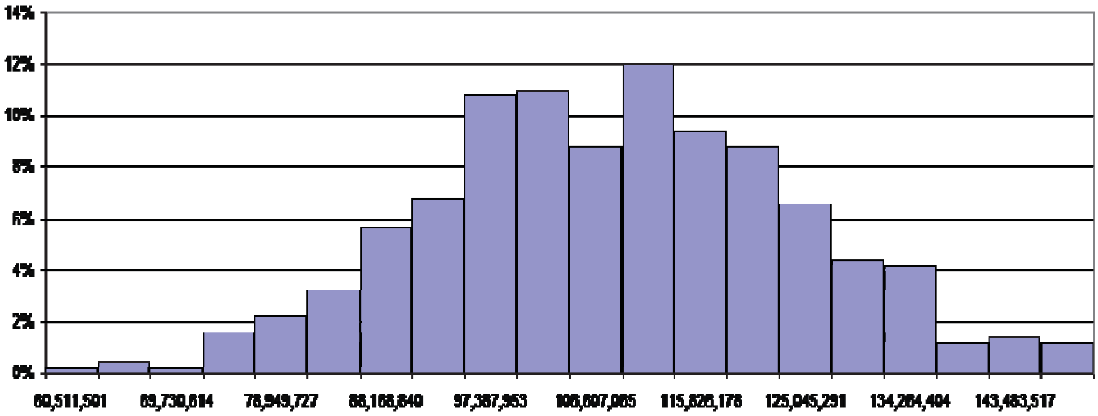


Figure A.10.10.2- Pellumbari HPP – NPV risk analysis (5%)

Kaludh HPP 18MW

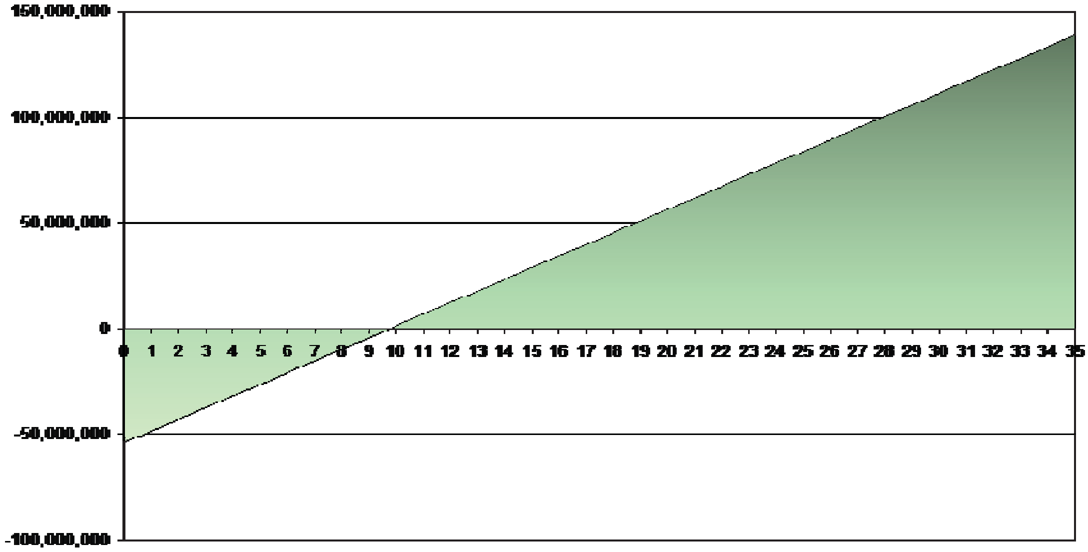


Figure A.10.10.3- Kaludh HPP – Cashflow

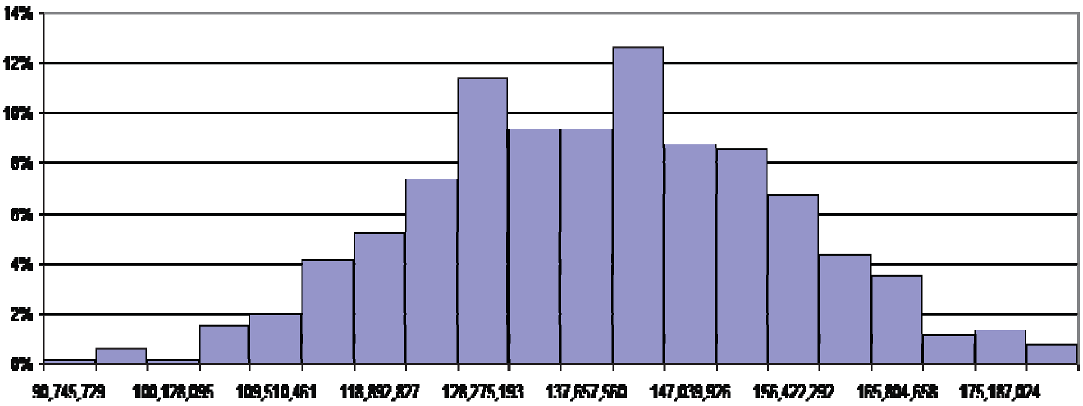


Figure A.10.10.4- Kaludh HPP – NPV risk analysis (5%)

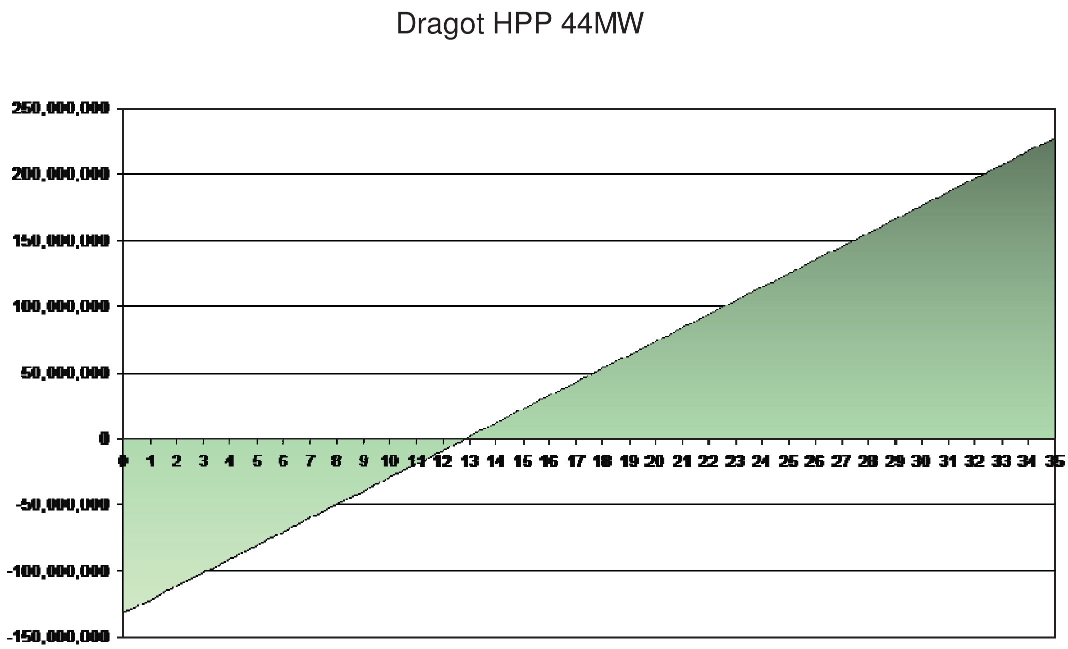


Figure A.10.10.5- Dragot HPP – Cashflow

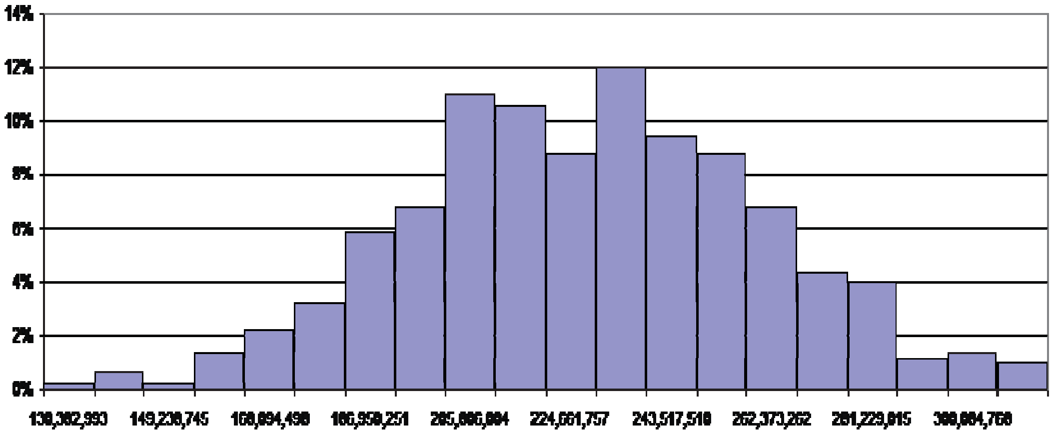


Figure A.10.10.6- Dragot HPP – NPV risk analysis (5%)

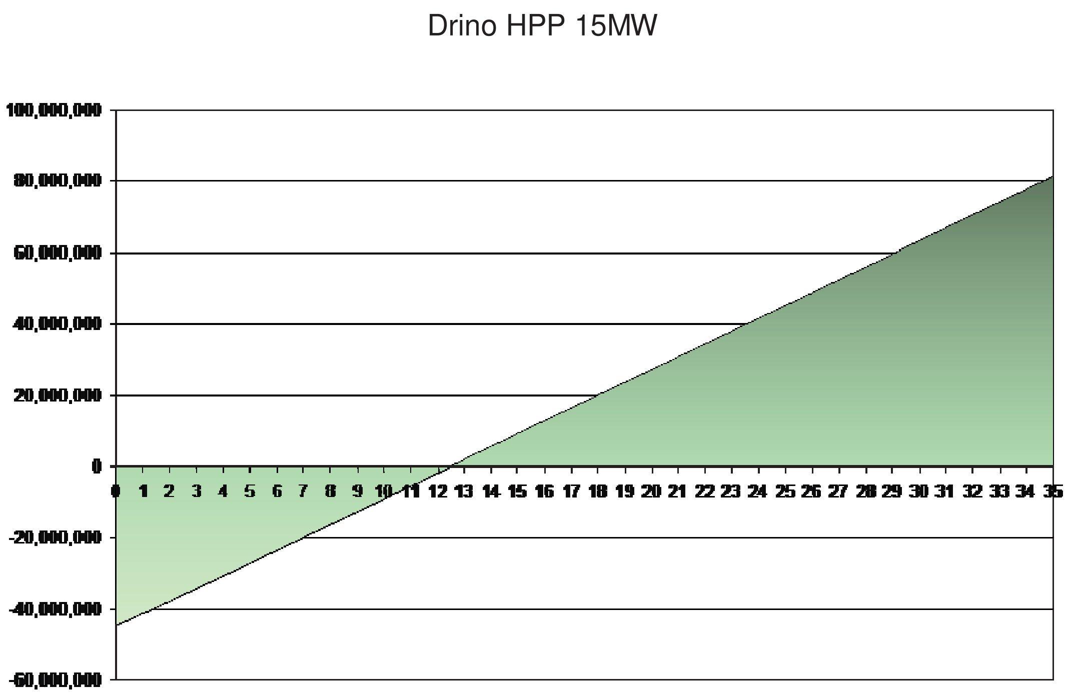


Figure A.10.10.7- Drino HPP – Cashflow

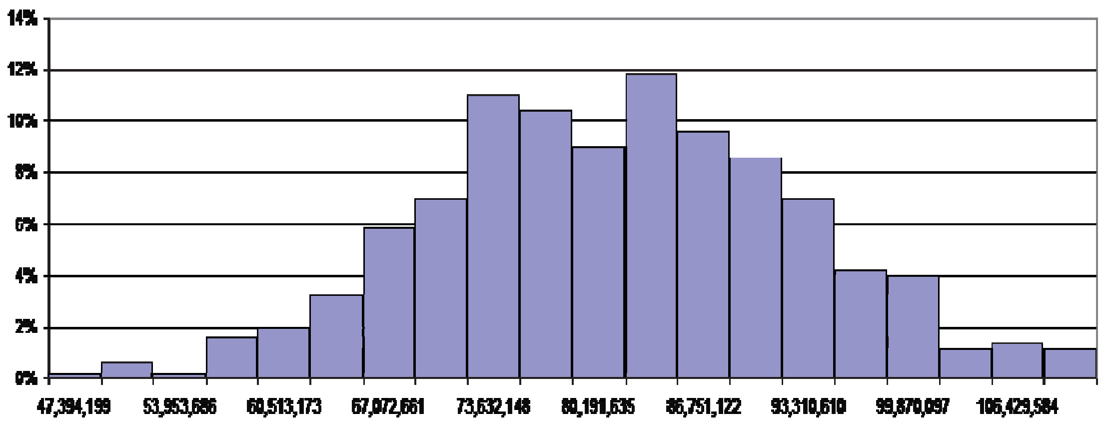


Figure A.10.10.8- Drino HPP – NPV risk analysis (5%)

Memaliaj HPP 29.5MW

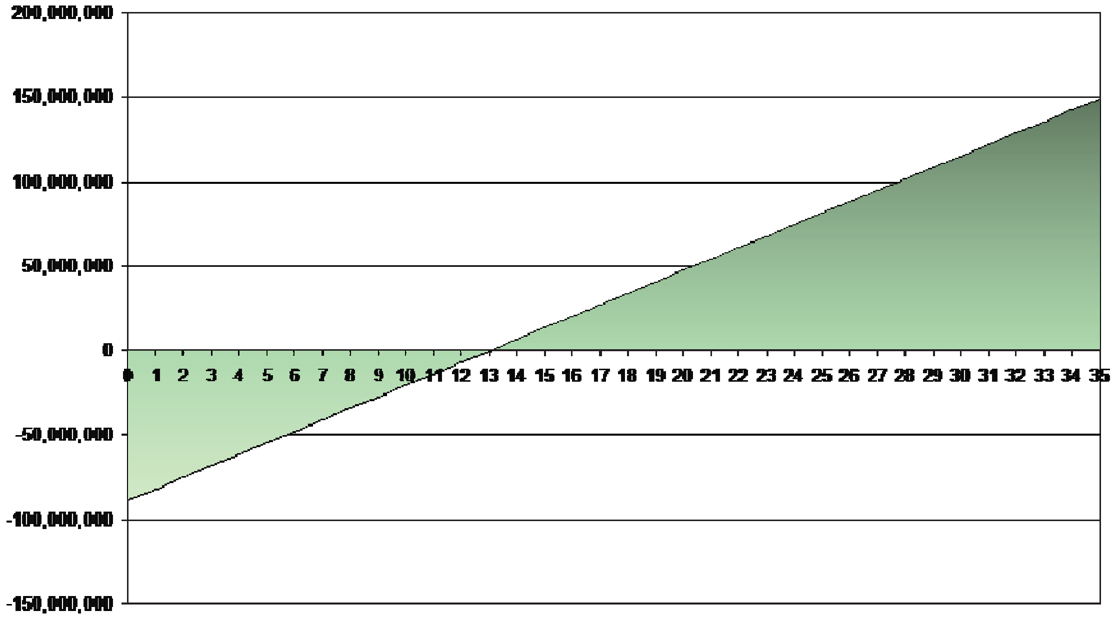


Figure A.10.10.9- Memaliaj HPP – Cashflow

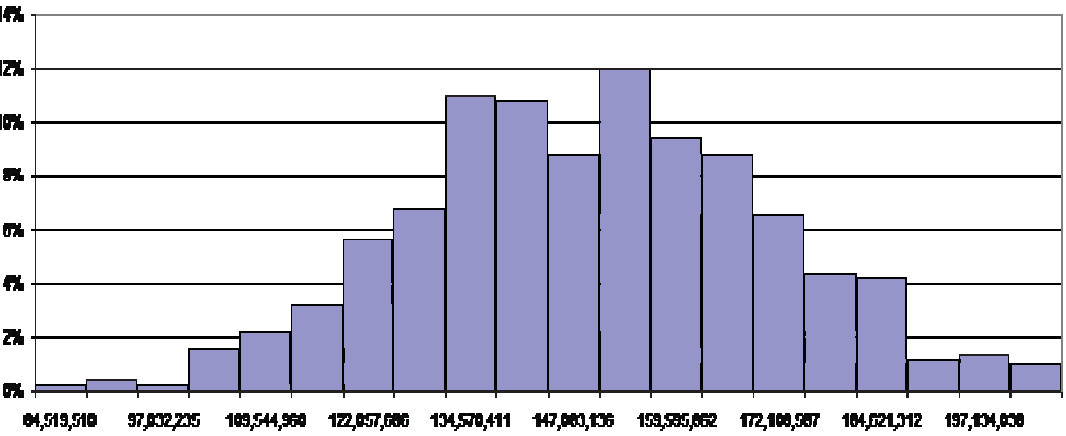


Figure A.10.10.10- Memaliaj HPP – NPV risk analysis (5%)

Kalivac bis HPP 10.2MW

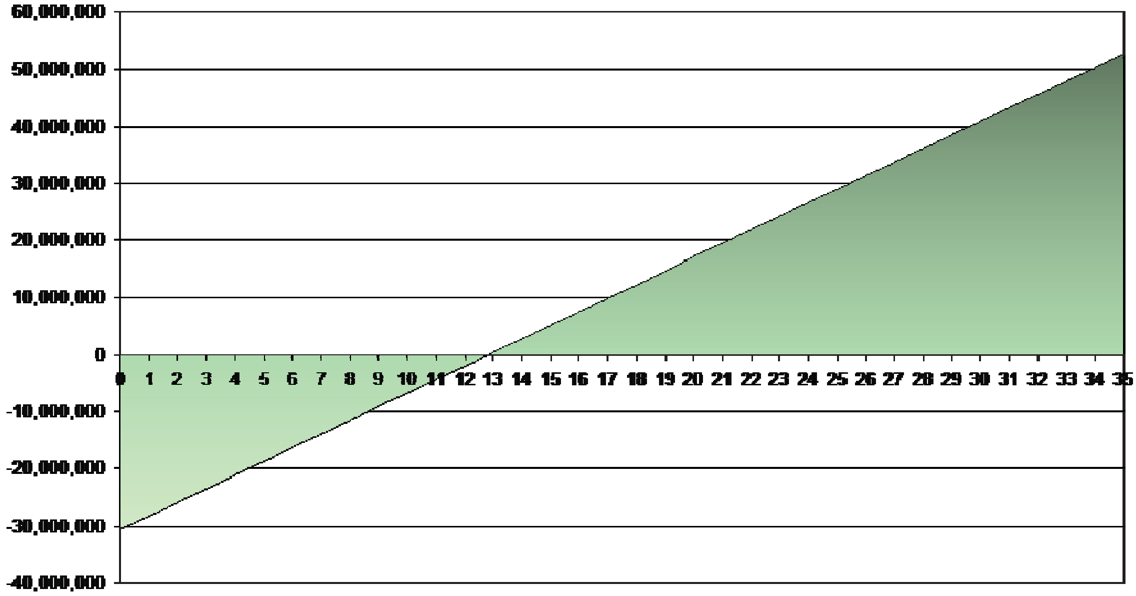


Figure A.10.10.11- Kalivac bis HPP – Cashflow

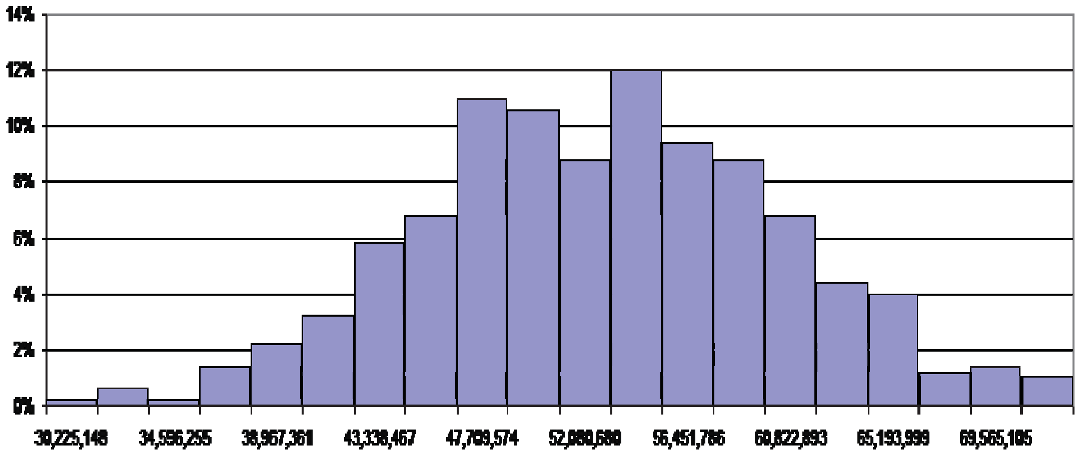


Figure A.10.10.12- Kalivac bis HPP – NPV risk analysis (5%)

Dorza HPP 85MW

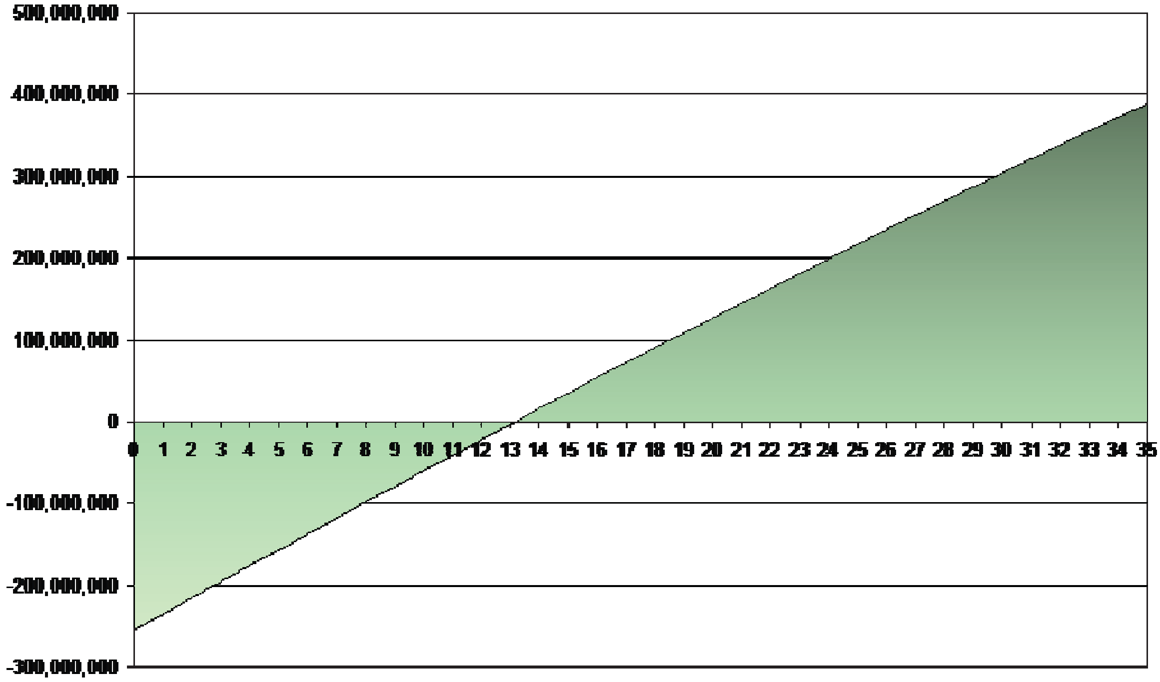


Figure A.10.10.13- Dorza HPP – Cashflow

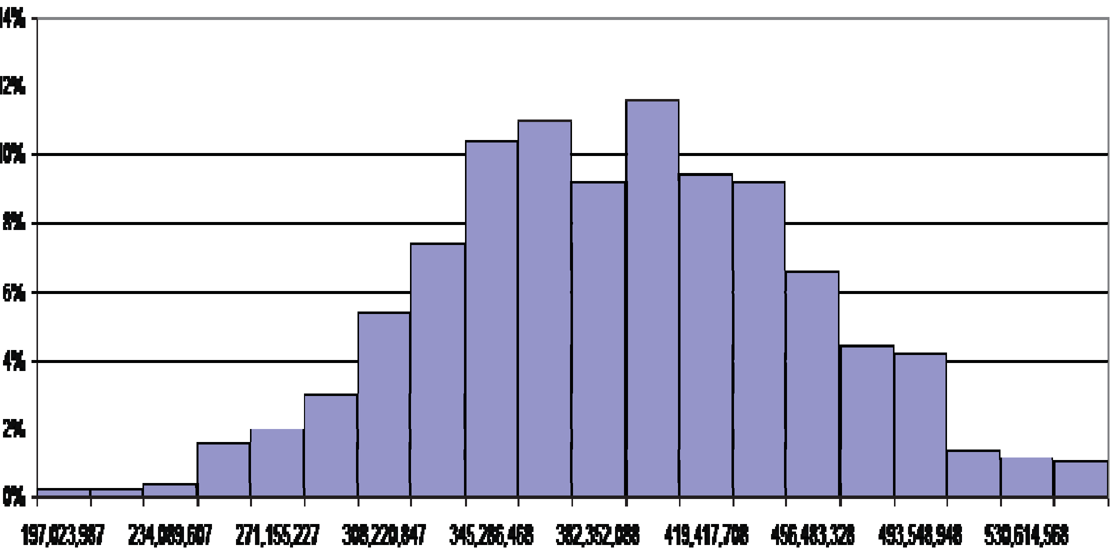


Figure A.10.10.14- Dorza HPP – NPV risk analysis (5%)

Drizar I HPP 36.5MW

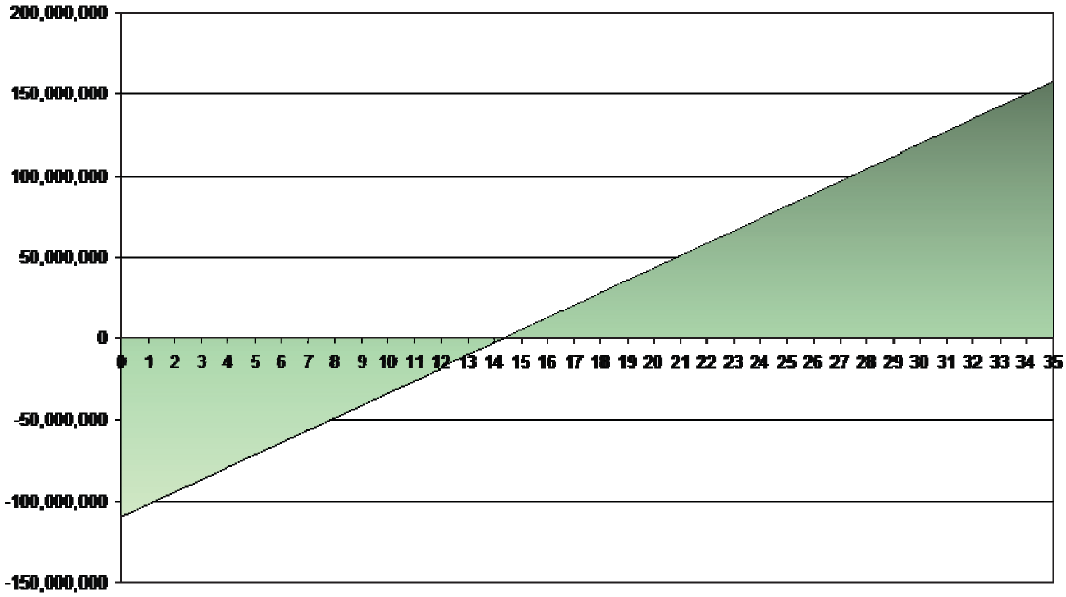


Figure A.10.10.15- Drizar I HPP – Cashflow

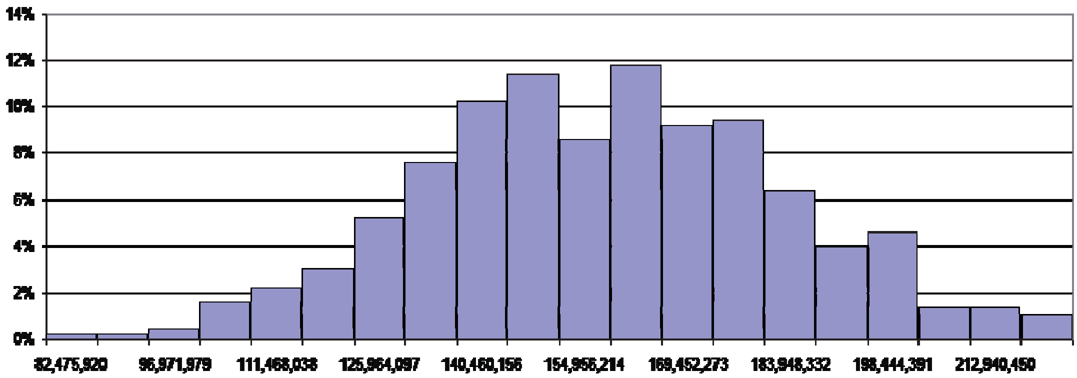


Figure A.10.10.16- Drizar I HPP – NPV risk analysis (5%)

Drizar II HPP 36.5MW

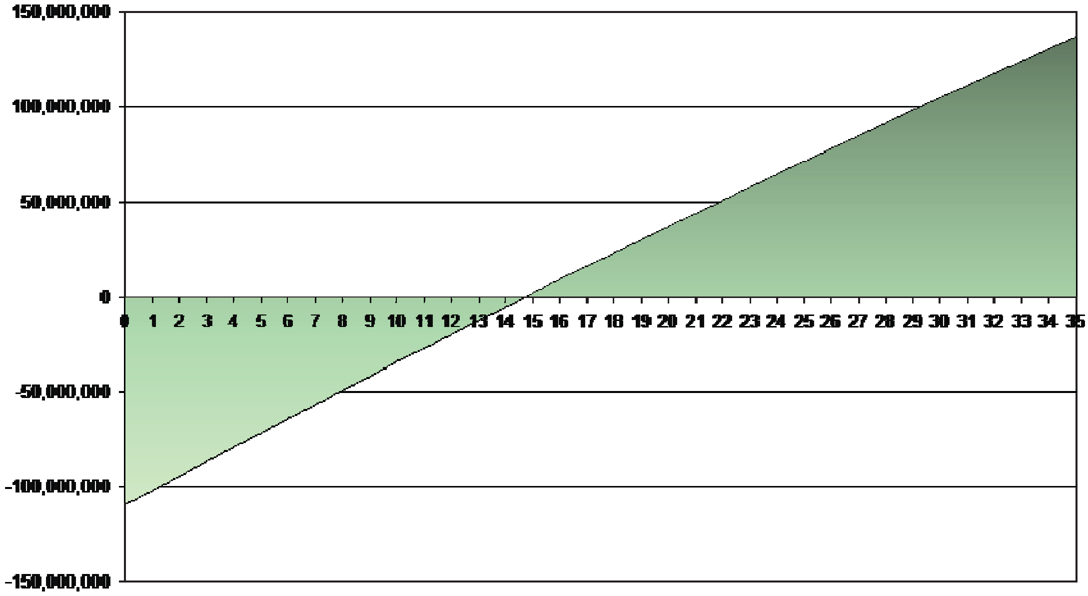


Figure A.10.10.17- Drizar II HPP – Cashflow

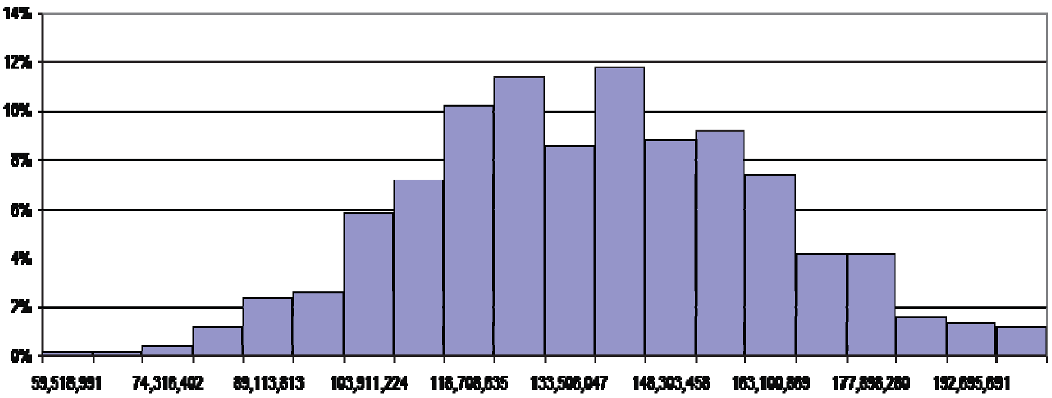


Figure A.10.10.18- Drizar II HPP – NPV risk analysis (5%)

Gjonca HPP 35MW

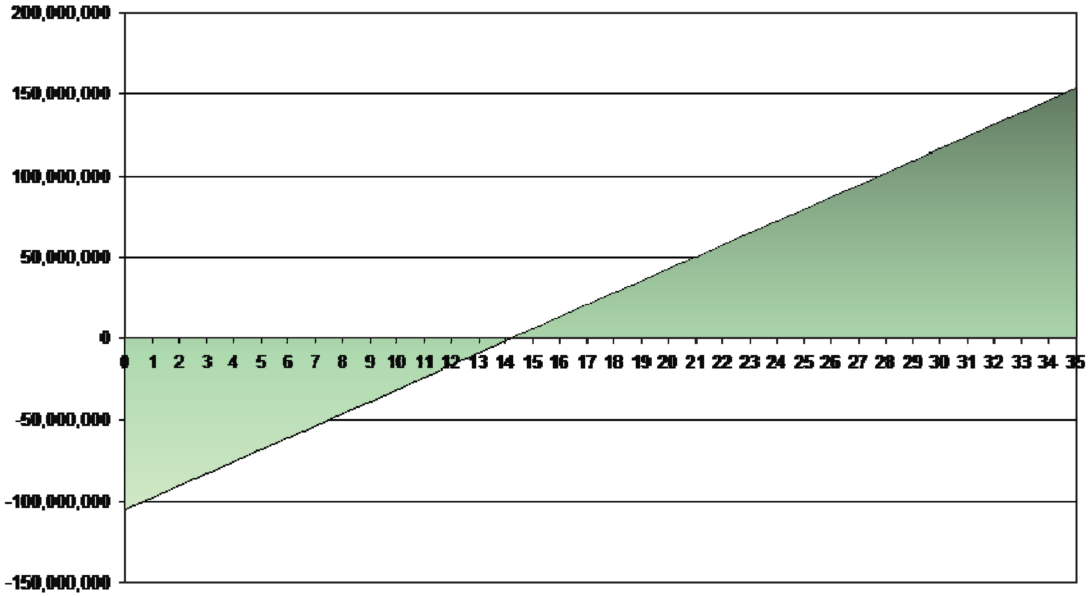


Figure A.10.10.19- Gjonca HPP – Cashflow

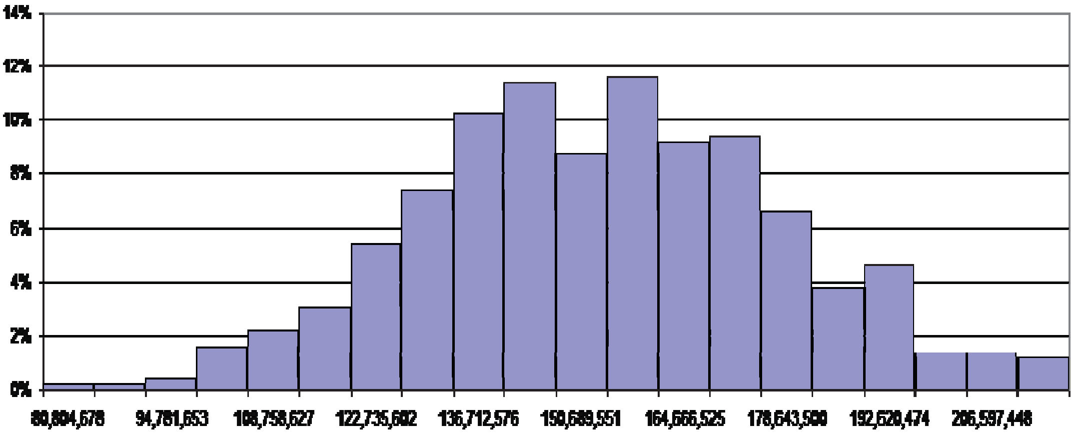


Figure A.10.10.20- Gjonca HPP – NPV risk analysis (5%)

Vjosa I HPP 10.2MW

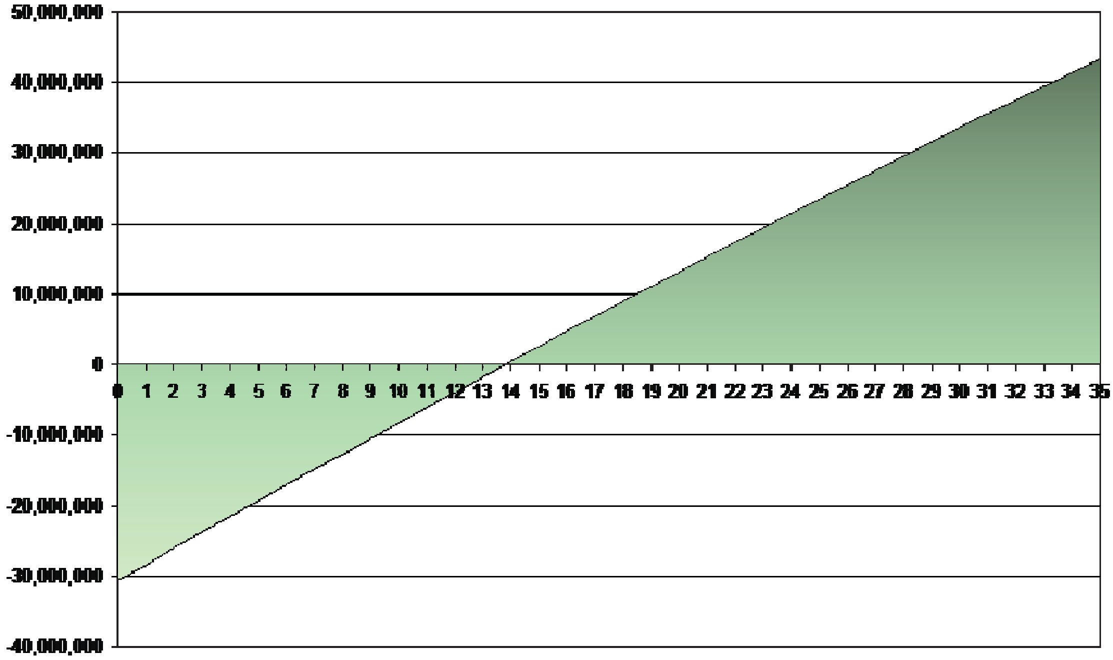


Figure A.10.10.21- Vjosa I HPP – Cashflow

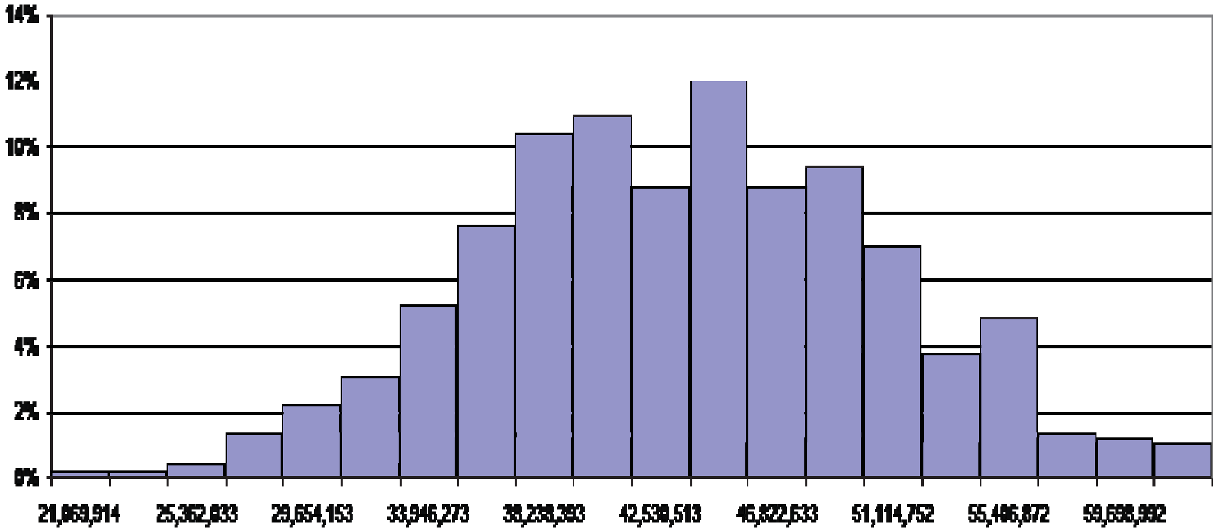


Figure A.10.10.22- Vjosa I HPP – NPV risk analysis (5%)

Vjosa II HPP 32.8MW

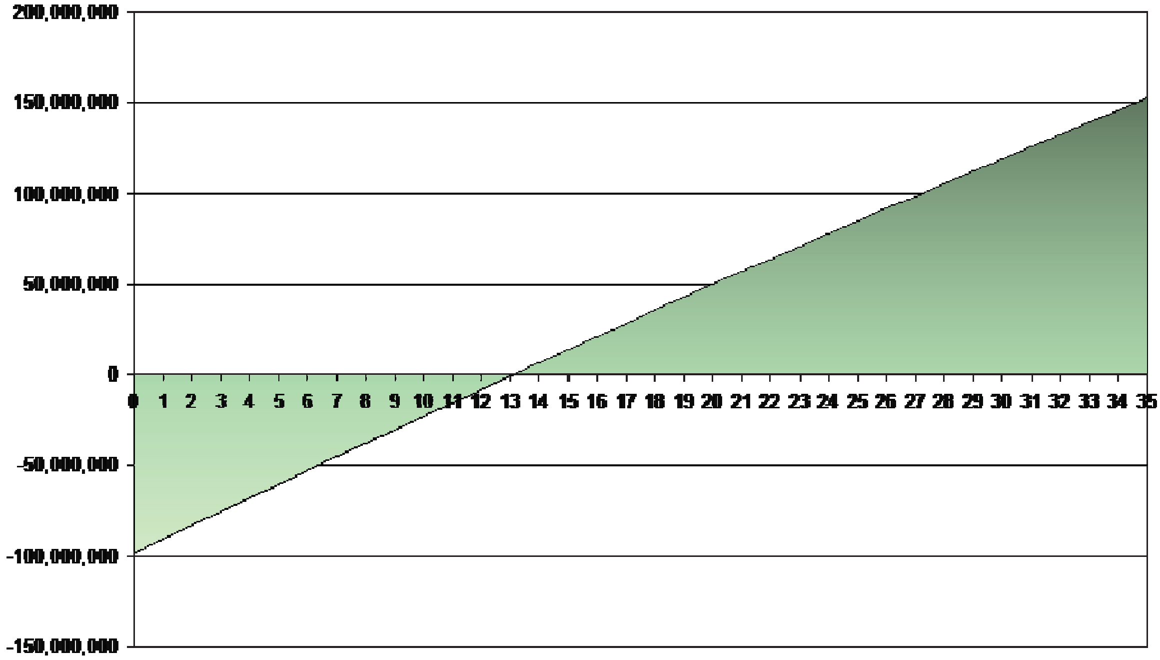


Figure A.10.10.23- Vjosa II HPP – Cashflow

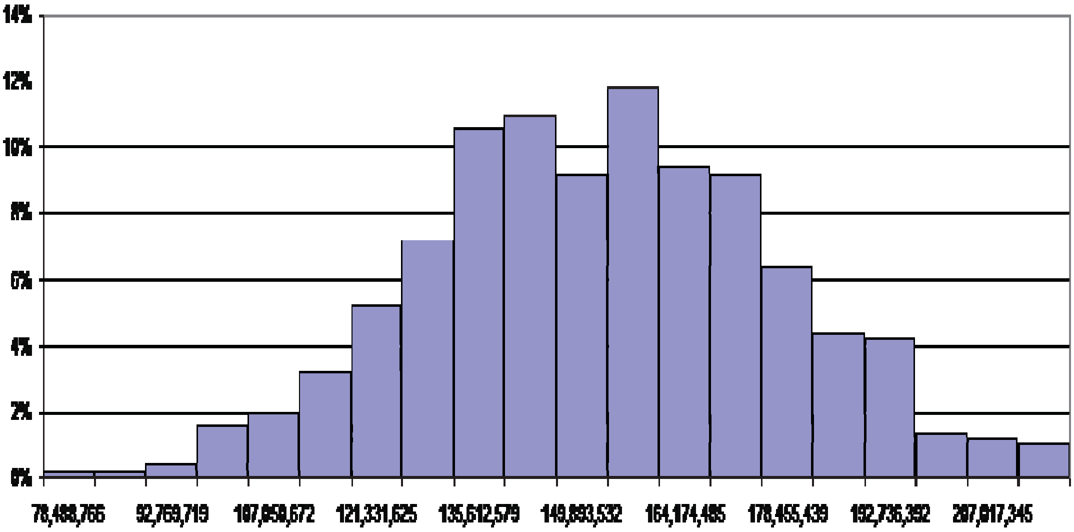


Figure A.10.10.24- Vjosa II HPP – NPV risk analysis (5%)

Vjosa III HPP 24.6MW

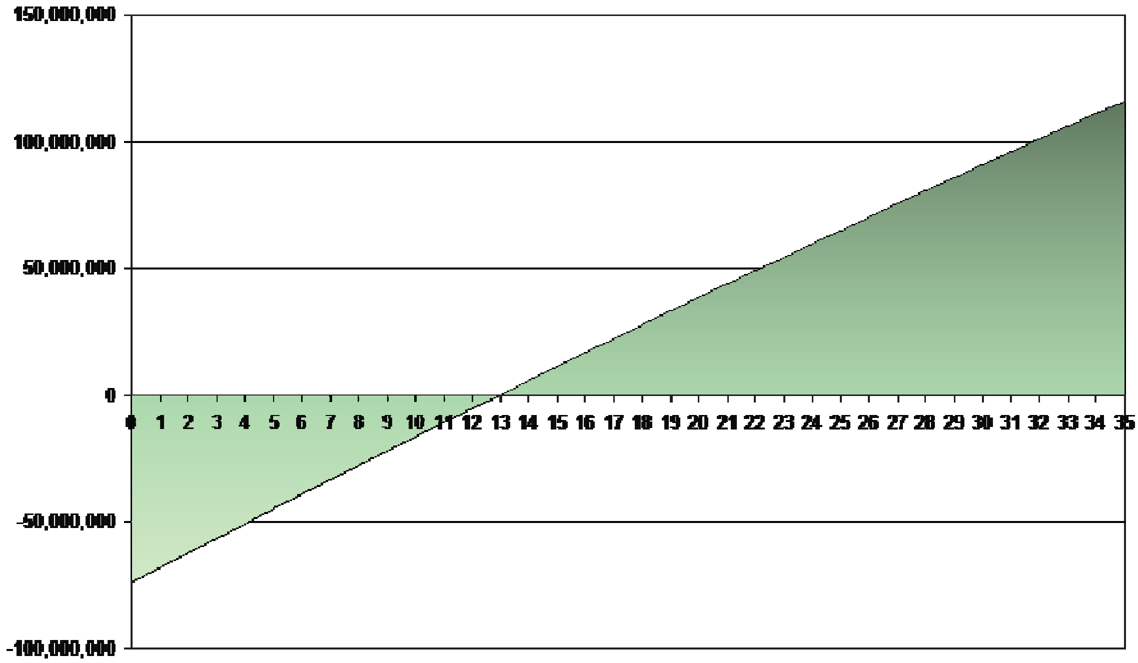


Figure A.10.10.25- Vjosa III HPP – Cashflow

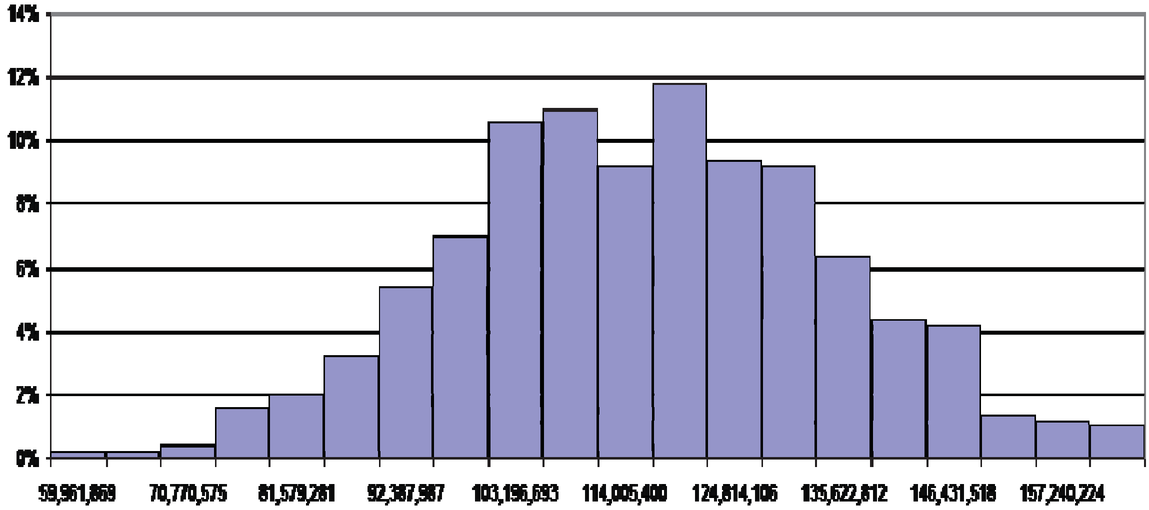


Figure A.10.10.26- Vjosa III HPP – NPV risk analysis (5%)

10.11 Hydropower plant sites map

Figure A.10.11.1- Pellumbari 22MW and Kaludh 18MW HPPs

Figure A.10.11.2- Dragot 44MW HPP

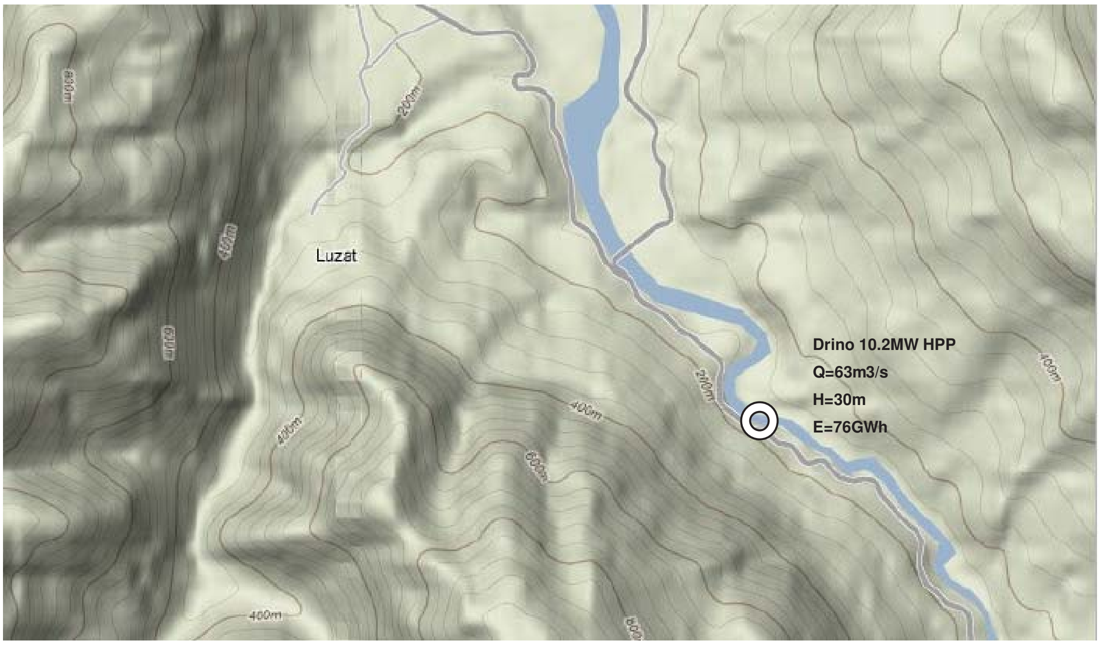


Figure A.10.11.3- Drino 15MW HPP

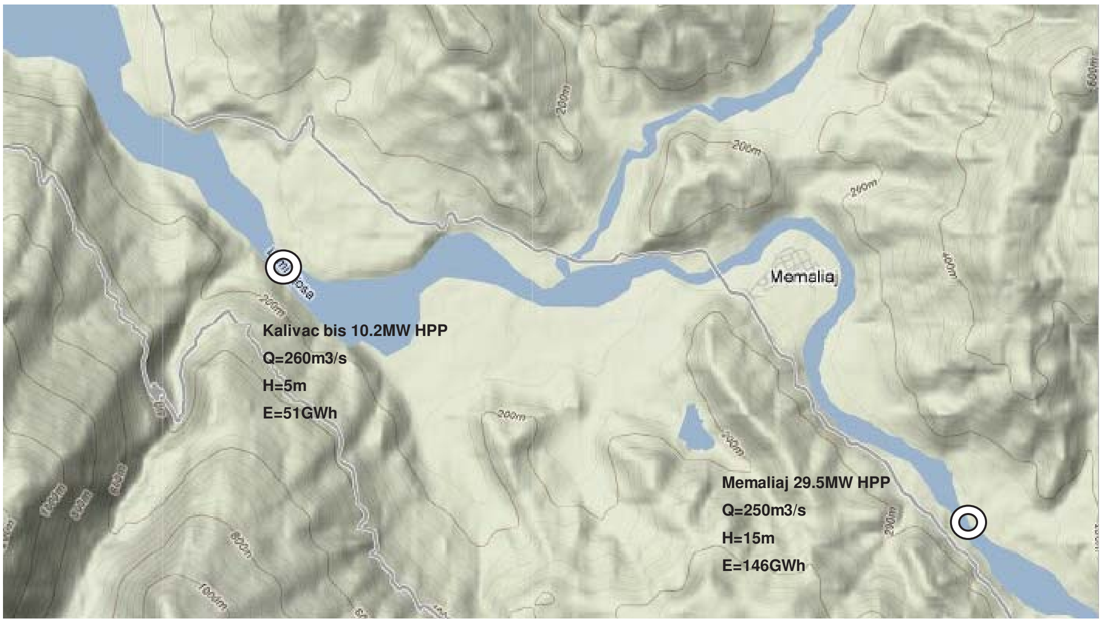


Figure A.10.11.4- Memaliaj 29.5MW and Kalivac bis 10.2MW HPPs

Figure A.10.11.5- Dorza 85MW HPP

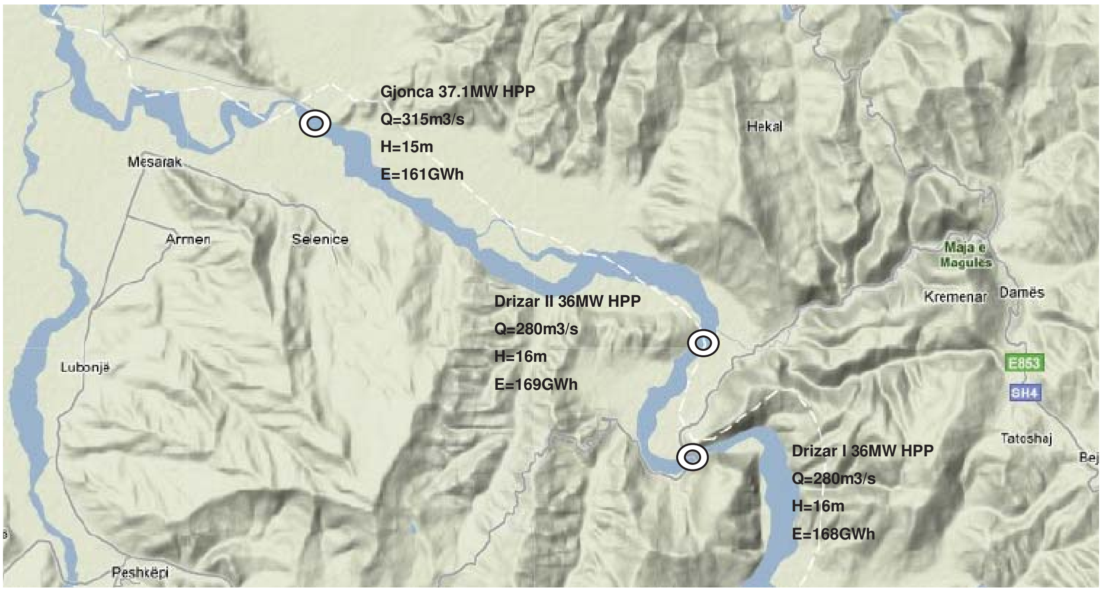
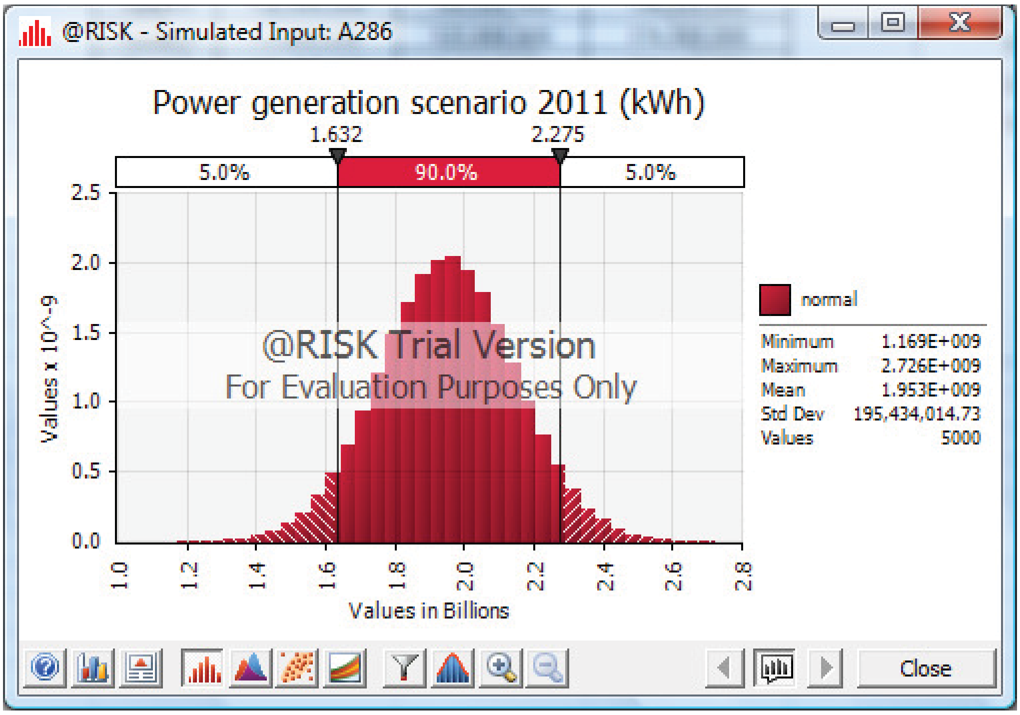


Figure A.10.11.6- Drizar I 36MW, Drizar II 36MW and Gjonca 37.1MW HPPs

10.12 Montecarlo simulation scenarios

- Power generation scenario on 2011



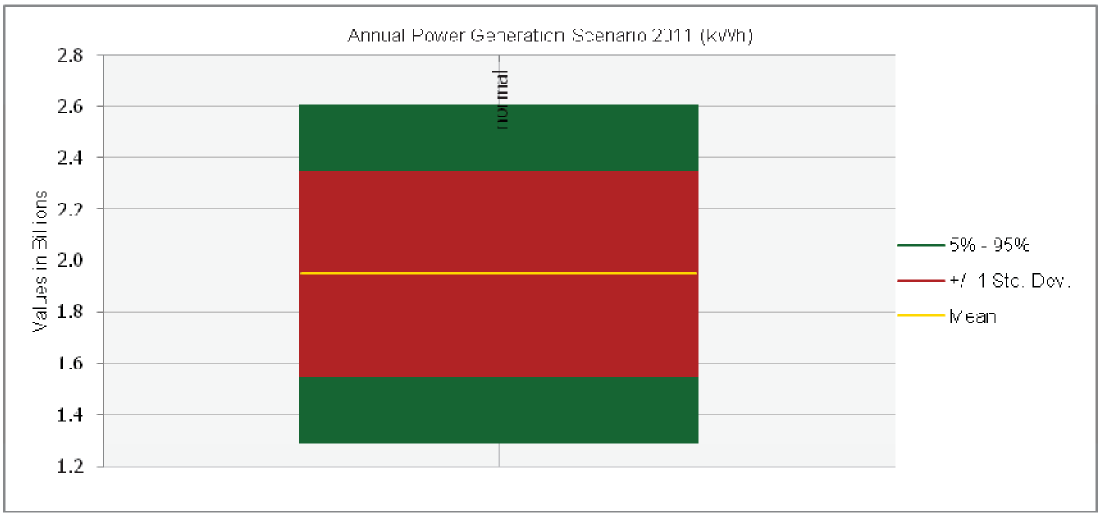


Figure A.10.12.1- Power generation scenario on 2011 by normal Montecarlo simulation using Palisade @Risk Industrial 5.7 evaluation software version

- Power generation scenario on 2050

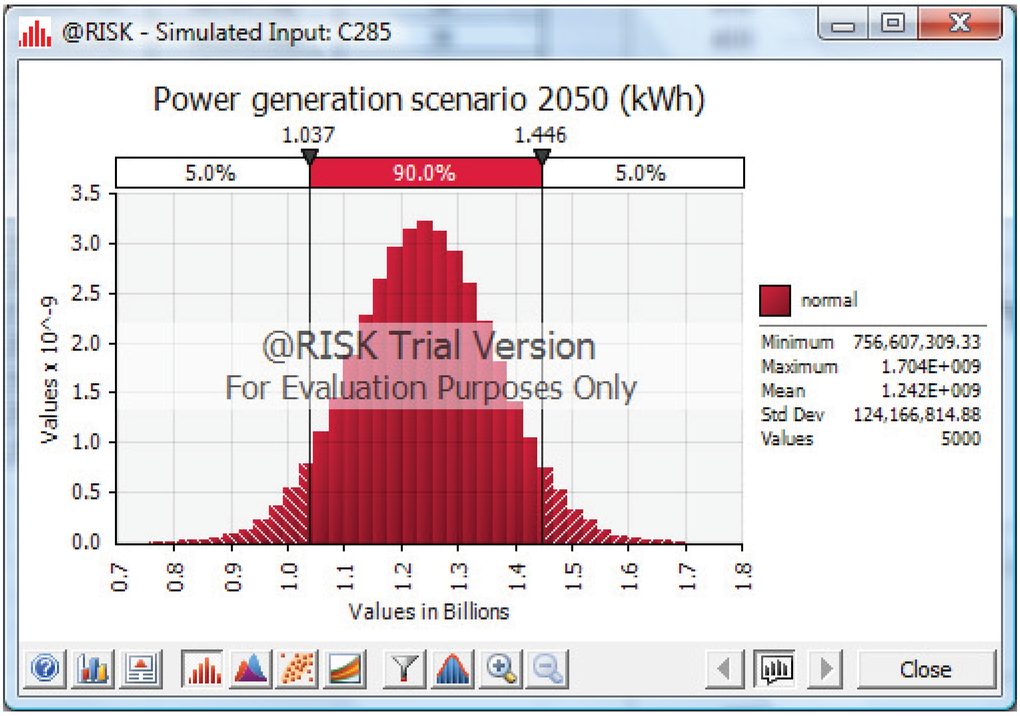


Figure A.10.12.2- Power generation scenario on 2050 by normal Montecarlo simulation using Palisade @Risk Industrial 5.7 evaluation software version

10.13 DFEM with New LocClim data

"New Local Climate Estimator 1.10 (LocClim) is a software tool designed for the interpolation of agroclimatic data, offering the possibility of producing local climate data from the regional stations. Where the station data are unavailable, new LocClim gives the average monthly climate conditions (8 variables) taken from the agroclimatic database of the Agromet Group of the Food and Agriculture Organisation of the United Nations." (LocClim 1.10 User manual 2006).

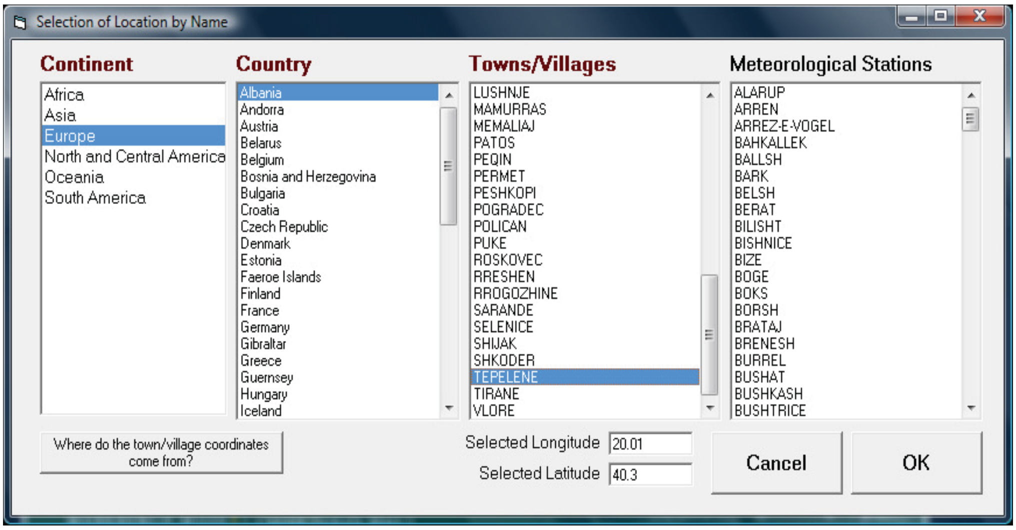


Figure A.10.13.1- New Local Climate Estimator 1.10 tool

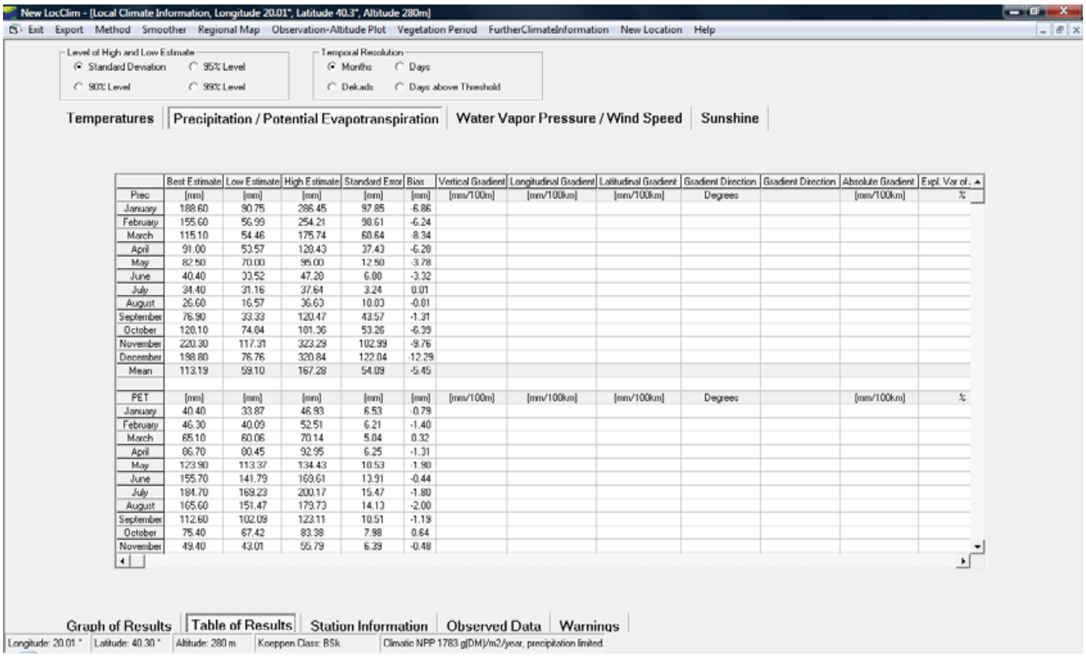


Figure A.10.13.2- New LocClim 1.10 with monthly precipitation and ETp data

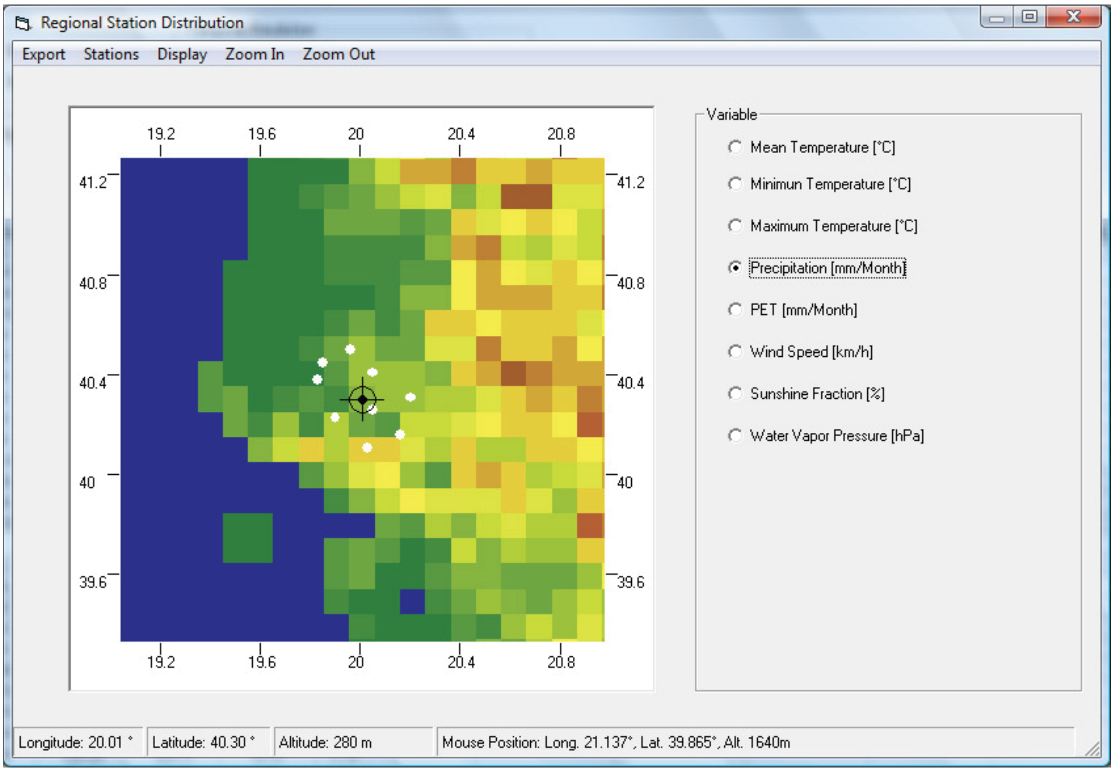


Figure A.10.13.3- New LocClime 1.10 with precipitation regional station distribution

The site data of the precipitation (mm), the air temperature (°C), the solar radiation and the potential evapotranspiration Etp (mm) should be put in the DFEM input data rows respectivelly as is shown in the follow Figures A.10.1.1 and A.10.13.4.

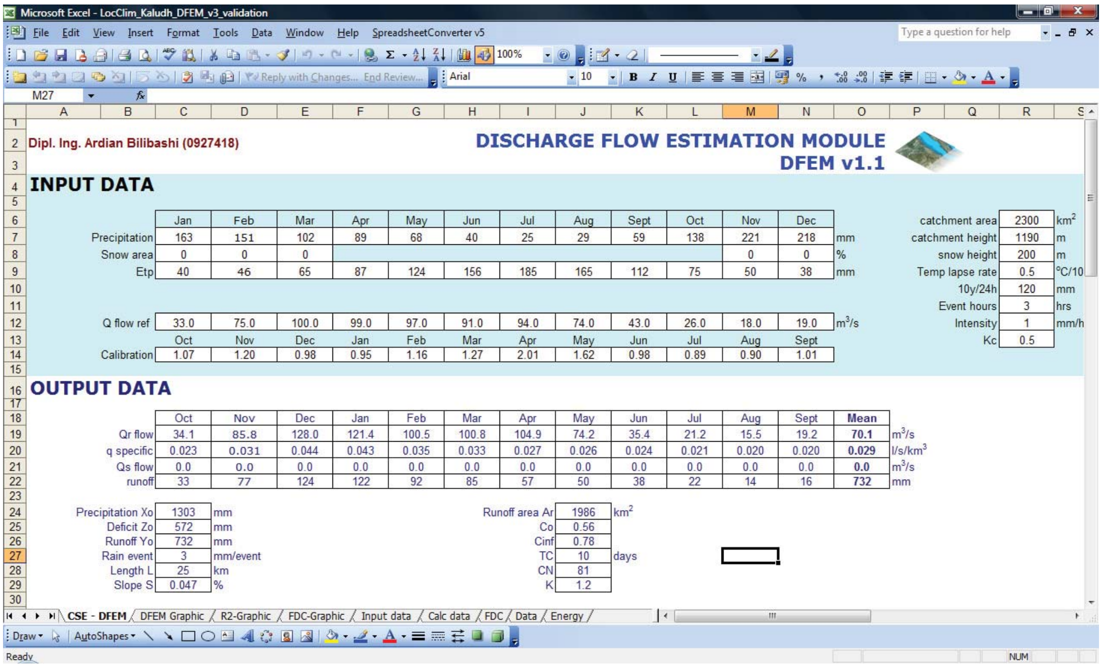


Figure A.10.13.4- DFEM module with monthly precipitation and ETp input data

Another application is to use the database of SamSamWater website where the site location is defined directly to Google Map or by its coordinates (latitude, longitude and altitude). The results are the interpolation data of the precipitation (mm) and the potential evatranspiration ETp (mm). In this case, it is given only the regional data and these are the DFEM input data.

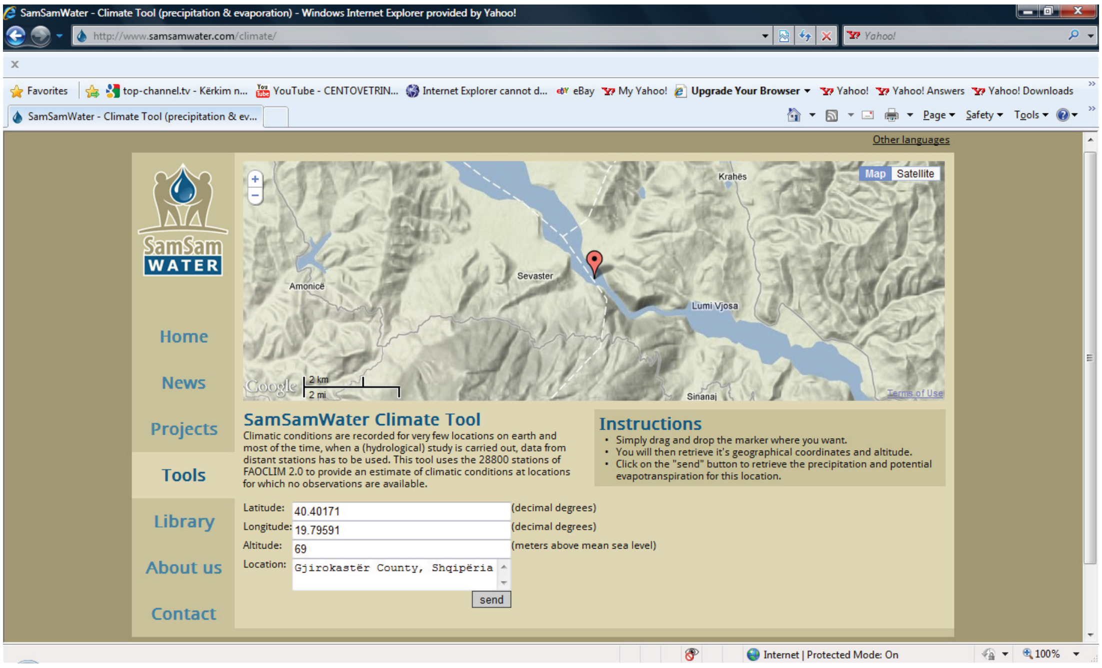


Figure A.10.13.5- SamSamWater website at Dorza site

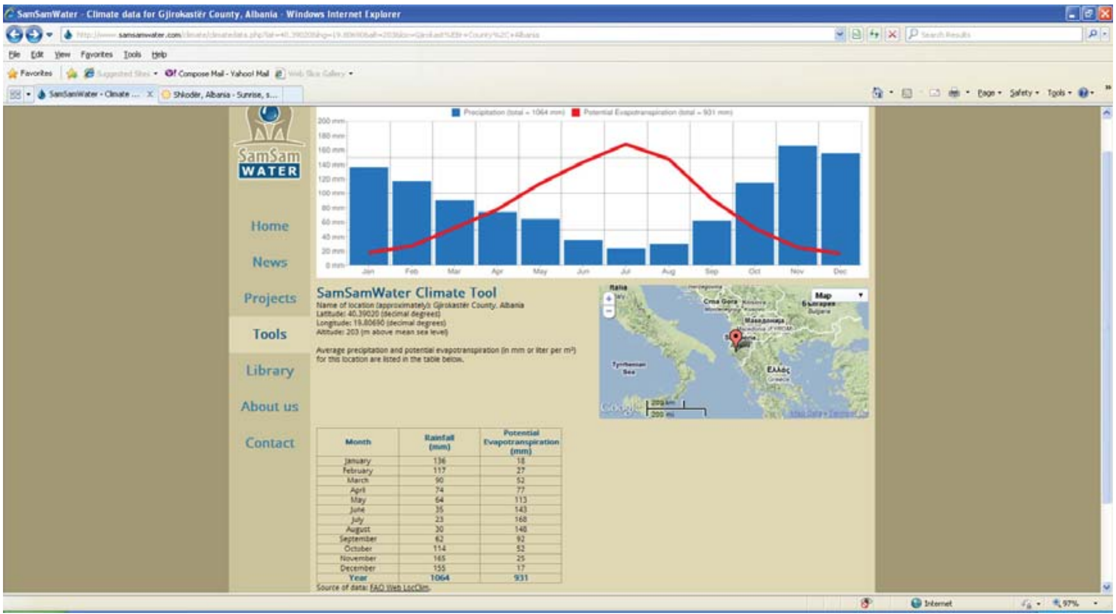


Figure A.10.13.6- SamSamWater website with the monthly precipitation and potential evatranspiration ETp input data at Dorza site

In general, the procedure to estimate the discharge water flow with DFEM module is as follows:

- define the site and the catchment area (by Google Map and Global Mapper),
- chose the regional stations of the catchment area,
- copy the data (precipitation, temperature, radiation and evatranspiration ETp),
- past the data to the input data rows of the DFEM module,
- get the results in the table and graphical form.

Using DFEM module and LocClim 1.10 tool, it is estimated the discharge water flows of Kaludh, Dragot and Dorza sites. After the calibration with the input data of Institute of Energy, Water and Environment (IEWE) during 1960-1990, the module is filled with the new LocClim 1.10 data values (precipitation and ETp) and the discharge water flows are estimated (Q LocClime). These results are compared with the observed discharge (Q Ref) and the discharge water flow estimated using IEWE data (Q IEWE). The main “goodness of fit” values are estimated as good.

a- Kaludh site discharge water flow

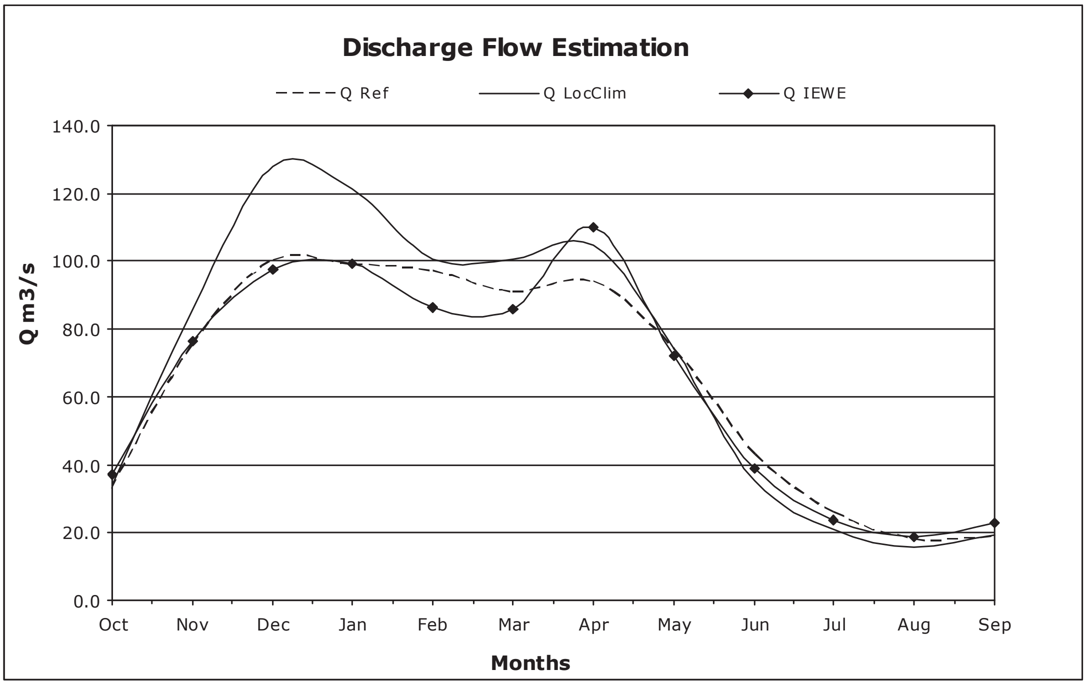


Figure A.10.13.7- Kaludh discharge flow calculated by LocClim data and compared with IEWE data

Table A.10.13.1 Kaludh discharge flow calculated by LocClim 1.10 data

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter	IEWE
Oct	34.1	33.0	-3	1.0	0	37.1
Nov	85.8	75.0	-14	0.0	0	76.7
Dec	128.0	100.0	-28	0.4	0	97.7
Jan	121.4	99.0	-23	0.6	0	99.1
Feb	100.5	97.0	-4	1.0	0	86.5
Mar	100.8	91.0	-11	0.9	0	85.9
Apr	104.9	94.0	-12	0.9	0	110.2
May	74.2	74.0	0	1.0	0	71.9
Jun	35.4	43.0	18	0.9	0	39.0
Jul	21.2	26.0	19	1.0	0	23.6
Aug	15.5	18.0	14	1.0	0	18.7
Sep	19.2	19.0	-1	1.0	0	22.7
Mean	70.1	64.1	-9	0.8	0	64.1

b- Dragot site discharge water flow

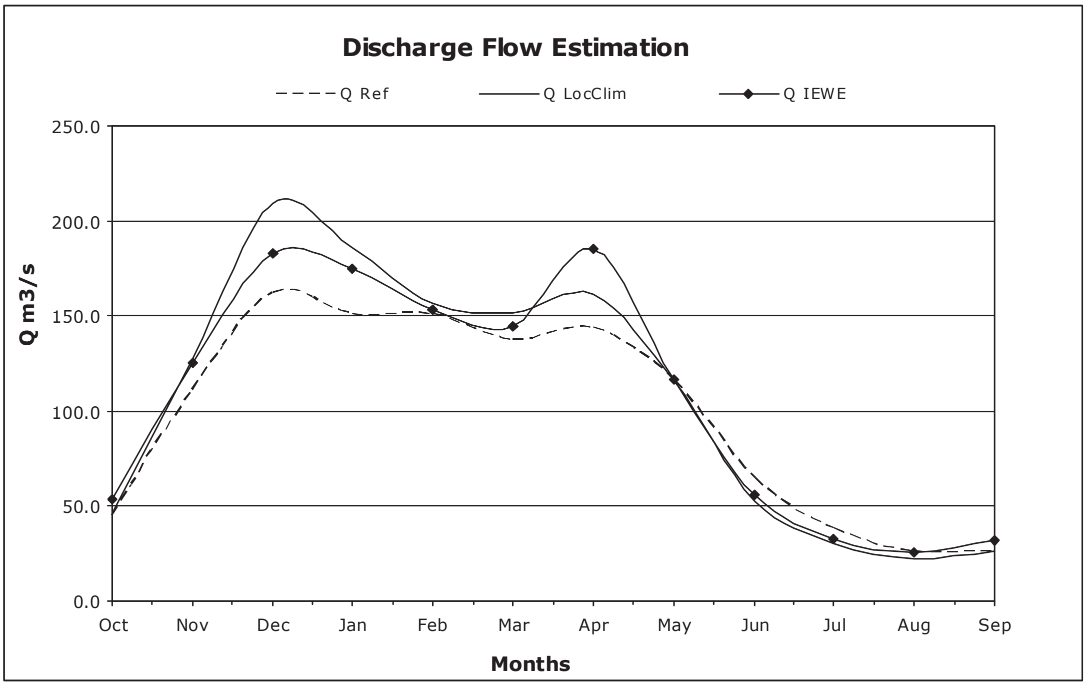


Figure A.10.13.8- Dragot discharge flow calculated by LocClim data and compared with IEWE data

Table A.10.13.2 Dragot discharge flow calculated by LocClim 1.10 data

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter	IEWE
Oct	46.6	45.0	-3	1.0	0	53.8
Nov	127.6	111.0	-15	0.0	0	125.5
Dec	208.9	162.0	-29	0.5	0	182.9
Jan	186.3	151.0	-23	0.6	0	174.6
Feb	156.2	151.0	-3	1.0	0	153.6
Mar	152.0	137.0	-11	0.9	0	144.3
Apr	161.2	144.0	-12	0.9	0	185.2
May	116.0	116.0	0	1.0	0	116.6
Jun	52.6	65.0	19	0.9	0	56.3
Jul	30.4	38.0	20	1.0	0	32.4
Aug	22.0	26.0	15	1.0	0	25.5
Sep	26.1	26.0	-1	1.0	0	31.8
Mean	107.2	97.7	-10	0.8	0	106.9

c- Dorza site discharge water flow

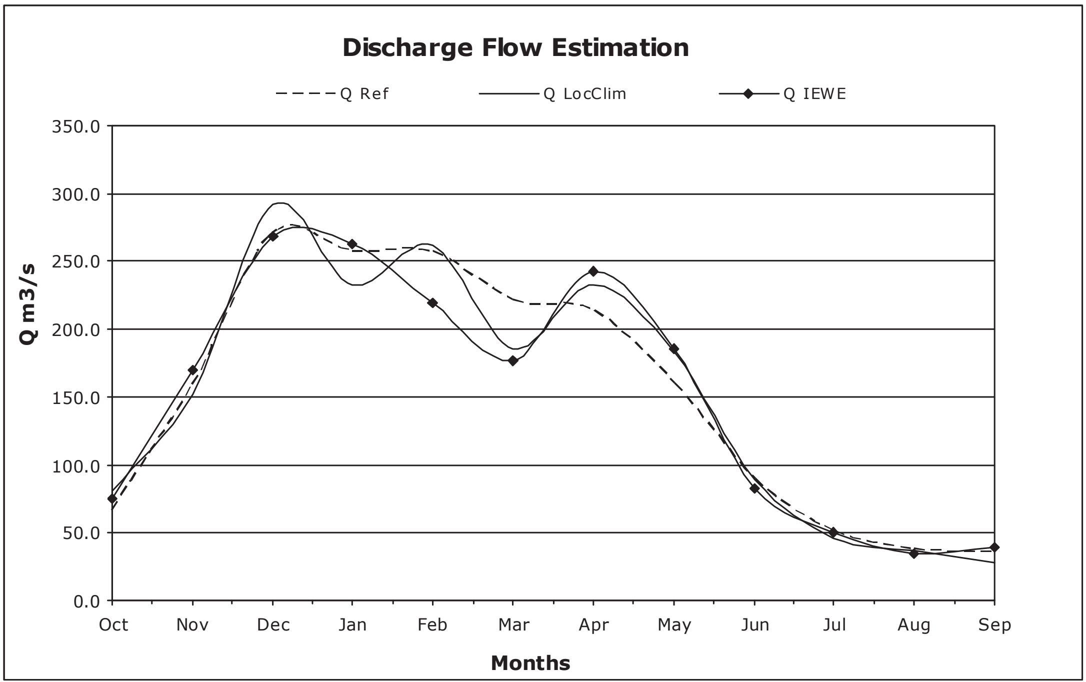


Figure A.10.13.9- Dorza discharge flow calculated by LocClim data and compared with IEWE data

Table A.10.13.1 Dorza discharge flow calculated by LocClim 1.10 data

	Q-DFEM	Q Ref	Mass error	Nash error	Shulz criter	IEWE
Oct	80.7	66.3	-22	1.0	0	74.9
Nov	152.5	158.8	4	0.2	0	170.5
Dec	292.1	270.1	-8	1.0	0	268.3
Jan	232.6	257.4	10	0.9	0	263.3
Feb	261.1	257.7	-1	1.0	0	219.5
Mar	186.1	221.6	16	0.7	0	177.1
Apr	232.3	213.4	-9	0.9	0	243.2
May	183.3	159.5	-15	0.0	0	185.7
Jun	89.7	89.3	0	1.0	0	82.4
Jul	45.6	52.0	12	1.0	0	49.8
Aug	37.4	38.0	2	1.0	0	34.8
Sep	28.5	36.0	21	1.0	0	39.0
Mean	151.8	151.7	0	0.8	0	150.7