No.

General Direction of Dam and Large Hydraulic Works
Ministry of Agriculture and Hydraulic Resources
The Republic of Tunisia

THE STUDY ON INTEGRATED BASIN MANAGEMENT FOCUSED ON FLOOD CONTROL IN MEJERDA RIVER IN THE REPUBLIC OF TUNISIA

FINAL REPORT

VOLUME-III SUPPORTING REPORT

JANUARY 2009

JAPAN INTERNATIONAL COOPERATION AGENCY

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THE STUDY
ON
INTEGRATED BASIN MANAGEMENT FOCUSED ON FLOOD CONTROL
IN
MEJERDA RIVER
IN
THE REPUBLIC OF TUNISIA

Composition of Final Report

Volume I EXECUTIVE SUMMARY

Volume II MAIN REPORT

Part 1	**General (Introduction & Current Conditions of Study Area)**	
Part 2	**Phase I Study :**	**Understanding of Present Conditions and Formulation of Framework for the Master Plan**
Part 3	**Phase II Study :**	**Formulation of the Master Plan**

Volume III SUPPORTING REPORT

Supporting Report A :	**HYDROLOGY AND HYDRAULICS**
Supporting Report B :	**WATER SUPPLY OPERATIONS**
Supporting Report C :	**RESERVOIR OPERTION**
Supporting Report D :	**RIVER IMPROVEMENT AND FLOOD PLAIN MANAGEMENT**
Supporting Report E :	**FACILITIES DESIGN AND COST ESTIMATE**
Supporting Report F :	**BASIN PRESERVATION**
Supporting Report G :	**FFWS AND EVACUATION/FLOOD FIGHTING**
Supporting Report H :	**INSTITUTION AND ORGANIZATION**
Supporting Report I :	**ECONOMICS AND FINANCE**
Supporting Report J :	**ENVIRONMENTAL AND SOCIAL CONSIDERATION**

Volume IV DATA BOOK

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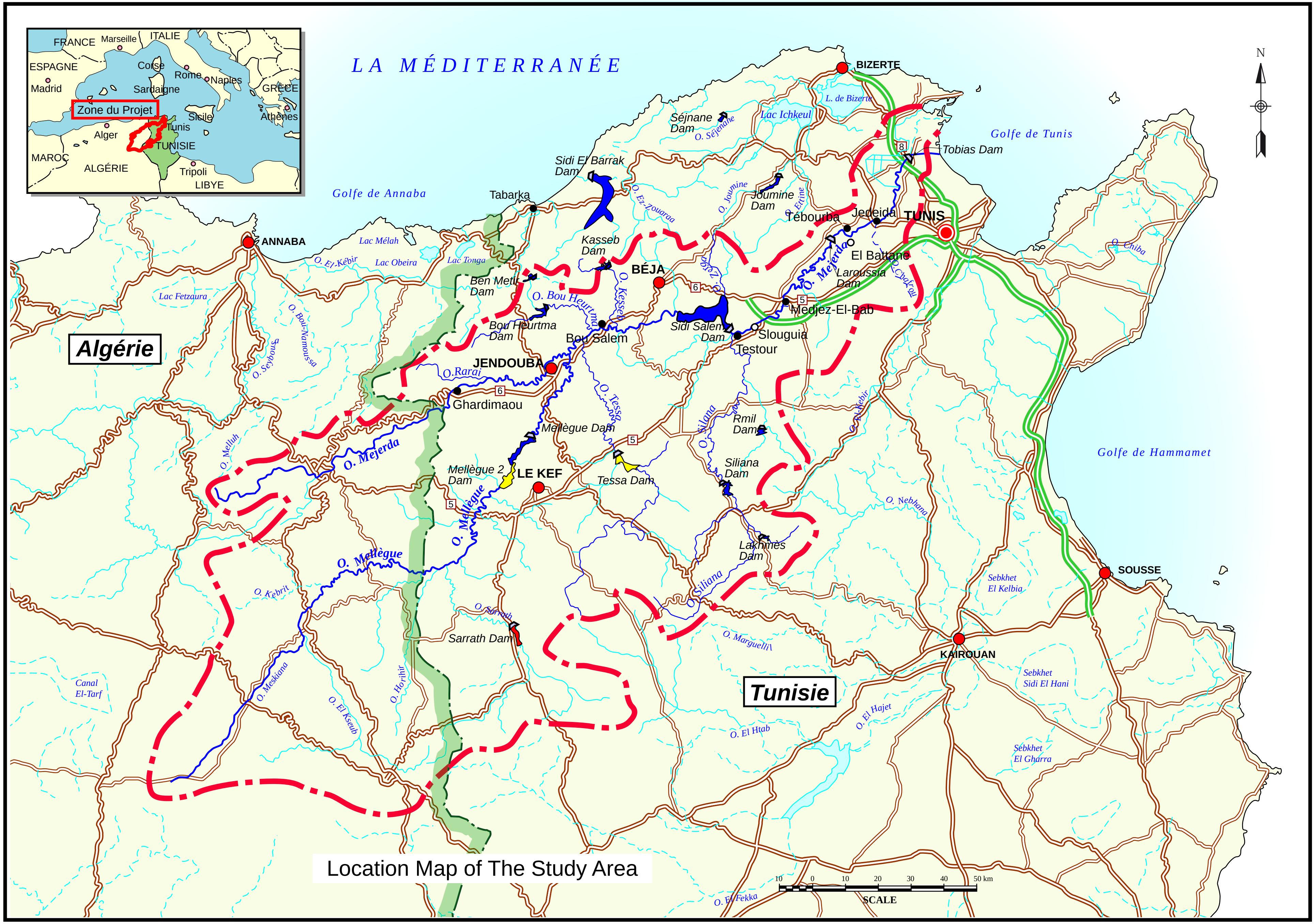

Location Map of The Study Area

ABBREVIATIONS AND GLOSSARIES

French Origin Abbreviations for Names of Tunisian Institutions

	English	French
A/CES	Soil and Water Conservation Service	Arrondissement de la Conservation des Eaux et du Sol
A/EPPI	Public Irrigated Areas Exploitation Service	Arrondissement de l'Exploitation des Périmètres Publics Irrigués
AFD	French Development Agency	l'Agence Française de Développement
A/GR	Rural Engineering Service	Arrondissement du Génie Rural
A/ME	Maintenance of Equipments Service	Arrondissement de la Maintenance des Equipements
A/RE	Water Resources Service	Arrondissement des Ressources en Eau
AVFA	Agricultural Vulgarization and Training Agency	Agence de Vulgarisation et de la Formation Agricoles
ANPE	National Agency for the Protection of the Environment (Tunisia)	Agence Nationale de Protection de l'Environnement
BIRH	Hydraulic Inventory and Research Bureau	Bureau de l'Inventaire et des Recherches Hydrauliques
BCT	Central Bank of Tunisia	Banque Centrale de la Tunisie
BPEH	Bureau of Water Planning and Hydraulic Equilibriums(MARH)	Bureau de la Planification et des Équilibres Hydrauliques (MARH)
CITET	International Centre of Environment Technologies	Centre International des Technologies de l'Environnement
CNS	The Drought National Commission	La Commission Nationale de la Sécheresse
CNE	National Water Committee	Comité National de l'Eau
CRS	The Drought Régional Commission	La Commission Régionale de la Sécheresse
CRDA	Regional Commissary for Agricultural Development	Commissariat Régional au Développement Agricole
CSS	The Drought Specialized Commission	La Commission Sectorielle de la Sècheresse
DGACTA	General Direction of Development and Preservation of Agricultural Lands (under MARH)	Direction Générale de l'Aménagement et de la Conservation des Terres Agricoles (MARH)
DGAJF	General Direction of Juridical and Land Property	Direction Générale des Affaires Juridiques et Foncières (MARH)
DGBGTH	General Direction of Dams and Large Hydraulic Works (under MARH)	Direction Générale des Barrages et des Grands Travaux Hydrauliques (MARH)
DGEDA	General Direction of studies and Agricultural Development (under MARH)	Direction générale des ÉTUDES et du Développement Agricole (MARH)
DGEQV	General Direction of Environment and Life Quality (under MEDD)	Direction Générale de l'Environnement et de la Qualité de la Vie (MEDD)

	English	French
DGF	General Direction of Forests (under MARH)	Direction Générale des Forêts (MARH)
DGGREE	General Direction of Rural Engineering and Water Exploitation (under MARH)	Direction Générale du Génie Rural et de l'Exploitation des Eaux (MARH)
DGFIOP	General Direction of Financing, Investments and Professional Organisms (under MARH)	Direction Générale du Financement, des Investissements et des Organismes Professionnels (MARH)
DGPA	General Direction of Agriculture Production (under MARH)	Direction Générale de la Production Agricole (MARH)
DGPCQPA	General Direction of Agricultural Product Quality Control and Protection (under MARH)	Direction Générale de la Protection et du Contrôle de la Qualité des Produits Agricoles (MARH)
DGRE	General Direction of Water Resources (under MARH)	Direction Générale des Ressources en Eau (MARH)
DGSV	General Direction of Veterinary Services (under MARH)	Direction Générale des Services Vétérinaires (MAHR)
DHMPE	Direction of Surrounding Hygiene and Environment Protection	Direction de l'Hygiène du Milieu et de la Protection de l'Environnement
DTIS	Direction of the Scientific Information Processing	Direction du Traitement de l'Information Scientifique
GIC	Collective Interest Organizations	Groupements d'Intérêt Collectif
INAT	National Agronomical Institute of Tunisia (under MARH)	Institut National Agronomique de Tunisie
INM	National Institute of Meteorology (under Ministry of Transportation)	Institut National de la Météorologie (MT)
INS	National Statistics Institute	Institut National de la Statistique
INRGREF	National Research Institute for Rural Engineering, Water and Forestry (MARH)	Institut National de Recherche en Génie Rural, Eaux et Forêt
IRESA	Institution of Agricultural Research and Education	Institution de la Recherche et de l'Enseignement Supérieur Agricole
MARH	Ministry of Agriculture and Hydraulic Resources	Ministère de l'Agriculture et des Ressources Hydrauliques
MEDD	Ministry of Environment and Sustainable Development	Ministère de l'Environnement et du Développement Durable
MEHAT	Ministry of Equipment, Housing and Country Planning	Ministère de l'Equipement de l'Habitat et de l'Aménagement du territoire
MF	Ministry of Finance	Ministère des Finances
OEP	Animal Husbandry and Pasture Agency	Office de l'Elevage et de du Pâturage
ONAS	National Sanitation Agency	Office National de l'Assainisssement
OTED	Tunisian Observatory for the Environment and Sustainable Development	Observatoire Tunisien de l'Environnement et du Développement Durable
SECADENORD	The North Water Canal, Adductions and System Management Company	Société d'Exploitation, Canalisation et d'Adduction des Eaux du Nord

	English	French
SONEDE	Water Exploitation and Distribution National Company (WEDNC)	Société Nationale d'Exploitation et de Distribution des Eaux
UTAP	Tunisian Agriculture and Fishery Association	Union Tunisienne de l'Agriculture et de Pêche

French Origin Abbreviations for Other than Names of Tunisian Institutions

	English	French
GEORE	Optimum Management of Water Resources	Gestion Optimale des Ressources en Eau
JORT	Official Journal of the Republic of Tunisia	Journal Officiel de la Tunisie
MEDROPLAN	The Mediterranean Drought and Preparedness and Mitigation Planning	Etat de préparation de sécheresse et planification méditerranéenne de réduction
NGT	General Levelling of Tunisia (Topographic datum in Tunisia)	Nivellement Général de la Tunisie
PHE	Maximum Water Level	Niveau des Plus Hautes Eaux
PISEAU project	Water Sector Investment Project	Projet d'Investissement du Secteur de l'Eau
SINEAU	Water Resources National Information System	Système d'Information National des Ressources en Eau
SYCHTRAC	Real Time Hydrological Data Collection and Flood Warning System	Système de Collecte des Données Hydrologiques en Temps Réels st Annouce de Cures

English Origin Abbreviations (or Other Languages)

	English	French
AfDB	African Development Bank	Banque africaine de développement (BAfD)
BOD	Biological Oxygen Demand	Demande Biologiste en l'Oxygène
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora	Convention de Washington sur le Commerce International des Espèces de Faune et de Flore Sauvages Menacées d'Extinction
COD	Chemical Oxygen Demand	Demande Chimique de l'Oxygène
EIA	Environmental Impact Assessment	Evaluation de l'Impact sur l'Environnement
EIRR	Economic Internal Rate of Return	Taux Interne de Rentabilité Economique
FAO	Food and Agriculture Organization of the United Nations	Organisation pour l'Alimentation et l'Agriculture (FAO)
FFWS	Flood Forecasting and Warning System	Système de prévisions de crue et d'alerte
F/S	Feasibility Study	Etude de Faisabilité
GDP	Gross Domestic Product	Produit intérieur brut (PIB)

	English	French
GEOSS	Global Earth Observation System of Systems	Système Global d'Observation du globe des Systèmes
GIS	Geographical Information System	Système d'Information Géographique
G/S	Gauging station	Station de jaugeage
GSM	Global System for Mobile Communications	Système global pour communications mobiles
GTZ	German Office for Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit)	Coopération Technique Allemande
IEE	Initial Environmental Examination	Examen Initial sur l'Environnement
IFAD	International Fund for Agricultural Development	Fonds International de Développement Agricole (FIDA)
IUCN	The World Nature Conservation Union	Union Internationale pour la Conservation de la Nature
JBIC	Japan Bank for International Cooperation	Banque Japonaise de Coopération Internationale
JICA	Japan International Cooperation Agency	Agence Japonaise de Coopération Internationale
MDGs	Millennium Development Goals	Objectifs du Millénaire pour le développement (OMD)
M/P	Master Plan	Plan directeur
NGO	Non-governmental Organization	Organisation Non Gouvernementale
O&M	Operation and Maintenance	fonctionement et Maintenance
PR1	Progress Report 1	Rapport d'Avancement n1
SMS	Short Message Service	Service de message court
TND	Tunisian Dinar	Dinar Tunisien
TOR	Terms of Reference	Termes de Référence1
UN	United Nations	Organisation des Nations unies (ONU)
UNDP	United Nations Development Programme	Programme des Nations Unies pour le Développement
UNESCO	United Nations Educational, Scientific and Cultural Organisation	Organisation des Nations Unies pour l'Education, la Science et la Culture
UNSO	United Nations Sudano-Sahelian Office	Office Soudano-Sahélien des Nations Unies
WB	The World Bank	La Banque Mondiale
WMO	World Meteorological OrganiZation	Organisation Mondiale de la Météorologie

Glossary (French Technical Terms, Tunisian Local Terms and Other Specific Terms)

Term	Explanation
governorate	A regional government unit under the state in Tunisia

MEASUREMENT UNITS

Length

mm	=	millimetres
cm	=	centimetres (= 10 mm)
m	=	meters (= 100 cm)
km	=	kilometres (= 1,000 m)
in.	=	inch (= 2.54 cm)
ft.	=	foot = 12 inches (= 30.48 cm)
yard	=	3 feet = 36 inches (= 0.9144 m)
mile	=	1760 yards (= 1,609.31 m)

Volume

cm^3	=	Cubic-centimetres (1.0 cm x 1.0 cm x 1.0 cm or 1.0 m-lit.)
m^3	=	Cubic-metres (1.0 m x 1.0 m x 1.0 m or 1,000 lit.)
lit.	=	Litre (1,000 cm^3)
cusec	=	ft^3 / sec
lpcd	=	Litre per capita per day

Area

cm^2	=	Square-centimetres (1.0 cm x 1.0 cm)
m^2	=	Square-meters (1.0 m x 1.0 m)
km^2	=	Square-kilometres (1.0 km x 1.0 km)
ha	=	Hectares (10,000 m^2)

Weight

g	=	Grams
kg	=	Kilograms (1,000 g)
ton	=	Metric tonne (1,000 kg)

Currency

US$	=	United State Dollars (USD)
¥	=	Japanese Yen (JPY)
TND	=	Tunisian Dinar

Time

sec.	=	Seconds
min.	=	Minutes (60 sec.)
hr.	=	Hours (60 min.)

Supporting Report A

HYDROLOGY AND HYDRAULICS

ABBREVIATIONS

French Origin Abbreviations for Names of Tunisian Institutions

	English	French
CRDA	Regional Commissary for Agricultural Development	Commissariat Régional au Développement Agricole
DGBGTH	General Direction of Dams and Large Hydraulic Works (under MARH)	Direction Générale des Barrages et des Grands Travaux Hydrauliques (MARH)
DGRE	General Direction of Water Resources (under MARH)	Direction Générale des Ressources en Eau (MARH)
INAT	National Agronomical Institute of Tunisia (under MARH)	Institut National Agronomique de Tunisie
INM	National Institute of Meteorology (under Ministry of Transportation)	Institut National de la Météorologie (MT)
MARH	Ministry of Agriculture and Hydraulic Resources	Ministère de l'Agriculture et des Ressources Hydrauliques

French Origin Abbreviations for Other than Names of Tunisian Institutions

	English	French
GEORE	Optimum Management of Water Resources	Gestion Optimale des Ressources en Eau
NGT	General Levelling of Tunisia (Topographic datum in Tunisia)	Nivellement Général de la Tunisie
PHE	Maximum Water Level	Niveau des Plus Hautes Eaux
SYCHTRAC	Real Time Hydrological Data Collection and Flood Warning System	Système de Collecte des Données Hydrologiques en Temps Réels st Annouce de Cures

English Origin Abbreviations (or Other Languages)

	English	French
DEM	Digital Elevation Model	modèle numérique de terrain (MNT)
FFWS	Flood Forecasting and Warning System	Système de prévisions de crue et d'alerte
F/S	Feasibility Study	Etude de Faisabilité
GIS	Geographical Information System	Système d'Information Géographique
G/S	Gauging station	Station de jaugeage
GTZ	German Office for Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit)	Coopération Technique Allemande
JICA	Japan International Cooperation Agency	Agence Japonaise de Coopération Internationale
M/P	Master Plan	Plan directeur
O&M	Operation and Maintenance	fonctionement et Maintenance

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Supporting Report A : Hydrology and Hydraulics

Abbreviations

Table of Contents

Page

List of Tables

List of Figures

Page

List of Related Data Contained in Data Book

Page

CHAPTER A1 HYDROLOGICAL INVESTIGATION

A1.1 General

A1.1.1 Purposes of the Hydrological Study

The hydrological studies for this JICA Study have been conducted to provide necessary hydrological background information for formulating the flood management master plan in the Mejerda River basin. The major tasks of the hydrological studies were;

- to acquire primary and secondary data of the experienced major floods, and to clarify their hydrological characteristics (**Chapter A3**)
- to estimate discharge and volume of low flow inflow at dam sites with different probabilities as basic data for the water supply operation analysis of the dams conducted under the Study (**Chapter A4**)
- to estimate hydrographs of different probable floods from each sub-catchments to be utilized for the reservoir operation and inundation analyses (**Chapter A5**)
- to estimate the inundation area, depth and duration caused by different probable floods, in order to supply basic data for river improvement and flood management planning (**Chapter A6**)
- to reveal the present conditions in the river channels so as to provide background information for river improvement planning (**Chapters A2 and A7**)

A number of hydrological studies have been conducted in the past projects and studies of the Mejerda basin. The findings of these previous works have been reviewed and some of the results have been incorporated into this study. Where necessary, the previous findings have been updated with additional data being available.

A1.1.2 Data Collection

Meteorological and hydrological data in the Mejerda River basin and adjacent areas were collected for this Study from the two major responsible agencies, the Ministry of Agriculture and Hydraulic Resources (MARH) (mainly DGRE and DGBGTH) and the National Institute of Meteorology (INM). DGRE (General Direction of Water Resources) under MARH is the responsible agency for observation and operation/maintenance of rainfall and stream gauging stations, whereas INM operates meteorological (including some rainfall) stations. DGRE and INM exchange data when necessary. Fundamental climate data at dam sites are observed and stored also by DGBGTH (General Direction of Dams and Large Hydraulic Works) under MARH along with dam operation records.

(1) Climate data

Climatological monthly data at principal stations were collected from INM and MARH.

(2) Rainfall

The following two types of rainfall data were collected from MARH and INM.

- Daily rainfall at 89 stations (1990/91 – 2005/06 with missing periods)

- Hourly rainfall at a few stations during the major floods (1973 Mar., 2000 May, 2003 Jan. and 2004 Jan.)

Availability of rainfall data is summarised in **Table A1.1.1**, and locations of the rainfall stations are shown in **Figure A.1.1**.

(3) Discharge / stream flow

The following discharge data were collected at MARH:

- Instantaneous (or hourly) discharges during the major floods at principal stations (DGRE and DGBGTH)
- Daily discharge at 30 stream gauging stations (1989/90 – 2002/03 with missing periods) (DGRE)
- Recorded daily outflow and estimated daily inflow volumes at dam sites (DGBGTH)
- Monthly inflow (volume) at dam sites (DGBGTH, extracted from an existing database developed under the previous studies, such as EAU2000 and GEORE)

Discharge rating curves at the principal stream gauging stations were also furnished by DGRE.

Locations of the major stream gauging stations are shown in **Figure A1.1.2**, and are schematically presented in **Figure A1.1.3** together with the major dams, tributaries, and cities/towns. Availability of discharge data is summarised in **Table A1.1.2**.

(4) Data in Algeria

The following hydrological data in the Algerian territory of the Mejerda River basin were provided by MARH.

- Monthly rainfall at 41 stations (1913/14 – 2003/04 with missing periods)
- Daily discharge data (at seven stations with missing periods, limited availability)

A1.2 Review of Collected Data

A1.2.1 Review of Collected Data

The collected rainfall and stream discharge data has been scrutinized before being used in subsequent analyses. Regression analysis between recording station data sets were performed and missing data in the available data sets have been filled based on established relations where necessary.

A1.2.2 Notes on Collected Data

(1) Reliability and Homogeneity of Data

Among the available hydrological data, the data sets of daily discharge and daily rainfall in the Tunisian side of the basin showed fine availability and reliability. Hourly (or instantaneous) data, on the other hand, seems to be managed in a different way. Analysing hourly discharge hydrographs often encountered difficulties because data from different sources, such as DGRE's records often show inconsistencies.

A new real time hydrological data collection and flood warning system (SYCHTRAC: Système de Collecte des Données Hydrologiques en Temps Réels et Annouce de Cures), which is currently being installed in the Mejerda River basin, is expected to bring about significant improvement of hydrological information management in the basin. Rainfall, water level and discharge data can be stored at the sole data base, which avoids discrepancy of data. The SYCHTRAC also realizes that data from a reliable source can be shared among DGRE, DGBGTH and other offices of MARH, during both flood and non-flood periods.

(2) Datum of water level data

Water level data observed by DGRE are currently expressed by independent gauge readings. These need to be connected to the NGT elevation system, which has been widely applied to the Tunisian topographic information, such as altitudes in topographic maps, topographic survey results and structural design. Besides, this NGT information of gauge reading datum should be disclosed so that DGRE's water level information can easily be applied and utilized for practical plans and activities.

(3) Data in Algeria

Hydrological data in the Algerian territory of the Mejerda River basin basically are provided on a monthly basis at present. Acquiring daily and hourly level of hydrological data in the Algerian parts of the Mejerda basin would be necessary for more detailed hydrological analyses in the future stages. Timely acquirement of data in the Algerian territory could also bring a margin for flood management measures.

Acquiring data from sources other than Algerian agencies, such as from an international satellite observation system, could be a future option.

A1.3 Climate in the Study Area

(1) General

Tunisia, which lies on the frontier between the hot desert in the south and the Mediterranean in the north, is dominated by the air system of the subtropical Saharan desert in summer and of the moderate zone in other seasons.

In summer, the weather in Tunisia is steady, hot and dry due to the progression of subtropical high pressures towards the north. In winter and transition seasons when the subtropical pressures withdraw towards the south, Tunisia takes part in the west of the moderate air system, and is covered by frontal disturbances and masses of air from different origins. Hence, during these seasons, especially in the northern part of Tunisia where the study area is situated, the weather becomes rather unstable and frequent precipitation could be observed.

Climate data at the major stations in the study area are provided in **Data A1 in Databook**, and their average monthly values are summarized in **Table A1.3.1**.

(2) Rainfall

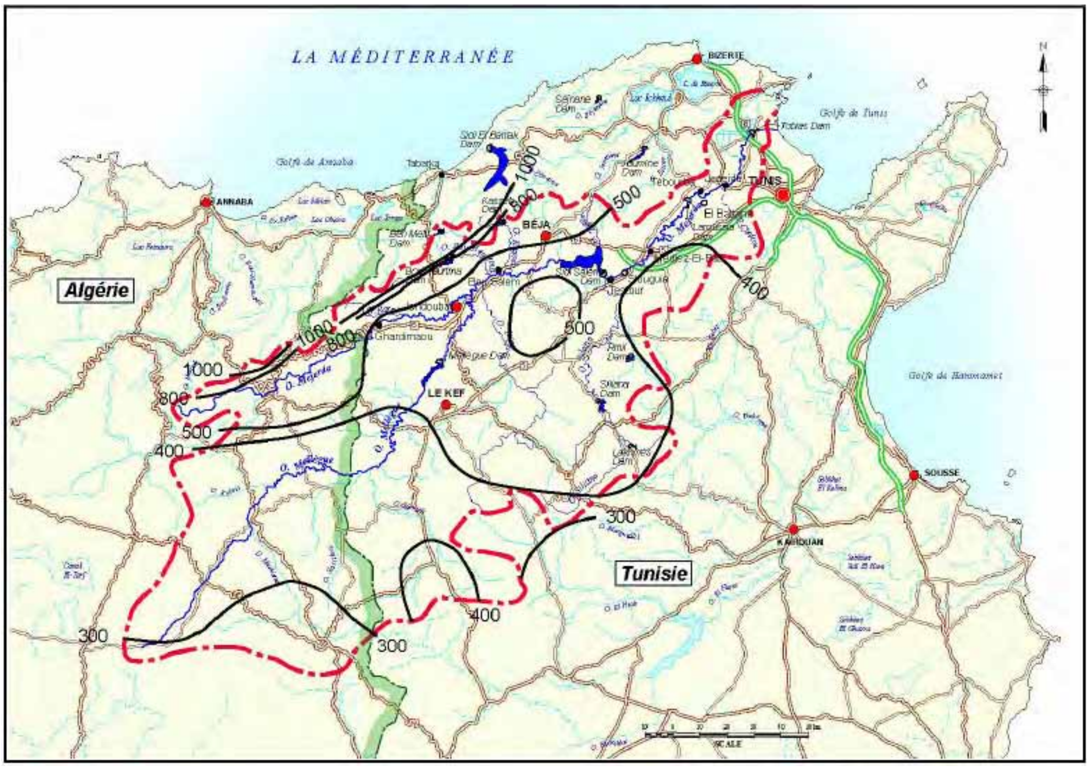
Three major origins of rainfall in Tunisia are;

- Disturbances coming from the western Mediterranean (penetration of disturbances at the north Atlantic to Mediterranean or the ones born near the west end of the Mediterranean). This type covers about two thirds of the rainfall cases in Tunisia.

- Disturbances coming from the eastern Mediterranean (such as the region of Cyprus). This type occupies about 11% cases of rainfall. This type tends to be observed in autumn and to cause intensive rainfall.
- Disturbances of the north of Sahara moving towards east or northeast from southwest. After passing through Tunisia and resting on the Mediterranean, these relatively dry air masses could trigger heavy rainfall on the eastern parts of the country.

Generally, the average annual rainfall shows decrease trends towards the south in Tunisia. It reaches 1,500 mm in the Kmir Mountains at the northwest edge of Tunisia, and reduces to less than 100 mm towards the south end of the country.

Such regional variation of the annual rainfall can also be observed in the study area as in the following isohyetal map. The average annual rainfall exceeds 1,000 mm in the northwest part of the study area, whereas the southern part has an annual rainfall as low as 300mm.



Isohyetal Map of the Mejerda River Basin (Average Annual Rainfall 1949-2006)

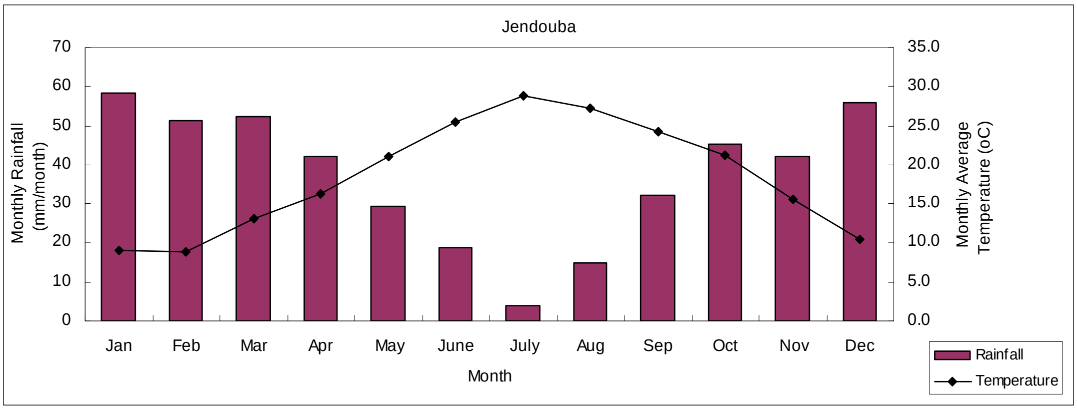
Further details on rainfall characteristics in the study area are discussed in the subsequent section.

(3) Temperature, evaporation, sunshine and humidity

Climateological data are presented in **Table A1.3.1** and **Data A1 in Databook**.

In general, the temperature is in increasing trend towards the southern desert area in Tunisia, whilst the precipitation and humidity shows adverse trends.

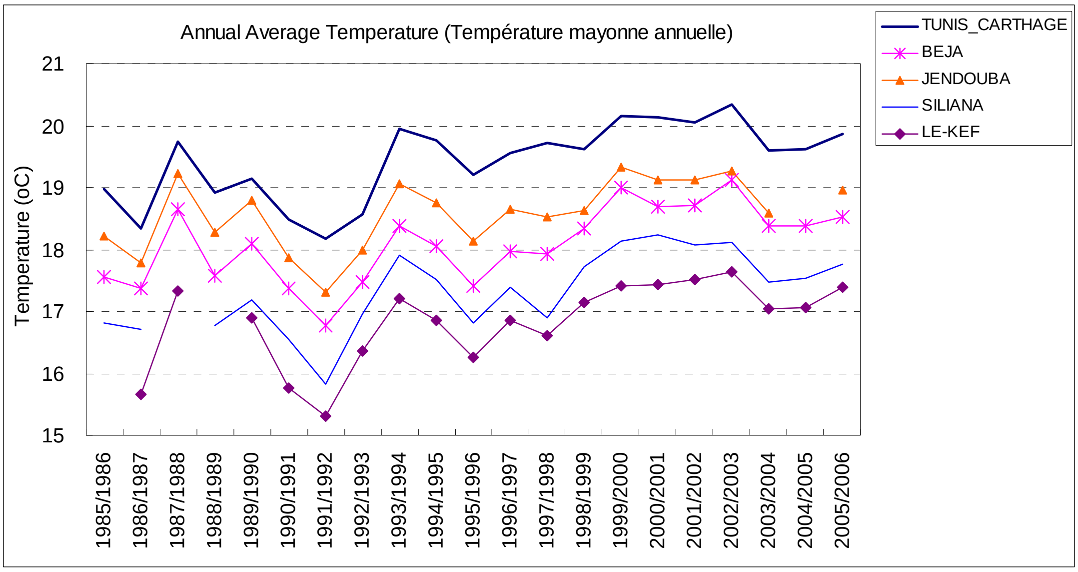
The extreme north and northern areas of Tunisia where the Mejerda River basin is situated can be distinguished by mild and wet winter, and hot and dry summer. Usually, temperature, evaporation, and sunshine duration reach their maximums in July and August in the Study Area, whilst humidity as well as precipitation becomes smallest during these months. The following graph illustrates a typical seasonal variation of temperature and rainfall in the study area.



Source: Summarized by the Study Team based on Annual Report 2005 (Almanach 2005), INM

Average Monthly Rainfall (1961-1990) and Monthly Average Temperature in 2005

The annual average temperature in the study area ranges between about 16 and 20 ^{o}C as shown in the chart below. The average temperature at Siliana and Le-Kef at higher altitudes tends to be lower than those of other stations. July and August are the highest months in the study area. The monthly mean temperature in these months is from about 27 to 28.5 ^{o}C at the major stations, and the monthly mean maximum temperature reaches 32 to 37^{o}C. The absolute maximum temperature records higher values. In July 2005 at Jendouba, for instance, it was recorded at 46.8 ^{o}C, whilst the average monthly temperature in this month was 28.8 ^{o}C.



Annual Average Temperature at Major Stations in the Study Area

The annual mean relative humidity at the major stations in the study area ranges from 60 to 68%. It becomes highest in December to January, 75 to 85%, and lowest in July, 49 to 60%. The Tunis-Carthage station located near the sea shows higher humidity during summer than that of other stations.

The annual average evaporation in the study area varies from 1300 to 1800mm.

(4) Wind

Observed monthly average wind velocity ranges between 2.0 to 4.5 m/s at the major stations in the study area as shown in **Table A1.3.1** and **Data A1 in Databook**.

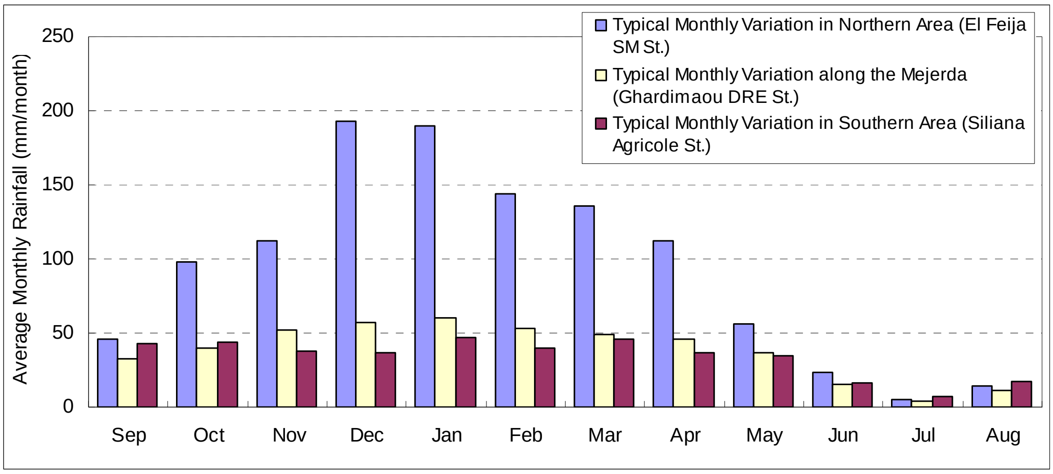
A1.4 Rainfall Characteristics in the Study Area

A1.4.1 Reliability Analysis

Reliability of the available rainfall data sets was scrutinized based on a double mass curve analysis. The data sets of several stations which showed potential severe errors were decided to be discarded. Missing data in the reliable data sets were computed based on relationships established with other stations by the regression analysis.

A1.4.2 Spatial and Seasonal Variations

As mentioned earlier, the annual rainfall in the study area has a wide range from around 300mm in the southern parts to over 1,000 mm in the north. This difference is consequent mainly on notably abundant rainfall during the wet season in the northern parts. Precipitation during the dry to transition seasons (from June to September) generally differs little among regions as in the chart below. On the contrary, the wet season rainfall in the northern areas (the left bank areas) becomes significantly large especially in December and January, whilst these months do not provide a distinct peak in the southern part of the study area where right bank tributaries including the Mellegue are situated.

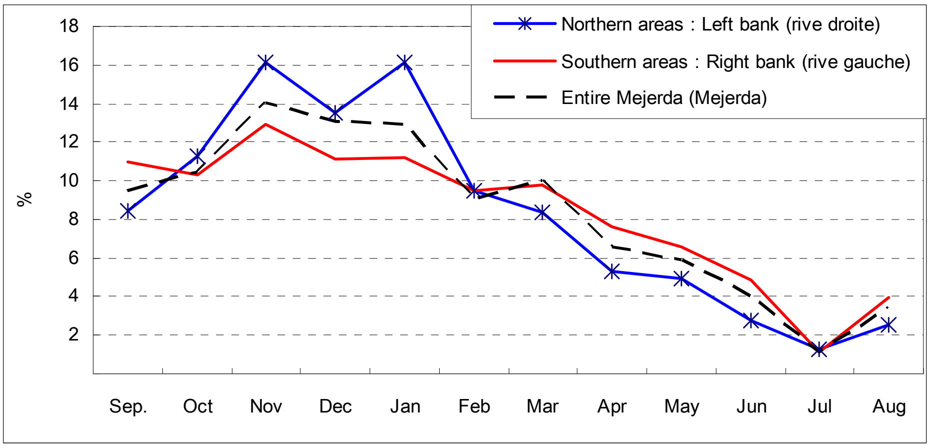


Source : Developed by the Study team based on DGRE daily rainfall data (Average of 1950/51-2005/06)

Monthly Variation of Rainfall in Different Regions

Seasonal and regional variation in the occurrence of intensive rainfalls was also examined, based on the recorded annual maximum daily rainfall. The following figure compares the monthly distribution of incidences (as percentages) of annual maximum daily rainfall in the northern and southern parts of the study area.

The figure means that in the northern parts intensive rainfall is more likely to occur from November to January, whilst it could occur throughout from September to June in the southern parts.



(unit %)

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	total
Northern Areas (Left bank)	8.4	11.3	16.1	13.5	16.1	9.5	8.4	5.3	4.9	2.8	1.2	2.5	100
Southern Areas (Right bank)	11.0	10.3	12.9	11.1	11.2	9.5	9.8	7.6	6.5	4.9	1.1	4.0	100
Entire Mejerda	9.5	10.4	14.0	13.0	12.9	9.1	10.0	6.6	5.9	4.0	1.1	3.5	100

Note : The number of occurrence of annual maximum daily rainfall in the month / The total number of annual maximum daily rainfall data.
Left (or Right) : Total of stations located on the left (or right) bank of the Mejerda River
Period : 1900/01 – 2005/06 (For this analysis, missing data are not filled.)

Source : the Study Team

Monthly Variation of Occurrence of Annual Maximum Daily Rainfall

A1.4.3 Characteristics of Annual Variations

(1) Annual rainfall, and dry and wet years

Figure A1.4.1 shows the fluctuation of annual rainfall and its 10 year moving average over the years after 1968 in the basin and at some typical stations between 1968/69 (September 1968 to August 1969) and 2005/06. The figure implies that in general the Mejerda basin is currently in the wet period since 2002 after suffering from the sever droughts in the late 80's to 2001. Dry and wet years were also examined based on the basin annual rainfall. **Table A1.4.1** enumerates the basin annual rainfall during the period from 1968/69 to 2005/06. The rainfall amount of consecutive two and three years is also presented in the table.

The following years recorded the five lowest precipitations during the said period. This result matches with the fact that the two most serious droughts in the last 80 to 90 years in the basin occurred in 1987-88-89 and 1993-94-95.

Years Recorded Low Precipitation (Basin Average Rainfall)

Rank	Annual rainfall		2 year rainfall		3 year rainfall	
	period	mm/year	period	mm/year	period	mm/year
1	1993/1994	316	1993 Sep. – 1995 Aug.	675	1992 Sep. – 1995 Aug.	1092
2	1987/1988	347	1987 Sep. – 1989 Aug.	700	1987 Sep. – 1990 Aug.	1113
3	2001/2002	350	1992 Sep. –1994 Aug.	734	1999 Sep. – 2002 Aug.	1228
4	1988/1989	353	1988 Sep. –1990 Aug.	766	1991 Sep. – 1994 Aug.	1303
5	1994/1995	359	2000 Sep. –2002 Aug.	815	1976 Sep. – 1979 Aug.	1319

Source : the Study Team

The years which recorded high annual rainfall correspond to the years with remarkable floods listed in **Table A3.3.1** as compiled below.

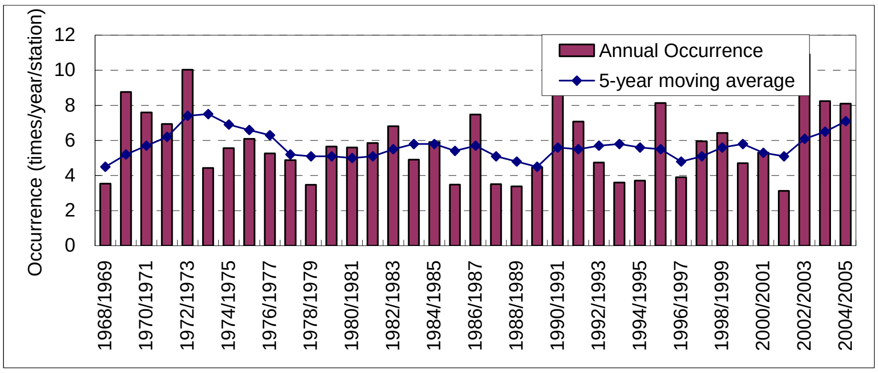
Years Recorded High Precipitation

Rank	Period	Basin Average Annual Rainfall (mm/year)	Notable Flood occurred during the period
1	2002/2003	780	2003 Jan.
2	1972/1973	721	1973 Mar.
3	2003/2004	701	2004 Jan.-Feb.
4	1969/1970	691	1969 Sep.-Oct.
5	1995/1996	676	-

Source : the Study Team

(2) Annual variation of the occurrence of intensive rainfall

The following chart shows the occurrence of the rainfall more than 20mm/day in a year (times per year per station) since 1968.



Source : the Study Team

The number of the occurrence of intensity rainfall seems to be in an increasing trend since 2002 corresponding to the annual rainfall amount. However, the occurrence in the recent years is still at the experienced level in the mid '70s, and the available data could not explain that the recent increase exceeds the range of ordinary annual variation.

Occurrence of Intensity Rainfall (20mm/day) in a Year

Average (times per year per station)	Period (5 years interval)
5.2	1965/66 –1969/70
6.9	1970/71 – 1974/75
5.1	1975/76 – 1979/80
5.8	1981/82 – 1984/85
4.5	1985/86 – 1990/91
5.6	1991/92 – 1994/95
5.8	1995/96 – 1999/00
7.1	2001/02 – 2004/05

Source : the Study Team

A1.4.4 Probability Analysis of Point Rainfall

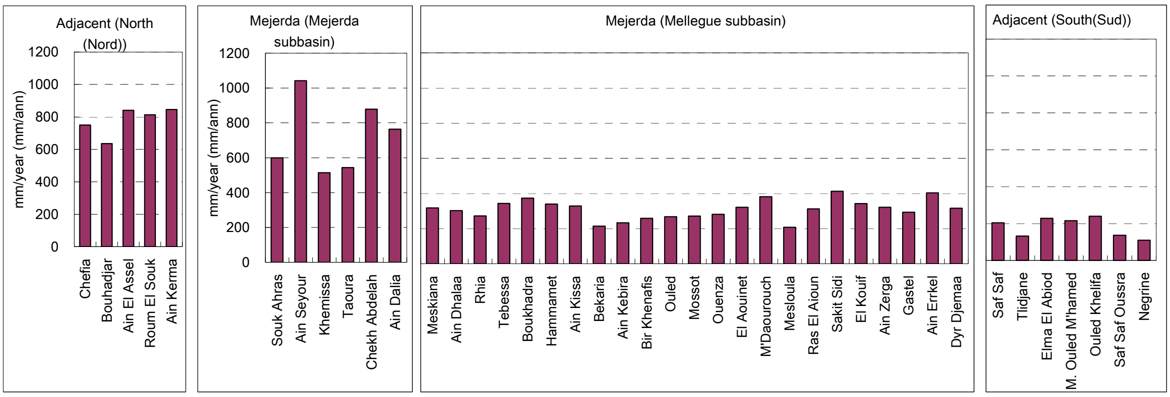
Under this JICA Study, probabilities of six day rainfall, which produced one peak of flood hydrographs in the past major floods, were analyzed. The latest DGRE's daily rainfall records until 2005/06 were utilized for the analysis. Statistical distributions examined are Pearson type III, Log Pearson type III, Gumbel, Log-normal and GEV (Generalized Extreme Value). The probabilities at the major stations are presented in **Table A1.4.2**. The disparities of distributions applied to the left and right bank areas suggest regional variations of rainfall features in the Mejerda basin.

Probabilities of basin average rainfall were also analysed in this study for estimating runoff from the sub-catchments in the basin. Details on the basin average rainfall are described in **Chapter A5**.

A1.4.5 Monthly and Annual Rainfall in the Algerian Territory of the Mejerda River Basin

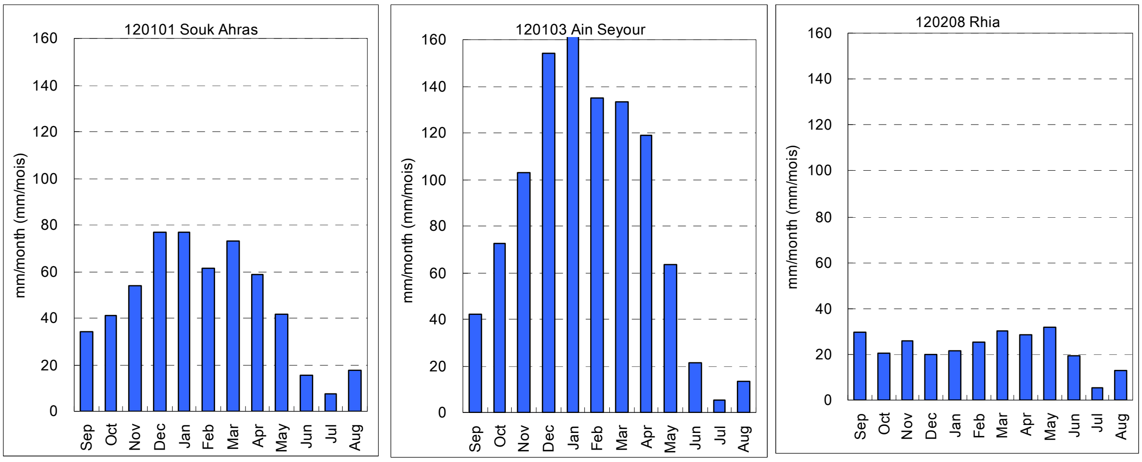
Figure A1.1.1 contains the Algerian rainfall stations whose monthly data are available at MARH. The following charts present examples of monthly and annual rainfall at some stations in different parts of the Algerian territory of the Mejerda River basin. Details cannot be discussed due to limitations of data in Algeria. However, existing data suggest that the annual rainfall and monthly variation in the Algerian territory show similar characteristics to those in the Tunisian territory (see the isohyetal map in **Section A1.3** also); that is,

- The north edge receives the highest annual rainfall, and the annual rainfall generally declines towards the south.
- Monthly rainfall drops to the bottom in July and August.
- Stations in the northern parts indicate more significant peaks of the monthly rainfall in the wet season, whereas the monthly values from September to May in the southern areas, namely in the Mellegue sub-basin, fluctuate little.



Period: Year started operation of each station – 2003/2004
Source: the Study Team, developed based on data obtained from MARH

Average Annual Rainfall at Stations in Algerian Territory of the Mejerda River Basin



(1) Mejerda sub-basin (2) Mellegue sub-basin

Source: the Study Team, developed based on data obtained from MARH

Average Monthly Rainfall at Typical Stations in Algerian Territory of the Mejerda River Basin

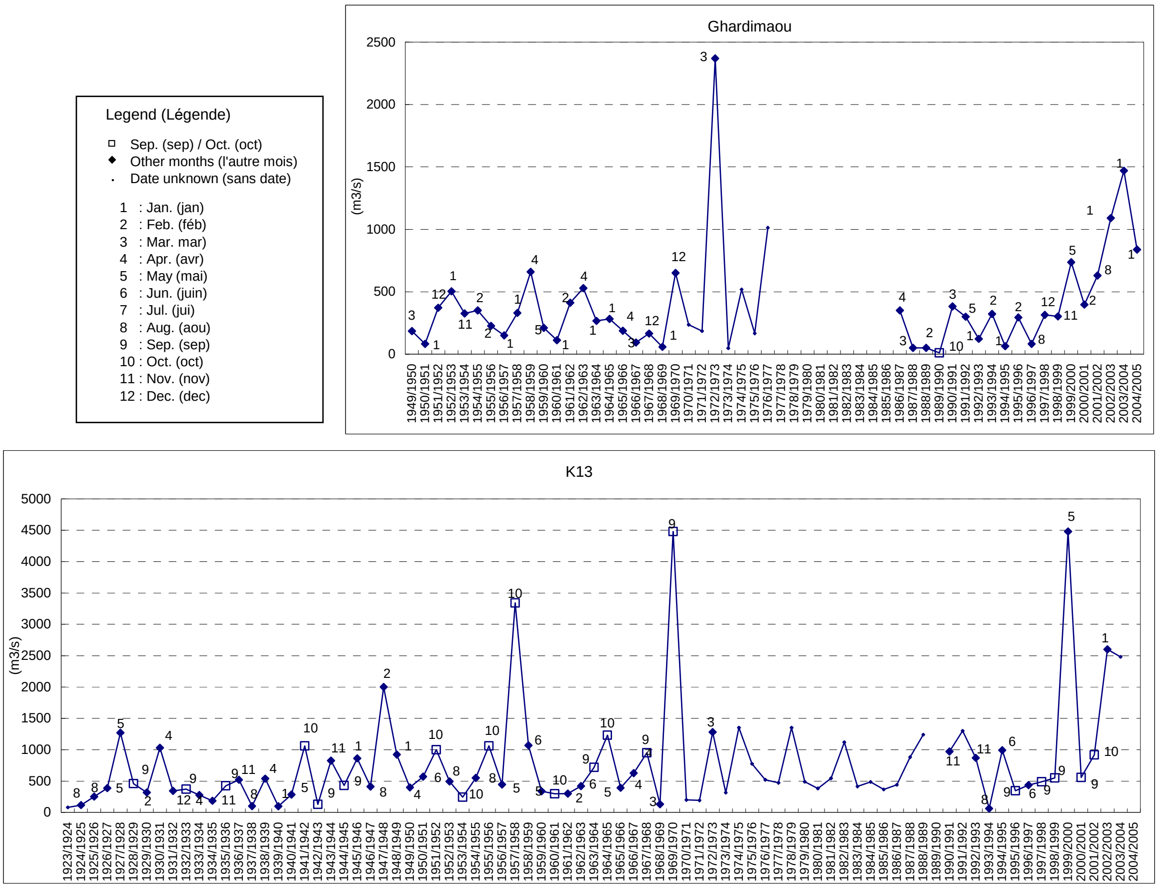
A1.5 Flood Flow Characteristics

A1.5.1 Seasonal Variation of the Incidences of Annual Peak Discharge

The following charts show the recorded annual peak discharges and the months of their presence at the Ghardimaou and Mellegue K13 stream gauging stations (see **Table A1.5.1**). The following characteristics can be observed from the charts.

- At the K13 station, September and October have been dominant to the presence of the annual peak discharges over the history (20 out of 60 records). However, the annual peaks associated with the recent major floods were observed in other months, such as January in 2003 and May in 2000.
- At the Ghardimaou station, December to February are prevailing months of the presence of the annual peak discharges (24 out of 41 records), including the recent major floods. The annual peak discharges are seldom observed at Ghardimaou in September and October on the contrary to K13.

These differences of the two stations represent the distinct flood characteristics from the northern and southern parts of the basin. It should be noted that the peaks at the two stations could happen in the same month (during the same series of flooding) as the charts indicates. Coincidence of the two peaks at the two stations could be resulted in serious flooding in the Mejerda basin, such as the ones in March 1973, May 2000 and January 2003.



Source: the Study Team, developed based on data obtained from MARH

Recorded Annual Maximum Discharges and Months of their Presence

A1.5.2 Probability of Peak Discharge

The frequency analysis of annual peak discharges at major stations was made in the "Monograhies Hydrologiques" using data up to 1975/76. This study updated probabilities adding available recent data (1976/77 to 2003/2004) and applying statistical methodologies which have become popular after 1980s, such as GEV (Generalized extreme value). **Table A1.5.1** enumerates the available observed annual peak discharge data at the major stations.

The statistical probabilities of discharges can be discussed when the flow are not affected by dam operation. Hence, annual peak discharges during the following periods at each station were utilized for the frequency analysis.

Station	**Period used**	**Remarks**
Ghardimaou	start – the latest data	No dam impact
Jendouba	start – the latest data	No dam impact
Bou Salem	start – 1952/53	before starting Mellegue Dam operation
Mellegue K13	start – the latest data	No dam impact

Source: the Study Team

The following table summarised the results at Ghardimaou and Mellegue K13, two of the most important stations for determining flood conditions in the basin. The differences between the figures in the existing study and by this study were led by added recent data and the new probability distribution applied.

Probable Peak Discharges

Unit : m^3/s

Return period	**Ghardimaou**		**Mellegue K13**	
	In existing study	**By this study**	**In existing study**	**By this study**
2 yr	250	250	480	490
5 yr	500	520	1000	980
10 yr	750	790	1510	1420
20 yr	1050	1150	2100	2080
50 yr	1500	1830	3100	3340
100 yr	1870	2550	4050	4710
Distribution	Log Normal	GEV	Log Normal	GEV
Data used	‘49/50-‘76/77	‘49/50-‘04/05	‘24/25- ‘75/76	‘24/25 - ‘03/04

Source : Existing study (“Monograhies Hydrologiques”, 1981) and the Study Team

It should be noted that the values for the 100 year probability could demonstrate a general trend only. Computation of such a small probability using data covering the period shorter than 100 years could give low reliability.

A1.5.3 Probability of the Volume of Inflow

Probabilities of the flood inflow volume for 30 days, which could be one of indicators to discuss magnitudes of floods with a long duration, were also analyzed. A period of 30 days was applied because a flood with multiple peaks was found to continue about 30 days (6 to 8 days x 4 peaks) according to the experienced flood data.

The computed probable inflows at Ghardimaou are:

Probable Inflow Volumes

unit : M m^3

Return period	Ghardimaou
2 yr	45
5 yr	80
10 yr	110
20 yr	140
50 yr	180
100 yr	220

Source: the Study Team

The right bank tributaries tend to have flash floods, and the volume is not the primary feature to express floods from in that area.

A1.5.4 Shapes of Hydrographs

The recorded annual peak discharges in **Table A1.5.1** proved that the following observations in the 1970s, stated in the "Monographies Hydrologiques" (1981), are still valid.

- The median is smaller than the mean at all stations
- Differences between the median and the mean are larger for the right tributaries than the mainstream and the left bank tributaries.

These features explain stronger irregularities of flood runoff from the right bank tributaries.

Regional differences can also be explained using a ratio of the six day inflow volume against the 30 day inflow volume (Q6/Q30) (see the table below). Six days correspond to duration of one peak of a flood and a series of floods with multiple peaks continued about 30 days in the Mejerda River basin according to the recorded hydrographs.

The Ratios of Q6/Q30 for Annual Maximum Q6s at the Major Stations

Basin	Mejerda			Right Bank Tributaries			
Station	1485400110 GHARDIMAOU	1485400160 JENDOUBA	1485400180 BOU SALEM GP6	1485101210 MELLEGUE K13	1485105060 PONT ROUTE (SARREATH)	1485201355 SIDI MEDIENNE	1485501635 JEBEL LAOUDJ COTE 140
CA (km2)	1490	2414	16483	9000	1520	1952	2066
River	Mejerda	Mejerda	Mejerda	Mellegue	Sarrath	Tessa	Siliana
Period	1950/51 - 2002/03	1901/02 - 2002/03	1930/31 - 1952/53	1938/39 - 2002/03	1978/79 - 2002/03	1977/78 - 2002/03	1976/77 - 1986/87
Min	0.28	0.25	0.27	0.29	0.38	0.20	0.34
Max	0.85	0.88	0.70	0.91	0.94	0.98	0.87
Range	0.57	0.63	0.43	0.62	0.56	0.78	0.53
Mean	0.51	0.52	0.44	0.65	0.73	0.67	0.64
Medien	0.49	0.51	0.41	0.67	0.75	0.61	0.67
			before Mellegue Dam installation				before Siliana Dam installation

Note : Data without influences of upstream dams were used.
Source : the Study Team

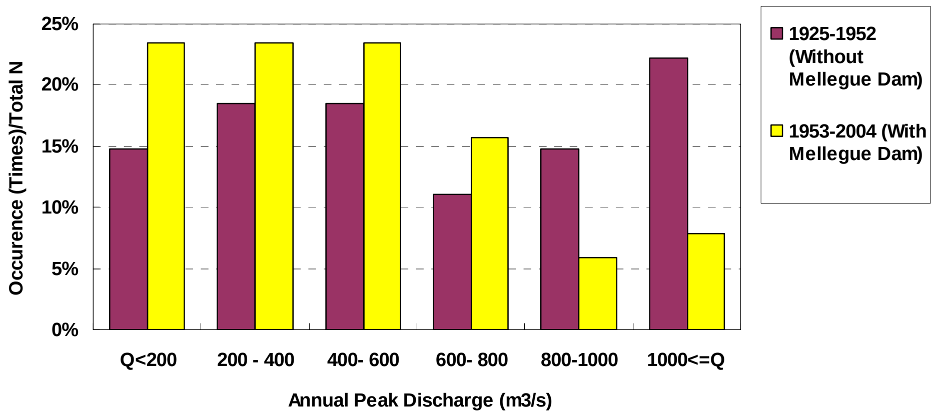
In general, a flood hydrograph at a station with a larger catchment area tends to present smaller values of Q6/Q30 (less acute peaks). However, in the case of the Mejerda River basin, a trend is dependent on the region. Q6/Q30 at the stations on the right bank tributaries including the Mellegue River holds higher figures than the stations along the upper reaches of the Mejerda River. These ratios indicate that the flood inflows from the right bank tributaries including the Mellegue generally show more sharp and acute hydrographs regardless of their catchment areas.

In short, existing records designate more irregular and acute hydrographs in the right bank tributaries, such as the Mellegue and the Tessa, than that in the Mejerda and the left bank tributaries.

A1.5.5 Impact of the Installation of Dams to Bou Salem

Impacts of the presence of the Mellegue Dam on discharges at Bou Salem (See **Figure A1.1.2** for its location) were examined in alternation of annual peak discharges in **Table**

A1.5.1. The occurrences of annual peak discharges at different ranges were counted during the period from 1925/26 to 2003/04, and their distribution before and after the installation of the Mellegue Dam was compared in the following chart (the presence of the annual peaks in per cent to the total count). The result says the occurrence of annual peak discharges of more than 800 m^3/s decreased remarkably after starting the Mellegue operation in 1952/53, and shifted to the ranges of smaller than 800 m^3/s. This implicates the annual peak level of discharges at Bou Salem has been influenced by the Mellegue Dam, and the dam could contribute to mitigating the annual peak level of discharges at Bou Salem.



Annual Peak Discharges at Bou Salem

	before 1925/26-1952/53	After Mellegue Dam Installation 1953/54-2004/05	
N	27	51 incl. 73 Mar Flood	50 excl. 73 Mar flood
Max	2,060	3,180	1,490
Min	150	81	81
Mean	759	512	467
Median	578	421	421

Source: the Study Team

The similar analysis was conducted to evaluate impacts of the Bou Heurtma Dam, but no notable effects were found. This would be due to the smaller catchment area of the Bou Heurtma Dam with 390 km^2 covering only 2.4% of the total catchment at Bou Salem (16,483 km^2), while the Mellegue dam catchment (10,309 km^2) extends 63 % of it.

CHAPTER A2 EXISTING RIVER SYSTEM

A2.1 Present River System and Riverbed Profiles

A2.1.1 River System and Catchment Area

(1) River system

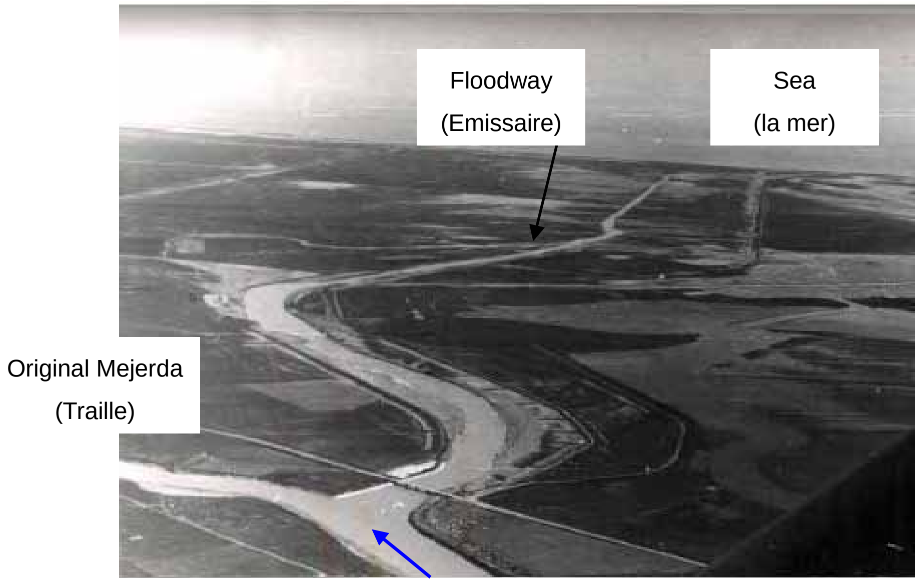
Figures A1.1.3 and A2.1.1 illustrate the river system and the major tributaries in the Mejerda River basin. Upstream parts of the Mejerda, Mellegue, and Rarai Rivers lie in the Algerian territory. The following table summarizes the lengths of the Mejerda mainstream and its major tributaries including the Algerian parts:

Length of Mejerda Mainstream and Major Tributaries

River Name	Length	River Name	Length
Mejerda	484 km	Mellegue (Meskiana-Mellegue)	317 km
Siliana (Roumel-Ousafa-Siliana)	171 km	Tessa	143 km
Bou Heurtma (El Kebir-Rhezala-Bou Heurtma)	64 km		

Source: Monographies Hydrologiques le Bassin de la Mejerda and the Study Team

There used to exist two outlets of the Mejerda River, the original river channel towards the north and an artificial floodway towards the east constructed in the 1950's during the French administration. (See the photograph below) However, the original Mejerda River was closed in 1990 when the Tobias Dam (movable weir) was constructed near the branch point, and the original Mejerda river course was converted to an irrigation canal conveying water taken at the dam to its command areas. The current river outlet of the Mejerda is the former floodway opened in the 1950's.



Source : MARH (Photo taken on 6 Apr. 1959 (after 1959 Mar Flood)

Original Mejerda River and Floodway near the Estuary in 1959

(2) Catchment area

The catchment area was measured by the Study Team based on several data sets, such as;

- GIS data developed from digitized official 1/25,000 and 1/50,000 maps in Tunisia issued by the Office of Topography and Mapping (Office de la topographie et de la cartographie).
- Grid elevation (digital elevation model, DEM) data developed from remote sensing data (76.0432 m x 76.0432 m, SRTM3 by NASA)

The following table summarizes the calculated catchment area.

Catchment Area of Mejerda River Basin

Tributary Name	Catchment Area (km^2)		Total
	Tunisia	Algeria	
Chafrou	610	0	610
Lahmar	530	0	530
Siliana	2,190	0	2,190
Khalled	470	0	470
Zerga	220	0	220
Beja	340	0	340
Kasseb	280	0	280
Bou Heurtma	610	0	610
Tessa	2,420	0	2,420
Mellegue	4,430	6,360	10,790
Rarai	310	40	350
Other Area	3,420	1,470	4,890
Total	15,830 (67%)	7,870 (33%)	23,700 (100%)

Source: the Study Team

The above area in Tunisia matches with the figure provided by DGRE (approximately 15,800 km^2). The value in Algeria also corresponds with the one in an official document published by an Algerian government agency. ("Les Cahiers de l'agence", Agence de Bassin Hydrograpique Constaintinois –Seybousse -Mellegue, Ministere de Ressources en Eau, Algeria)

The result confirmed that one third of the entire Mejerda River basin lies in Algeria. At the confluence of the Mejerda and the Mellegue Rivers, about 60% of each catchment area is situated in Algeria as in the following table.

River	In Tunisia	In Algeria	Total
Mejerda main stream (Upstream of the confluence with Mellegue)	1,080 km^2 (42 %)	1,510 km^2 (58 %)	2,590 km^2 (100 %)
Mellegue River	4,430 km^2 (41 %)	6,360 km^2 (59 %)	10,790 km^2 (100 %)

Source: the Study Team

Runoff from 323 km^2 of the area placed at the downstream end of the original Mejerida

River cannot should pour directly into the sea according to the topographic condition. (The total catchment area of the Mejerda 23,700 km^2 contains this 323 km^2.)

Out of 23,700 km^2 of the entire Mejerda River basin, 19,400 km^2 (approximately 80%) extends upstream of existing dams, which is called “controlled catchment area”. The primary contributor is the Sidi Salem Dam which holds 18,100 km^2 of the catchment. Remaining 1,300 km^2 is covered by Siliana and Rmil Dams.

A2.1.2 Riverbed Profiles and Slopes

(1) Upstream of Mejerda River: upstream end of Sidi Salem Reservoir - Algerian border (158km)

The riverbed profile is shown in **Figure A2.1.2(1)**, which was prepared based on the topographic survey results conducted under the Study in 2007.

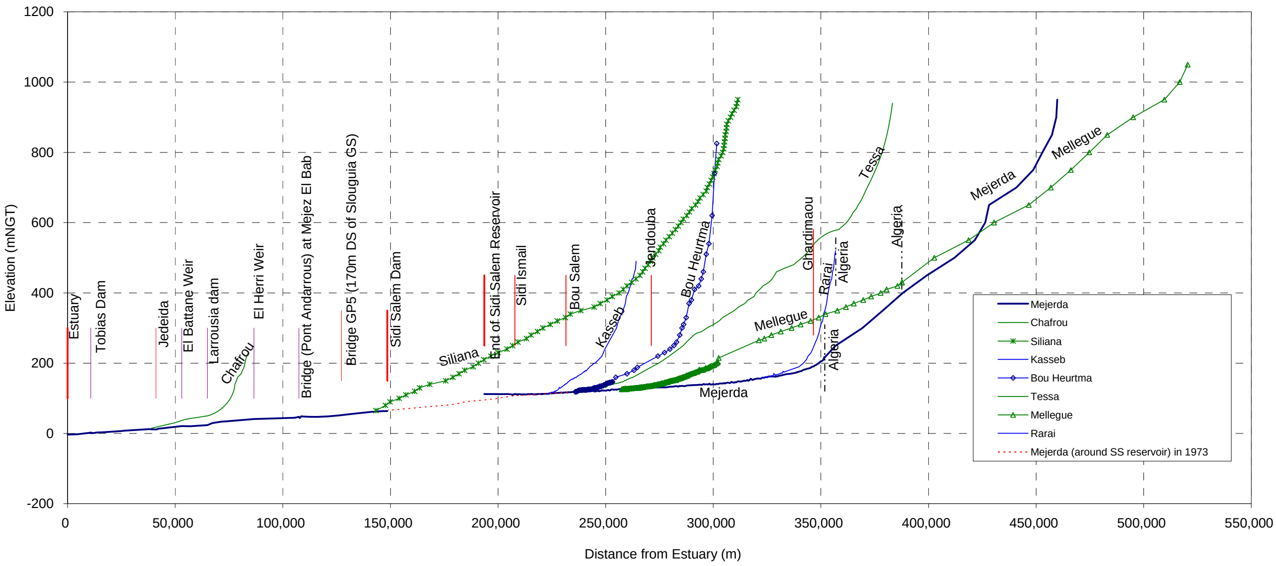
As in the profile, the stretch near the Sidi Salem Reservoir for about 25 km has a nearly flat slope, while upper stream reaches show moderate slopes of 1/2,800 (0.0003571) to 1/2,350 (0.0004255). (The bed slope near Jendouba is 1/2,800 (0.0003571) and a section between the Tessa and the Kasseb confluences is about 1/2,350 (0.0004255).) This implies significant sediment deposit occurs around the upstream end of the Sidi Salem Reservoir. Hydraulic situation around this part is explained in **Chapter A7**.

(2) Downstream of Mejerda River: downstream from the Sidi Salem Dam (148 km)

Figure A2.1.2(2) is the riverbed profile between the Sidi Salem Dam and the estuary, prepared based on the 2007 survey result conducted by MARH. Riverbed slopes generally ranges from around 1/2,000 (0.0005) to 1/3,000 (0.0003333). The profile indicates an inflection point of riverbed at the Larrousia Dam, which brings elevated riverbed on upper reaches. This could be led by trapped sedimentation by the dam. Andarous Bridge at El Battan, the old weir at El Battane and the Tobias Dam also are investigated to have caused fluctuation of the bed, but rather local phenomena.

(3) Tributaries

The following figure provides overview of the riverbed slopes of the Mejerda River and its tributaries. The profiles were prepared from the 2007 topographic survey results as well as available topographic maps with scales of 1/50,000 and 1/25,000. The figure reveals steeper slopes of the left bank tributaries on upstream reaches (the Rarai, the Bou Heurtma and the Kasseb).



Source: the Study Team

Profiles of the Mejerda and its Major Tributaries

A2.2 Flow Capacity

(1) Methodology

The flow capacity of the existing river channels was computed by the non-uniform flow method. River geometry data were acquired from the cross section survey results in 2007 by MARH for the Mejerda downstream of the Sid Salem Dam and by the Study Team for the upper Mejerda and upstream major tributaries. The flow capacity is derived from a bankfull discharge of each cross section, and then a capacity of reaches is determined taking a minimum value.

(2) Upstream areas from Sidi Salem Dam

Figures A2.1.2 present the computed flow capacity along with bed slopes. Although the capacities differ among the different reaches, in general, the capacity of the Mejerda mainstream could be said to range from 200 to 600 m^3/s. Approximate locations of sections whose capacity is smaller than other sections were shown in the map in **Figure A2.1.3** together with the inundated areas of the 1973 flood. The map indicates these sections with small flow capacities generally coincide with reaches with extending inundation areas.

Flow capacities are said to have decreased. The alternation of flow capacities are discussed in Chapter A7.

(3) Downstream areas from Sidi Salem Dam

Figure A2.1.2 shows the longitudinal profile and the flow capacity estimated by the non-uniform flow analysis on the downstream reaches of the Mejerda applying the 2007 topographic survey reslts. The figure indicates an inflection point of riverbed at the Larrousia Dam, which brings elevated riverbed on upper stream, as mentioned above. A water surface profile with the discharge of 200 m^3/s in **Figure A2.1.4** designates that water levels are raised parallel to the elevated riverbed at the Larrousia Dam.

Considerably small flow capacity was observed in the following reaches.

- Upstream of Larrousia Dam including Mejez El Bab (150-400 m^3/s)
- Downstream of Jedeida (250-300 m^3/s)
- Downstream of the Tobias Mobile Dam (150-300 m^3/s)

These areas coincide with the flood fragile areas confirmed by the inundation analysis.

Further, a general consensus among information from MARH and local residents is obvious decrease of flow capacities due to sedimentation. Historical changes of flow capacities of the Mejerda downstream are discussed in **Chapter A7**.

CHAPTER A3 HYDROLOGICAL CHARACTERISTICS OF FLOODS IN THE MEJERDA RIVER BASIN

A3.1 General

The chronology in **Table A3.1.1** reports that Mejerda River basin has experienced a number of floods. This subsection discusses characteristics of the following recent major floods from a hydrological view point.

- Flood occurred in March 1973 (1973 Mar Flood)
- Flood occurred in May 2000 (2000 May Flood)
- Flood occurred in January to February 2003 (2003 Jan Flood)
- Flood occurred in December 2003 to February 2004 (2004 Jan Flood)
- Flood occurred in January to March 2005 (2005 Flood)

Hydrological data, such as flood hydrographs at the major stream gauging stations, of the above floods are complied in **Databook A4**. The peak discharges at the major gauging stations are in **Figure A3.1.1**.

A3.2 Overall Flood Characteristics

(1) Seasonal and spatial variations

In the Mejerda River basin, significant floods can occur in any month from autumn to spring (September to May) as the list of the major floods in **Table A3.1.1** signifies. Despite the relatively small basin monthly rainfall in spring and autumn, violent floods could be observed in these seasons. This relates to attributes of inflows from Algeria and rainfall discussed in **Chapter A1**, such as;

- Runoffs with large peaks from the right bank tributaries are more likely to be observed in autumn, whereas large floods from the left bank tributaries and the Mejerda mainstream (at Gharidimoau) tend to be observed from December to February when the areas receive abundant rainfall.
- In the right bank tributary areas, intensive rainfall could occur throughout from autumn to spring.
- Runoffs from right bank tributaries tend to show sharp and acute hydrographs.

During winter from December to February/March when monthly rainfall tends to be high in the northern part of the study area, the upper reaches of the Mejerda River and the northern (left bank) tributaries are prone to cause flooding. Floods originated in the right bank tributary areas with a sharp peak could occur from spring (Apr. to May) to autumn (Sep. to Oct.) in response to intensive rainfall in these areas. Consequently, the major flood could occur in the Mejerda River basin not only in winter when monthly rainfall reaches a maximum but also during transition periods (autumn and spring).

The basin could be an origin of devastated floods, such as the ones in 1973 and 2003, when peaks from the Mejerda, from right bank tributaries and abundant rainfall in the entire basin coincide.

(2) Overall characteristics of the recent major floods

The above major floods displayed different features as summarized below. Further information is in Data A4 of Databook.

Summary of Hydrological Features of the Recent Major Floods

Flood	Affected Area	Inflow from Algeria	Rainfall	Function of Sidi Salem Dam
1973 Mar	• Entire basin	• High single peak • Mejerda and Mellegue	• High single peak • Entire Mejerda basin	- (Sidi Salem Dam not exist)
2000 May	• Upstream	• High single peak • Mellegue	• High single peak • localized on the Mellegue and Rarai basins	• Inundation on upstream of Sidi Salem dam. • Peak mitigated by Sidi Salem. No flood on downstream area.
2003 Jan	• Entire basin	• High multiple peaks to the Mejerda • High single peak inflow to the Mellegue	• High multiple peaks • Entire Mejerda basin	• The second or third peaks could not be stored by the dam and water was released. • Downstream inundations by local runoff and by released dam water.
2004 Jan 2005 Jan	• Upstream and donwstream	• Moderate multiple peaks to the Mejerda	• Moderate to high multiple peaks	• The second or third peaks could not be stored by the dam and water was released. • Downstream inundations by released dam water.

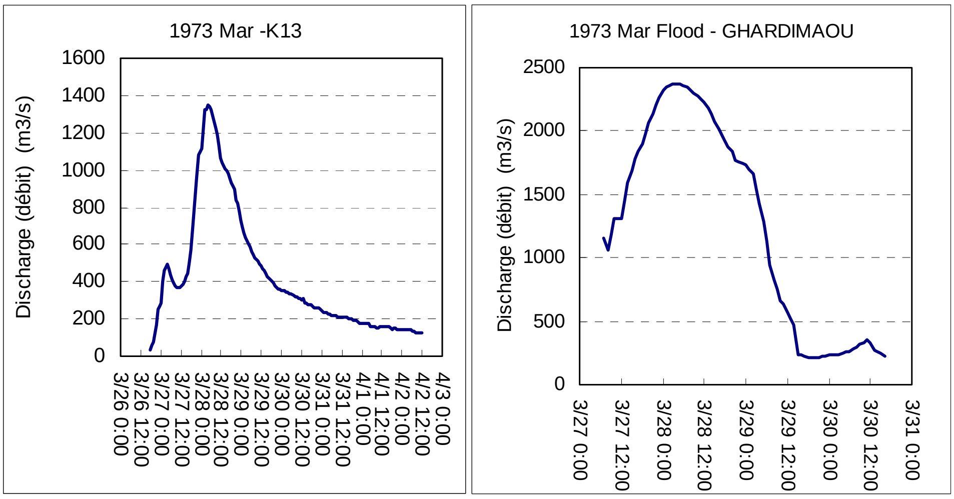
Source : the Study Team

A3.3 Hydrological Characteristics of the 1973 Mar Flood

This flood caused extensive inundation in the entire reaches of the Mejerda River as in **Figure A3.3.1**. At the time of this flood, the Sidi Salem Dam was not in operation yet and the Mejerda River possessed two outlets (the original river and the floodway at Tobias). Hydrological features of this flood are distinguished by:

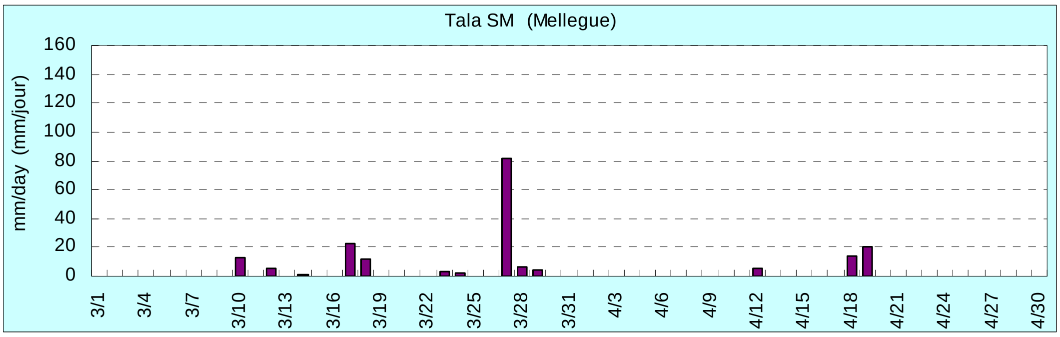
- High and single peak of inflow and rainfall, and
- Extensive rainfall covering the entire catchment of the Mejerda River.

The following typical hydrographs and hyetographs demonstrate these features.



(a) K13 (Mellegue) (b) Ghardimaou (Mejerda)

Examples of Hydrographs of 1973 Mar Flood



Example Hyetograph of 1973 Mar Flood

The peak discharges at the major gauging stations and of dam outflow are illustrated in **Figure A3.1.1**. The probability of the flood peak at Ghardimaou is estimated at 1/80. (see **Table A5.2.1**) The heavy rainfalls with probabilities of 1/15 to 1/25 (6 day basin rainfall) covered the entire Mejerda River basin.

Flood runoff derived by this heavy rainfall accompanied by high and acute inflows from Algeria produced high peak discharges in the Mejerda River and its tributaries. Inundation occurred because discharges in the river channels became beyond their flow capacities at the many reaches of the rivers.

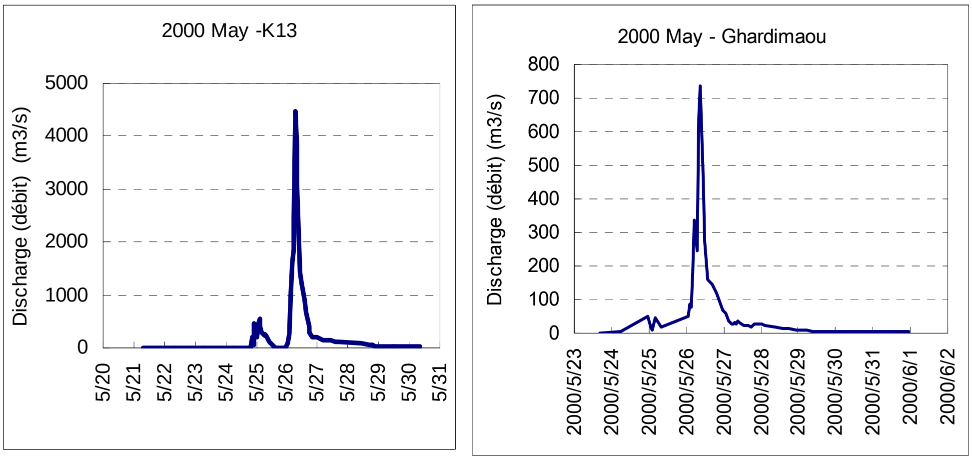
Water levels were reported to rise quickly from an ordinary wet season water level to the peak within six hours at Ghardimaou, for instance. The duration of high water level and inundation of this flood was reported to be rather short (not more than one week at most reaches), in connection with short duration of rainfall.

A3.4 Hydrological Characteristics of the 2000 May Flood

This flood caused severe inundation along the upper reaches of the Mejerda River, especially around the Jendouba and Bou Salem areas. Prominent hydrological features of this flood are:

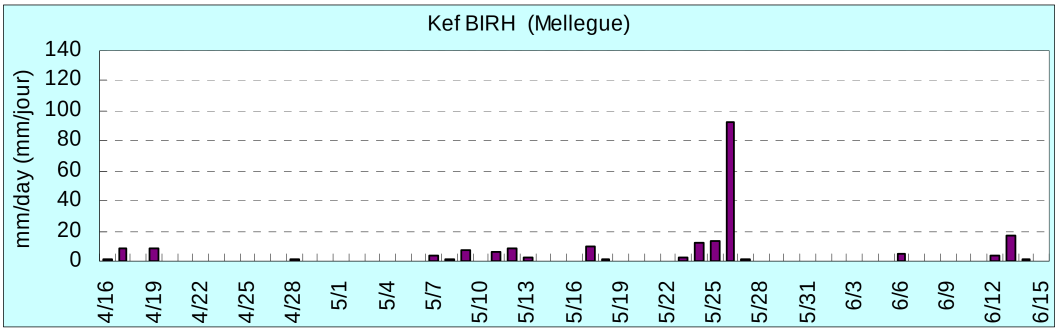
- High inflow to the Mellegue River (K13) with a single peak, and
- High but localized rainfall.

Typical hydrographs and hyetographs are presented below.



(a) K13 (Mellegue) (b) Ghardimaou (Mejerda)

Examples of Hydrographs of 2000 May Flood



Example Hyetograph of 2000 May Flood

Estimated probabilities of the peak discharge at Mellegue K13 reached at 1/90, whilst the peak at Ghardimaou falls into the range between 1/5 and 1/10. (see **Table A5.2.1**) Precipitation concentrated in the Mellegue, the Tessa and the Rarai sub-basins.

Due to a high and acute inflow, the Mellegue Dam needed to release water. The reservoir water level was high to be ready for the coming dry season when the inflow arrived. The outflow from the Mellegue Dam exceeded flow capacities of the downstream river channels, and overflowed. The inundation maps and other existing data explain that local depressions along the old river course of the Mellegue River played a role to convey overflowing water to the Jendouba area.

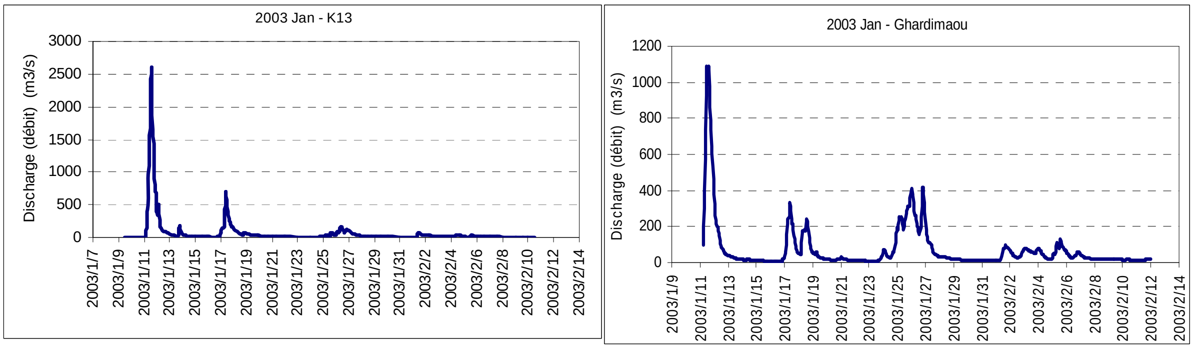
Inundation was limited to upstream of the Sidi Salem Dam, because the dam successfully mitigated the peak as the discharge distribution in **Figure A3.1.1** suggests.

A3.5 Hydrological Characteristics of the 2003 Jan Flood

This flood is characterized by:

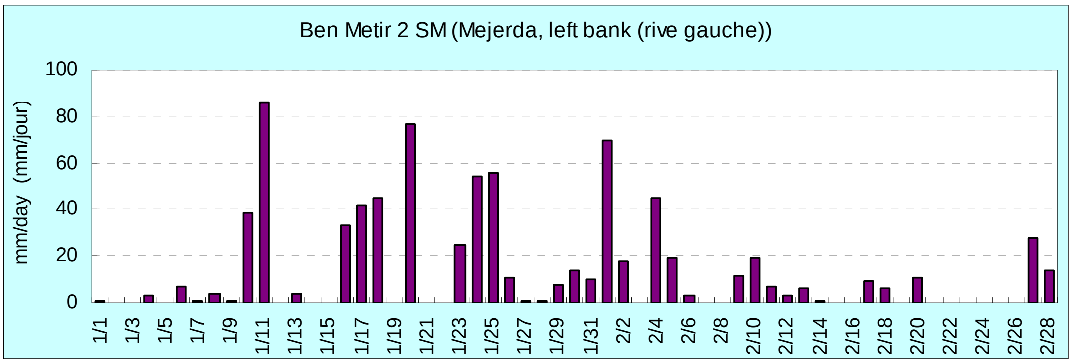
- High multiple peaks of inflow at Ghardimaou and K13, and
- High multiple peaks of rainfall.

Typical hydrographs and hyetographs are displayed below. The peak discharge at Ghardimaou is estimated at around 1/20 of a probability as in **Figure A3.1.1**, but a probability of the flood volume (197 million m^3, total for 30 days with four peaks) falls to about 1/70.



(a) K13 (Mellegue) (b) Ghardimaou (Mejerda)

Examples of Recorded Hydrographs of 2003 Jan Flood



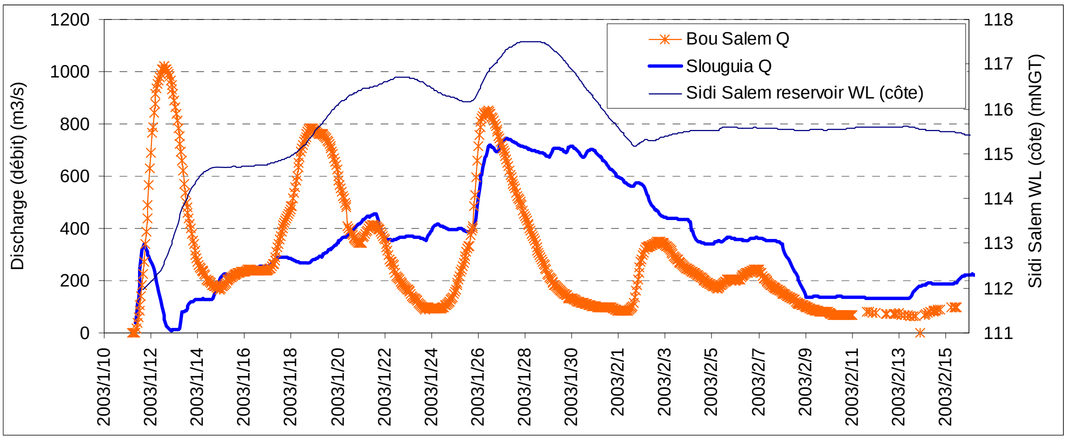
Example Hyetograph of 2003 Jan Flood

The contrast between the 2000 May and 2003 Jan Floods illustrates one of distinctive features of the 2003 Flood. As in the table below, the peaks of inflow to the Sidi Salem Reservoir of the two floods were nearly identical. However, the high discharge with a long duration of the 2003 Flood could not avoid a large peak of outflow unlike the 2000 May Flood.

Inflows and Outflows at Sidi Salem Dam during the 2000 May and 2003 Jan Floods

Flood	Inflow Max. (Sidi Salem)	Inflow Volume (at Bou Salem for 30 days)	Outflow Max. (Sidi Salem)	Note
2000 May Flood	1022 m^3/s	157 M m^3	52 m^3/s	Single peak
2003 Jan Flood	1065 m^3/s	827 M m^3	740 m^3/s	Four peaks

The hydrographs at Bou Salem and Slouguia and the Sidi Salem reservoir water level are compared in the following chart. The hydrograph at Bou Salem can interpret the inflow to the Sidi Salem Dam, and the one at Slouguia reflects outflow from the dam.



Source: the Study team based on data from DGBGTH and DGRE

Hydrographs of Inflow and Outflow of Sidi Salem Dam (2003 Jan Flood)

The primary abrupt peak at Slouguia on 11th of January was triggered by runoff from the Siliana River which joins the Mejerda River downstream of the Sidi Salem Dam and could not be controlled by the dam. That, the Sidi Salem Reservoir effectively mitigated peaks of the first and second waves of the inflow, but needed to increase releasing discharge up to 740 m^3/s when the third peak arrived. The presence of the forth peak prolonged high level of the release.

A consequence of the multiple peaks was a long duration of inundation on both upstream and downstream areas, especially in the downstream areas. The following table complies inundation durations at some locations in the downstream area. As presented in table, the inundation continued for a month or longer in certain areas.

Inflows and Outflows at Sidi Salem Dam during the 2000 May and 2003 Jan Floods

Name of Area in the downstream area	Inundated Area (ha)	Inundation duration (day)	Max. Water Level observed (cm)
Chaouat	(no data)	20	100
Jedeida	1,345	60	100
Henchir Hamada	(no data)	20	100
Side Thabet	250	45	80
Tobias	1,300	40	180
Utique	600	10 to 15	70

source : DGBGTH

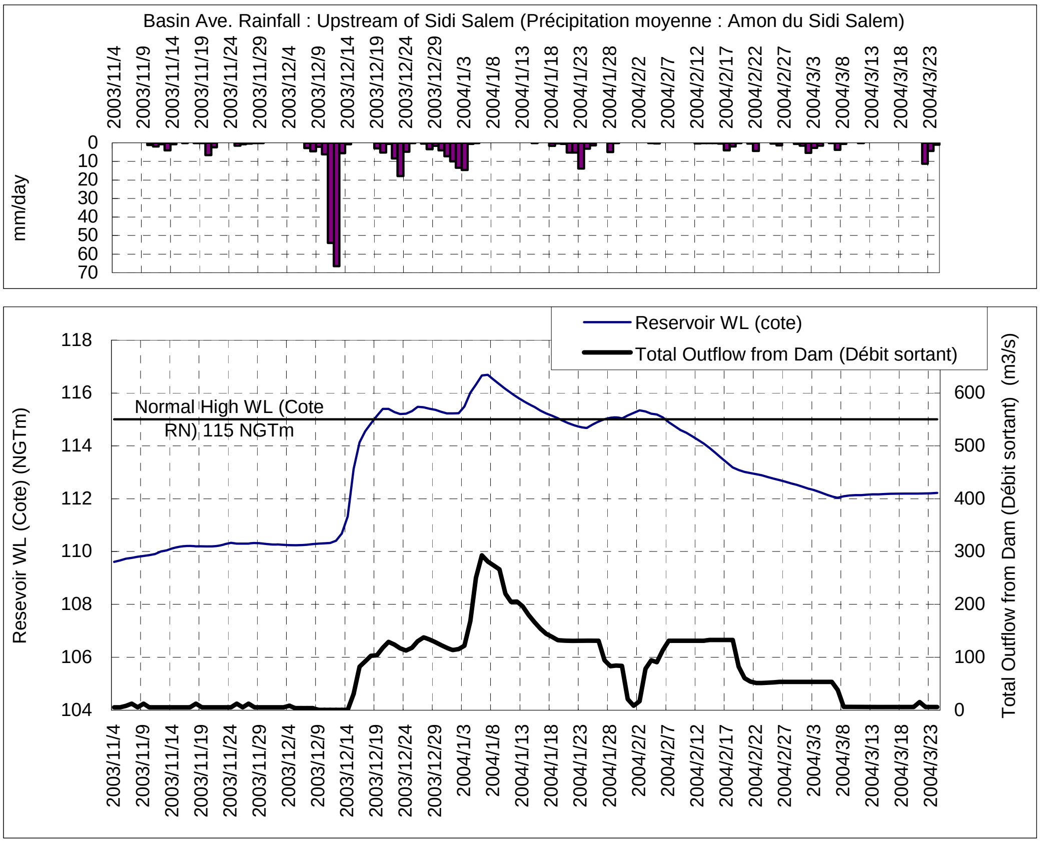
A3.6 Hydrological Characteristics of the 2004 Jan and 2005 Floods

Hydrological features of these floods are;

- Multiple peaks of inflow at Ghardimaou and K13, and
- Multiple peaks of rainfall.

The reservoir operation record during the 2004 Jan Flood indicated interesting relations among rainfall, outflow from the Sidi Salem Dam and downstream inundations. Similar phenomena were found in the 2005 Flood. The peak of the outflow was observed on 6th of January 2004 despite moderate rainfall around this day. This was led by significant antecedent rainfall (around 50 year probability of 6 day rainfall) during 10th to 13th of

December, 2003 followed by a high reservoir water level. When the moderate rain occurred during 29th of December to 3rd of January, water needed to maintain the normal high water level (Cote RN). Hence, the peaks of rainfall (10th to 13th of December) and downstream discharges occurred in separate periods, and high water levels of the Mejerda were observed on the downstream areas despite small rainfall around that day.



source : the Study Team, based on data from MARH

Relations among Rainfall, Reservoir Water Level and Outflow from Sidi Salem (2004 Jan Flood)

A3.7 Implication of Hydrological Characteristics of Past Floods

The past floods prove that the following hydrological phenomena could induce more serious floods which would inflict substantial damages in many parts of the Mejerda River basin.

- The simultaneity of all or some of high inflow peaks to the Mejerda, to the Mellegue and significant rainfall in the entire basin, and
- Multiple peaks of inflow and precipitation

Besides, flood behaviours are determined by the combination of additional hydraulic factors, such as;

- Receiving reservoir water level
- Outflow discharges from dams
- Flow capacity of river channels and structure sites

CHAPTER A4 LOW FLOW ANALYSIS

A4.1 Methodology and Data Used

(1) General

The purpose of the low flow analysis under this Study is to provide dam inflow amount data to be used for the water balance analysis which examines the required reservoir storage volume for water supply. Because this JICA Study focuses on the flood control, it should follow and apply existing plans, theories and concepts regarding water supply as long as available. In order to fulfil the purpose, the low flow analysis for this Study was conducted with the following steps:

- Review of existing studies
- Verification and update of data in existing studies
- Examining and determining historical inflow at existing and planned dam sites
- Statistical analysis of the dam inflow, and
- Deriving inflow at dam sites with probabilities corresponding to the security levels to be considered in the water balance study

The existing studies dealing with hydrological investigations to be referred to are "EAU2000" and "GEORE".

(2) Methodology of EAU2000 and GEORE

Monthly inflow at each dam site was derived by EAU2000 based on available DGRE observation data and past study results. Missing data were filled based on correlations of monthly inflow with those at neighbouring stations and/or other dam sites, and the data completed from 1946/47 to 1998/90.

Then, EAU2000 treated the sum of annual inflows at 16 dam sites located in the "Nord+Mejerda (north and Mejerda) area" (see the following table) as available water resources in the area. Some dams in the Mejerda River basin, such as the Siliana and the R'mel Dams, were classified in the separate area, and some other dams in the Majerda basin which supply water mainly for irrigation to their downstream areas were not considered in EAU2000.

Dams Counted in the Available Water Resources

Region	EAU2000	JICA Study
Mejerda	Sidi Salem Zouitina Mellita	Zouitina Sarrath Mellegue (or Mellegue 2) Tessa Ben Metir Bou Hertma Kasseb Beja Sidi Salem Khalled Lakhmess Siliana R'Mil
Extreme North	Kebir Zerga Moula Sidi Barrak Ziatine Gamgoum El Harka Sejenane Douimis Melah Joumine Ghezala Tine	Kebir Zerga Moula Sidi Barrak Ziatine Gamgoum El Harka Sejenane Douimis Melah Joumine Ghezala Tine

The frequency analysis on the total annual inflow (total at the considered 16 dams) was made by the Thomas plotting using data for 44 years from 1946/47 to 1989/90 in EAU2000. A year with the probability of non-exceedance 0.2 was determined as a “dry year”. In EAU2000, then, the year 1961/62 was selected as a “typical dry year (année type sèche)”.

GEORE extended the inflow data prepared by EAU2000 up to around 2003 as much as available applying additional data.

(3) Computation of inflow by this Study

This JICA Study incorporates 26 dam sites enumerated in the above table into the estimate of available water resources in the basin. The 26 dams constitute a water supply network system in the extreme north and Mejerda River basin, or independently provide water to their local command area in the Mejerda River basin.

Monthly inflow data at the 26 dam sites were derived through verification and filling of EAU 2000/GEORE data, and through involving supplemental data. Daily discharge data observed by DGRE were used for filling, and the method used for data standardisation and extension is the classical method of site to site correlation. The reference period for 56 years from 1946/47 to 1996/97 was selected. This is the maximum period that missing data at all 26 dam sites can be filled by the available data.

Then, the probability of total inflow was re-examined using the updated inflow data series.

This Study analyzed two and three consecutive year flow also, which were not considered in EAU2000.

A4.2 Frequency Analysis

Tables A4.1.1 and A4.1.2 present the annual, two and three consecutive year inflow from 1946/47 to 1996/97, and **Table A4.1.2** shows ranking of those inflows. The following table extracts five extreme drought cases of annual inflow among 56 years of records. This result agrees with the fact that the two significant droughts occurred in 1987-88-89 and 1993-94-95.

Five Cases with Lowest Annual Inflow (1946/47 – 1996/97)

Rank	Annual inflow	
	period	M m^3
1	1993/1994	504
2	1988/1989	617
3	1996/1997	650
4	1994/1995	714
5	1989/1990	789

The probability was computed using samples of the annual inflow for 56 years applying the same methodology of EAU2000, namely Thomas plotting. Following EAU2000, the probability of non-exceedance 0.2 (F=0.2) was determined as a standard of a dry year. The monthly variation and regional distributions of the inflow data sets for the years located near F=0.2 (1960/61, 1973/74, 1991/92) were scrutinised whether they do not display significant biases. 1960/1961 which could be judged to be typical, then, selected as a “typical dry year” for this Study. The probability and percentage of the annual inflow volume against the average is presented in **Table A4.1.2**. Results of extreme drought years and the typical dry year cases are extracted in the following table.

Four Cases with Lowest Annual Inflow and Typical Dry Year

Rank	period	M m^3	% of ave.	F
Extreme cases				
1	1993/94	504	26.4	0.019
2	1988/89	617	32.3	0.038
3	1996/97	650	34.0	0.057
4	1994/95	714	37.4	0.076
Typical	1960/61	1044	54.6	0.189

The probabilities of the two and three consecutive year inflows were estimated also by the Thomas plotting. The computed probabilities are enumerated in the **Table A4.1.2** and the following table presents the values of the three lowest cases for two consecutive years.

The case of synthetic two years (typical dry year 1960/61 x 2 times) with 2,088 M m^3 of the inflow (one cycle of two years) was estimated to occur once in 8.7 cycles in average. This could be interpreted that one cycle of the 2 year inflow with this amount could occur in average in 17 to 18 (8.7 x 2) years.

Three Cases with Lowest 2 Consecutive Year* Inflow and Synthetic 2 Year

Rank	period	Inflow ($M\ m^3$)	F	Once in N cycles*	Occurrence (one cycle* in N years)
1	93 Sep. – 95 Aug.	1219	0.0385	26.0	52
2	87 Sep. – 89 Aug.	1582	0.0769	13.0	26
3	91 Sep. –93 Aug.	2052	0.1154	8.7	17-18
Typical	1960/61 x 2 years	2088	0.115	8.7	17-18

Note : * : One cycle is two years without allowing overlapped years.

CHAPTER A5 FLOOD RUNOFF ANALYSIS

A5.1 Basic Concept and Conditions of Flood Analysis

A5.1.1 Basic Concept

The flood analysis was carried out to obtain runoff hydrographs from sub-catchments and at base points with probabilities of 2, 5, 10, 20, 50 and 100 year return periods. In addition, 200 year probable floods were also computed for the purpose of the dam operation study.

A six day rainfall was applied for this analysis, because six days can cover one peak of rainstorms which produced one peak hydrographs in the actual serious flood events (1973 Mar, 2000 May, 2003 Jan, 2004 Jan, and 2005 Floods).

The hydrological zones (HY-M, HY-U1, HY-U2, HY-D1 and HY-D2 in **Figures A5.1.1**) were determine in connection with zoning for flood control planning. The flood magnitudes along the Mejerda mainstream are described based on the probabilities of six day basin rainfall in the hydrological zones. This concept of basin average rainfall came from the investigation result of isohyetal maps of the past major floods, which explains that the rainfalls covered the almost entire basin during the extensive flood events. Spatially uneven rainfalls also caused floods, but the floods were triggered with local flooding. **Figure A5.1.2** is an example isohyetal map of the 2003 Jan Flood. Isohyetal maps for other floods are in **Data A4 in Databook**.

A5.1.2 Inflow from Algeria

The inflow from Algeria to the Tunisian parts of the Mejerda and Mellegue Rivers was considered as the boundary condition for the flood analysis of this study. With the concept of the basin rainfall, the probable inflow at the Algerian border can be regarded as the resulting discharge caused by the basin rainfall in the Algerian parts with the same probability to the Tunisia parts.

The probable inflows at the Algeria border were derived from the probability analysis of the observed peak discharges at the Ghardimaou and K13 stream gauging stations (G/S) (See **Section A1.5**). Discharges at K13 were converted to the one at BP-AM (the confluence of the Mellegue and the Sarrath Rivers (see **Figure A5.1.2**) in consideration of the differences of the catchment area as in **Table A5.1.1**. The derived probable inflow from Algeria is summarized below.

Probable Peak Discharges of Inflow at Algerian Borders

	CA	Probable Peak Discharge (m^3/s)						
	km^2	2-y	5-y	10-y	20-y	50-y	100-y	200-y
BP-AU1(Ghardimaou)	1480	250	520	790	1150	1830	2550	3540
BP-AM (Mellegue & Sarrath Conf.)	6230	440	930	1370	2120	3300	4420	6220

Source : the Study Team

A5.2 Flood Runoff Analysis

A5.2.1 Rainfall Analysis

(1) Rainfall probability

The daily rainfall records at each gauging station furnished by DGRE were utilized for the analysis. Those point rainfalls were first converted to daily basin rainfalls by the Thiessen method. Six day basin rainfalls were computed and their annual maximum values were extracted. Then, their frequency was analyzed through the comparison of various probability distributions. Probable basin rainfalls were assigned to each hydrological zone (HY-M, HY-U1, HY-U2, HY-D1 and HY-D2 in **Figures A5.1.2**).

The derived probable rainfalls are summarized in the following table, and **Table A5.2.1** lists the six day basin rainfalls and their probabilities related to the past major floods. For simplicity, the 6 day basin rainfall for HY-U2 was determined to be applied also to HY-D1 and HY-D2 as they presented similar values.

Probable Six Day Bain Rainfall (mm)

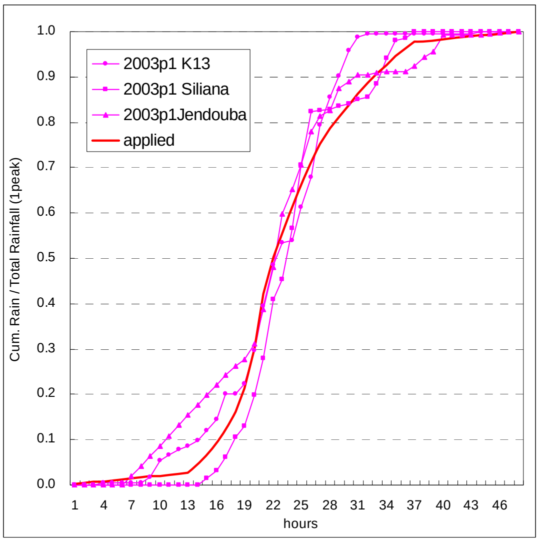
Zone	HY-M	HY-U1	HY-U2	HY-D1		HY-D2		HYd-Bh
Base Point (Point de base)	Mellgue& Mejerda Conf.	Mellgue& Mejerda Conf.	Sidi Salem Dam (Barrage)	Larrousia Dam (Barrage)		Estuary (Estuaire)		Bou Heurtma Dam (Barrage)
Catchment Area (Surface du bassin Versa) (km2)	4561	1154	10414	14172		15968		390
Return period (yr) (Période de retour) (an)								
1.01	25	42	28	28	(24)	28	(23)	86
2	55	75	60	60	(56)	60	(55)	143
5	82	101	84	84	(80)	84	(79)	185
10	104	121	100	100	(98)	100	(96)	215
20	128	141	118	118	(116)	118	(113)	246
30	143	155	129	129	(127)	129	(124)	264
50	164	171	143	143	(141)	143	(137)	289
100	195	196	163	163	(162)	163	(156)	324
200	230	224	184	184	(184)	184	(175)	361
Distribution	LP3	LP3	LP3	LP3		LP3		LP3

Note : Data used : 1968/69 - 2005/06
LP3: Log-Pearson Type III
( ): Original estimate
Source: the Study Team

Basin rainfalls of each dam catchment were computed, and were found to be close to the basin rain of hydrological zone which comprise the dam catchment, except for the case of the Bou Heurtama dam. Hence, an independent basin rainfall was applied to the Bou Heurtma catchment, and for other dam catchments, six day basin rainfall of an associated hydrological zone was determined to be applied.

(2) Design hyetographs

Figure A5.2.1 presents applied design hyetographs. These were developed from the typical rainfall time distribution pattern of available hourly rainfall data observed during the experienced major floods (1973, 2000, 2003, and 2004) obtained from MARH and INM. (The following charge is an example of cumulative hourly rainfall observed during the past floods. The design hyetograph was derived from the average of cumulative hourly rainfall.)



A5.2.2 Unit Hydrograph

The dimensionless unit hydrograph method was employed in this study for computing runoff from subcatchments in consideration of the basin characteristics, data availability, and the required accuracy for a master plan study. **Figure A5.2.2** illustrates sub-catchments for runoff analysis, and **Figure A5.2.3** schematically shows the runoff analysis model.

(1) Dimensionless unit hydrograph

Recorded hydrographs of the past major floods at the major gauging stations without impacts of dam operation were examined. The observed hydrographs at Ghardimaou and K13 G/Ss holding the adequately large catchment areas were selected to be utilized for developing a dimensionless unit hydrograph which represents the standardized basin runoff characteristics. **Figure A5.2.4** is the applied dimensionless unit hydrograph.

(2) Unit hydrograph

The dimensionless unit hydrograph was converted to a unit hydrograph for each sub-catchment. The parameters required are the catchment area and a lag time. (see **Figure A5.2.4**) The lag time Tcv can be derived by the following equation.

$$Tcv = C \times \left(L \times Lca / \sqrt{Sst}\right)^{0.38}$$

where; Tcv: Lag time. Time from the beginning of rise of net hydrograph to time of occurrence of on-half volume of hydrograph .

C: Constant, 0.72 for foothill drainage area

L: Mainstream length from outlet to watershed

Lca: Mainstream length from outlet to watershed centroid

Sst: Overall slope of mainstream

The required geometric parameters, such as catchment areas and river lengths, were measured on the digitized 1/50,000 and 1/25,000 maps issued by Office de la Topographie et de al Cartographie (Office of Topography and Mapping). **Table A5.2.2** enumerates parameters for each sub-catchment.

Figure A5.2.5 presents examples of obtained unit hydrographs against a unit excess rainfall of 10mm in 1 hour and **Table A5.2.2** enumerates peak discharges of unit hydrographs for each of sub-catchments.

A5.2.3 Probable Floods

(1) Runoff from each sub-catchment

2, 5, 10, 20, 50, 100 and 200 year probable runoff was computed. The rainfall inputs (design hyetographs) was transformed to runoff from each sub-catchment using the software HEC-HMS distributed by the US Army Corps of Engineers. The computed runoff hydrographs for sample sub-catchments are compiled in **Data A5 of Databook**, and peak discharges of runoff from each sub-catchment are listed in **Table A5.2.3**.

(2) Computation of probable floods

The resulting discharges at the base points along the Mejerda have to be computed according to the runoffs from each sub-catchment. In the Mejerda river network shown in **Figure A5.2.3**, ruonff hydrographs are transformed and mitigated by the reservoir operation as well as the flood routine along the river channels. Besides, this Study should involve the reservoir operation simulation for different scenarios in order to analyze effects of the improvement of reservoir operation to downstream floods.

Therefore, in this study, hydrographs at the base points were computed by the commercial software called MIKE BASIN which can simulate reservoir operation together with the river channel flood routine. **Figure A5.2.6** presents simulated discharges of natural (without dam), present ("Standard dam operation") and improved reservoir operation ("Optimised Operation 2030") cases. The river channels were assumed to be in the present condition. Details on the reservoir operation simulation by MIKE BASIN are described in **Supporting Report C**.

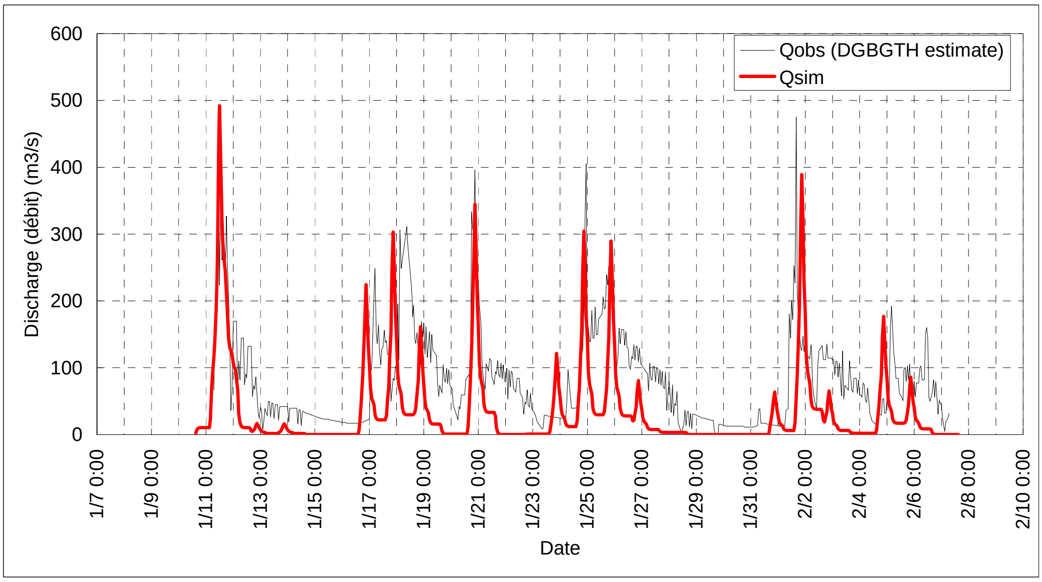
(3) Verification

Specific discharges of the acquired probable floods were examined in comparison with the ones from other sources, such as:

- Runoff from sub-catchments computed in this study.
- Probability analysis results of observed discharges at gauging stations in this study and existing studies (e.g. "Monographies Hydrologiques", 1981), and
- Probable discharges at existing and planned dam sites in existing studies/designs

Tables A5.2.3 and **A5.2.4** list probable peak discharges and corresponding specific discharges at various base points in the study area. **Figure A5.2.7** plots those specific discharges, and it proves that the specific discharges for the probable floods obtained by this study falls along curves formed by the specific discharges in the existing studies.

Another investigation was made through comparison between the recorded and simulated hydrographs. The following chart demonstrates a good match of the two hydrographs at the Bou Heurtma dam site.



Note: Qobs (DGBGTH estimate): Inflow estimated by observed reservoir water levels and recorded outflow discharges

Qsim : Simulated hydrograph

Source: the Study Team

Observed and Simulated Hydrographs at Bou Heurtma Dam Site (2003 Jan Flood)

Through these observations, the runoff analysis result was judged to be verified.

CHAPTER A6 FLOOD INUNDATION ANALYSIS

A6.1 General

The purposes of the inundation analysis for this Study were;

- to clarify flood mechanisms and characteristics, such as water levels, overflowing positions and flow directions on the flood plains,
- to compare inundation conditions before and after project implementation, and
- to obtain design water levels and other hydraulic parameters of the selected river improvement cases for preliminary design.

In order to evaluate effects of the reservoir operation improvement and of river improvement works separately, the following three cases of the project steps were considered. The inundation caused by five different probable floods (5, 10, 20, 50 and 100 years) for each of the following cases were simulated, and those simulation results have been utilized to estimate and evaluate flood damages (benefits by the river improvement) for establishing flood control planning.

Cases for Inundation Analysis
(Combination of Reservoir Operation and River Channel Conditions)

Cases	Reservoir Operation Type	River Channel
Before Project : Present Condition	Present standard operation	Present condition
After Project 1 : Improved Reservoir Operation	Improved operation (2030)	Present condition
After Project 2 : Improved Reservoir Operation + River Improvement	Improved operation (2030)	River Improvement (Master plan design by the Study)

Source: the Study Team

The reservoir operation type and the river channel shape in the above table are briefly described in the following table. Details on the reservoir operation types are discussed in **Supporting Report C** and river channel designs are in **Supporting Report D**.

Reservoir Operation Types	
Present Standard Operation	• Standard operation (Present typical operation) • Four existing selected dams (Sidi Salem, Mellegue, Bou Heurtma, Siliana) • Result of the reservoir operation analysis under the Study by MIKE BASIN
Improved Operation (2030)	• Recommended improved reservoir operation for the targeted year 2030 • Seven selected dams (Sidi Salem, Mellegue, Bou Heurtma, Siliana + Sarrath, Tessa, Mellegue 2) • Result of the reservoir operation analysis under the Study by MIKE BASIN

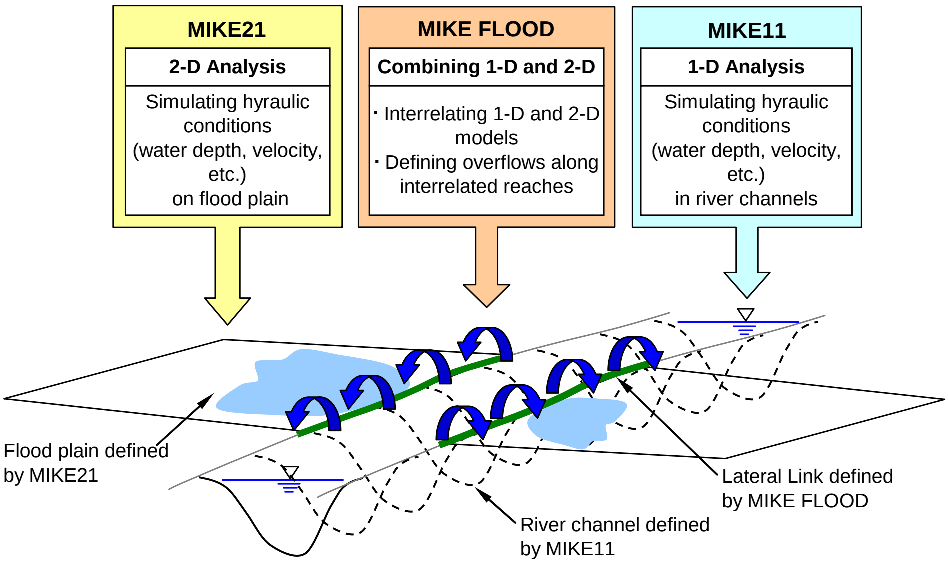
River Channel	
Present Condition	• 2007 topographic survey results (cross sections and longitudinal profiles) conducted by MARH and the Study Team
River Improvement	• Present condition (2007 topographic survey results conducted by MARH and the Study Team) + Anticipated river improvement alternatives (excavation, bypass channels and retarding basins) designed under the Study

Source: the Study Team

A6.2 Methodology

A6.2.1 Overall Model Description

Numerical models have been utilized to simulate inundation for various inflow and river channel conditions. The unsteady two dimensional model was employed to the inundation analysis for the study. The unsteady analysis was chosen, because it allows to investigate temporal changes of flood behaviours including the inundated area, water level and discharges. Further, the two dimensional model was applied accommodating to the widespread inundation area observed during the experienced floods, especially in the downstream areas. The commercial software MIKE FLOOD produced by DHI was used for this study. It enables to combine an one dimensional (1-D) and two dimensional (2-D) hydraulic models like below.

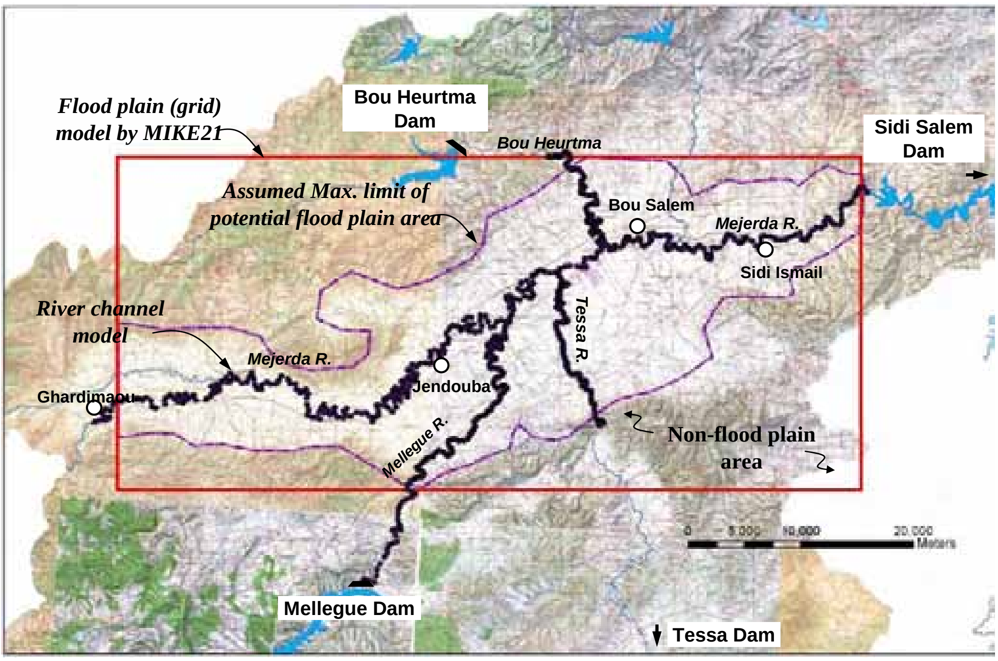


Source: the Study Team

Basic Concept of Relations among MIKE11, MIKE21 and MIKE FLOOD

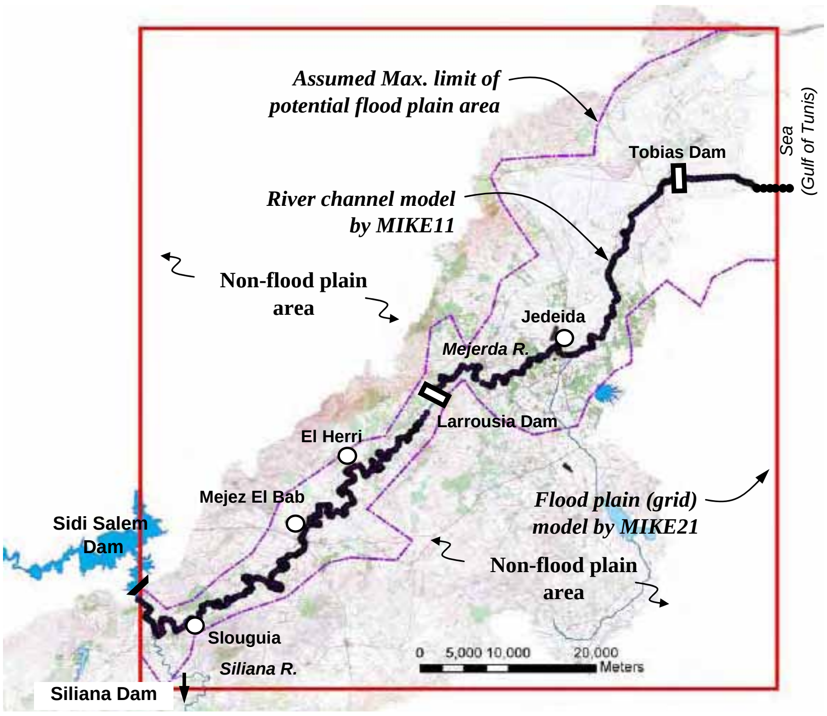
This section briefly states the simulation model, and details are contained in **Data A6 in Databook** (Training Text: Explanation Note on Inundation Analysis Model (MIKE FLOOD) for the Mejerda River Basin).

The inundation analysis model for this master plan study has been designed to cover potential flood plain areas in the entire Mejerda. The model was divided into the upstream and downstream models at the Sidi Salem Dam, because hydraulic conditions of the two zones are made discrete by the dam. The following maps indicate the extents covered by the models.



Source: the Study Team

The Area Covered by Mejerda Upstream Model



Source: the Study Team

The Area Covered by Mejerda Downstream Model

The 1-D part of the model was established along the Mejerda River and its major tributaries on the potential flood plains where cross section data in 2007 are available.

The 2-D part of the model was constructed along the 1-D model rivers using grid topography data (228 m x 228 m). The grid size was selected in consideration of the required accuracy for a master plan level of the study and intervals of the available cross sections (approximately 500m). An independent model with smaller grid size (76m x 76m) was prepared only for the Bou Salem city area so as to reproduce actual inundation conditions attributing to locally low banks of the Bou Hertma River.

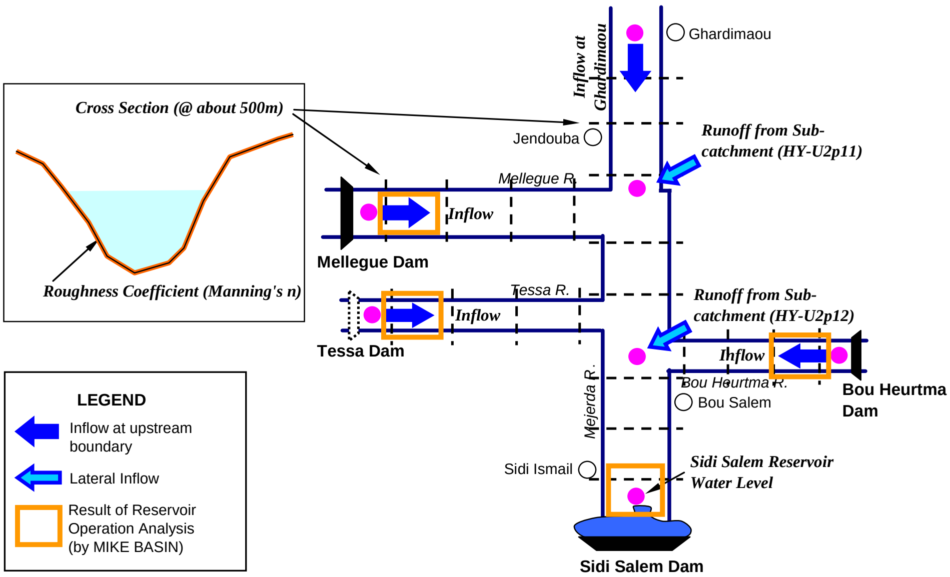
A6.2.2 Data Applied and Boundary Conditions

Major required inputs for building the model are listed below, and the subsequent figures illustrate the major inputs for the 1-D part of the model. The hydraulic boundary conditions are controlled by the 1-D model. As in the table, the inundation analysis model necessitates dam outflow discharges resulted from the dam operation simulation by MIKE BASIN as its inputs.

Required Major Input for Inundation Analysis Model

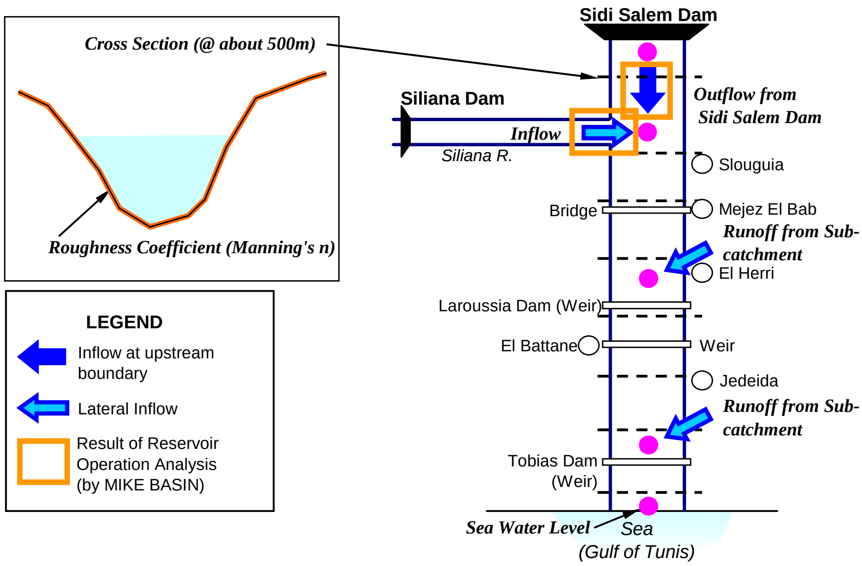
Input	Data source	Related Part
Cross section (coordinates of locations, intervals, and X, Z)	• Results of topographic survey conducted by MARH and the Study in 2007 • Designed cross section by the Study (for “After project, with river improvement case only)	1-D part
Upstream boundary condition (Outflow from dams, inflow from Algeria)	• Results of the reservoir operation analysis conducted under the Study (by MIKE BASIN) • Runoff analysis results done under the Study	1-D part
Downstream boundary condition (Reservoir water level, Sea water level)	• Existing studies • Results of topographic survey conducted by MARH in 2007	1-D part
Runoff inflow (lateral inflow) from sub-catchment	• Runoff analysis results done under the Study	1-D part
Structures (weir and bridge)	• Results of topographic survey conducted by MARH and the Study in 2007 • Existing drawings and reports	1-D part
Flood plain topography	Grid topography data	2-D part

Source: the Study Team



Source: the Study Team

MIKE11 Mejerda Model for Upstream of Sidi Salem Dam



Source: the Study Team

MIKE11 Mejerda Model for Downstream of Sidi Salem Dam

Based on the prior non-uniform analysis for flow conditions at bridge and other structure sites, the unsteady inundation analysis model was decided to consider the following bridges and structures which demonstrated rather significant impacts.

Upstream of Sidi Salem Dam	• A bridge over Bou Heurtma River at about 280m upstream of the confluence with the Mejerda
Downstream of Sidi Salem Dam	• Andarous Bridge at Mejez El Bab • Larrousia Dam • El Battane weir • Old Bridge at Jedeida • Tobias Mobile Dam • Other weirs crossing riverbed, such as a weir at the El Herri pumping station

The gates of the Larrousia and Tobias Mobile dams are assumed to be fully opened throughout flood periods of the major floods following the present operation.

A6.3 Calibration of Models

As described in the previous sections, a series of the flood analysis involves the two sets of simulation models, MIKE BASIN utilized for the probable flood computation and the MIKE FLOOD hydraulic/inundation simulation model applied to the flood inundation analysis. The two models were calibrated so as to be compatible with each other.

A6.3.1 Calibration of Reservoir Operation Simulation Model (MIKE BASIN)

MIKE Basin builds on a network model which can comprise river reaches, diversions, reservoirs, and water users. Technically, MIKE Basin is a quasi-steady-state mass balance model, however allowing for routed river flows.

The mathematical model of reservoirs and river reaches in the whole Mejerda River catchment was calibrated based on historical discharge records at dams and gauging stations. The most complete and reliable data came from floods in May 2000, in January up to February 2003 and in December 2003 up to January 2004, and these flood events were used for the calibration.

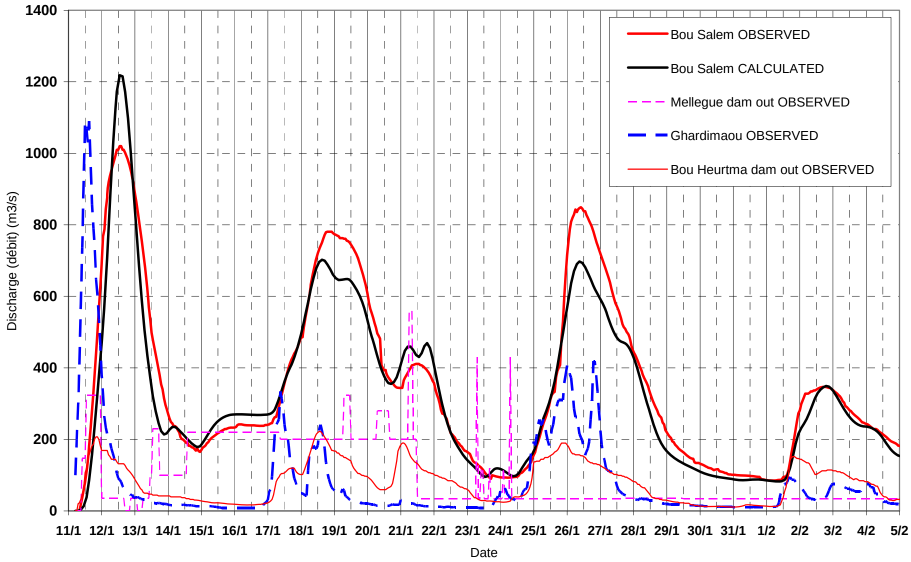
Calibration of river reaches in the model represents finding of flood routing equation parameters which can bring the same or adequately close flood wave propagation and reduction of flows to observed hydrographs.

Calibration results

Calculated discharge hydrographs at the most important points (stream gauging stations or dam sites) are compared with actually observed hydrographs as in the following figure for the Bou Salem gauging station. It could be seen from the chart that the calculated hydrograph corresponds to the observed one relatively well. For quantitative evaluation the following criteria are usually applied:

- Convergence of flood propagation times
  Replication of observed time with max. difference < 10 %
- Convergence of discharge values
  Replication of observed discharges with max. difference of peak discharge < 20 %

These criteria have been fulfilled for Bou Salem gauging station and also for all other evaluated points with minor exceptions which can be neglected. Through such investigations, the prepared MIKE Basin model was confirmed to describe flood routing and flood wave propagation in the Mejerda basin properly and can be applied to the simulations under this study.



Source: the Study Team

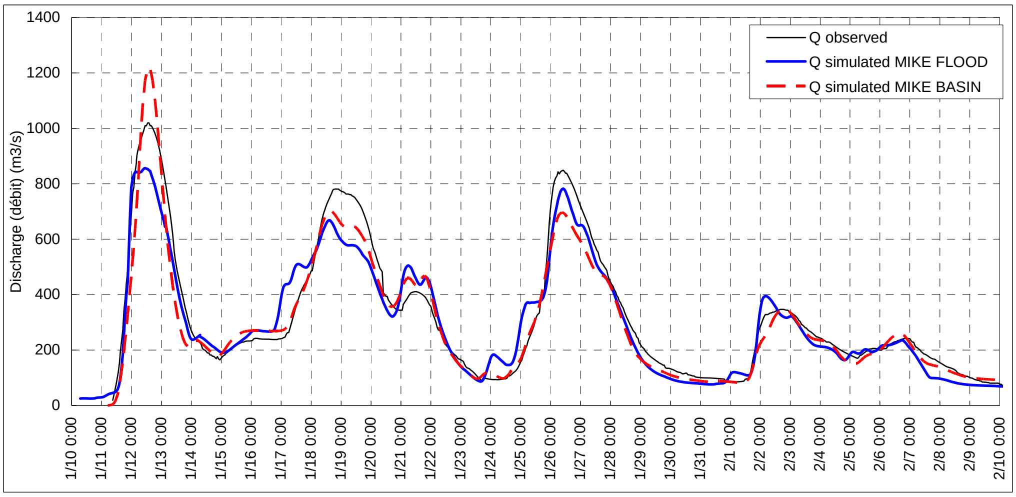
Calibration of MIKE Basin Model – Bou Salem Gauging Station, 2003 Jan Flood

A6.3.2 Calibration of Hydraulic / Inundation Analysis Model (MIKE FLOOD)

The model was calibrated based on hydrographs, water level, inundated area, depth, duration and flow direction on the flood plain. The 2003 Jan Flood, which can provide the most adequate and reliable inundation data, is mainly referred to for the calibration. It should be noted that due to deficiency of data, especially inundation maps, calibration of the inundation simulation model by other floods were found to be difficult.

(1) Hydrographs

Observed hydrographs from DGRE, MIKE FLOOD simulation results and MIKE BASIN simulation results were compared. The following chart is an example from the 2003 Jan Flood at Bou Salem.



Source: the Study Team

Observed and Simulated Hydrographs at Bou Salem (2003 Jan Flood)

The visual inspection gives the sight that three hydrographs match adequately. Further, the differences were evaluated by the sum of square of an error at each time step described by the following equation;

$$E = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{Q_0(i) - Q_c(i)}{Q_{op}}\right)^2$$

where; E: Error

$Q_0(i)$: Observed discharge at a time step i

$Q_c(i)$: Computed discharge at a time step i

$Q_{op}(i)$: Maximum of observed discharge

n: The total number of time steps for the computation

The appropriate E value for adequate fit is said to be 0.03 or less. 0.007 between the observed and MIKE FLOOD's hydrographs and 0.006 between the MIKE FLOOD and MIKE BASIN simulation results are within the acceptable range.

(2) Inundation area and depth, and water level

Existing inundation maps of the 2003 Jan Flood were compared with the simulation result. Overall simulated inundation maps of the 2003 Flood were presented in **Figure A6.3.1**. **Figure A6.3.2** compares the simulated and recorded boundaries of inundated areas at the Bou Salem, Mejez El Bab and El Battan – Jedeida areas, and the simulated inundation limits were found to be close to the observed ones. Available recorded inundation depth data were also confirmed to have similar tendencies with the simulation result.

(3) Flow direction

The simulation result was confirmed to demonstrate similar tendency of the progress of flood flows observed during actual floods, for example;

- In the Bou Salem area, flood water overflowing the right bank of the Bou Heurtma River move towards Bou Salem City.
- In the Jedeida area, flood water overflowing at downstream of Jedeida City (El Henna) on the left bank proceeds towards the El Mabtouh area in the north, and further to the north with the progress of the time.

As a conclusion, the simulation result by the MIKE FLOOD model has been confirmed to adequately agree with the observed records and MIKE BASIN results.

A6.4 Inundation Analysis Simulation Results

A6.4.1 Inundation under Present Conditions (Before Project Case)

The simulated total inundated area according to the return period (5 to 50 years) is summarised in the following table. Discharges including dam outflows applied to this case of the simulation are shown in **Figure A5.2.6 (1/3)**. The basic flood discharges for the associated selected planning scale (see **Section A6.4.3**) are marked in the figure.

In terms of the area of inundation, the region covering Jedeida to El Mabtouh low lying area (in D2) is the most predominant followed by the upstream reaches of Larrousia Dam (in D1) and the area around Bou Salem (in U2). This explains the experienced floods.

The limits of inundation with different probabilities obtained from the simulation were presented in **Data A7 of Databook**.

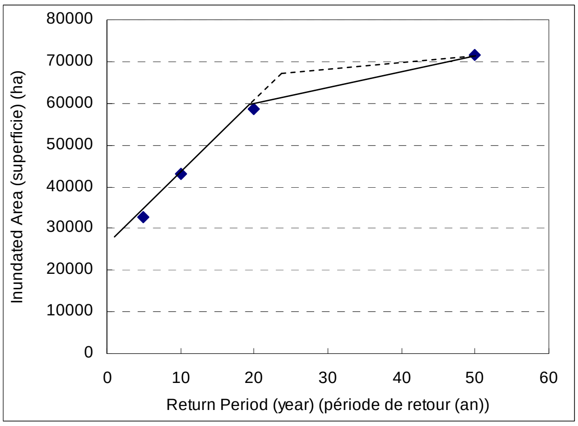
Inundated Area Derived from Simulation (Present Condition)

(unit: ha)

Zone	5-year	10-year	20-year	50-year
U1	350	790	1,890	4,960
U2	2,210	4,540	6,670	8,430
M	150	430	1,070	1,590
Upst Total*	**2,700**	**5,800**	**9,600**	**15,000**
D1	2,770	3,960	4,810	5,690
D2	27,080	33,400	44,070	50,810
Downst Total*	**29,900**	**37,400**	**48,900**	**56,500**
Total*	**32,600**	**43,100**	**58,500**	**71,500**

Note: * : rounded, Source :the Study team (Simulation result)

The subsequent chart shows the estimated relation between the total inundated area and the return period. The area increases with the return period up to 20 year (or could be more) linearly, but with larger return periods an increase rate drops. This trend would be brought by the topographical limit of flood plains.



Inundated Area (simulation) and Return Period

The major findings acquired from the simulation results are stated below. Generally, the simulation result was found to well explain actual flooding behaviours.

(1) Upstream of Sidi Salem Dam

<u>Common to all probable floods</u>

- The following reaches are particularly prone to have inundation.
  - Around the confluence of the Mejerda and Rarai Rivers
  - Around the confluence of the Mejerda and Mellegue Rivers
  - Bou Salem
  - Around the confluence with Kasseb River, especially around the old river course (ox tail) of the Mejerda
- Inundation in the Bou Salem area can be observed when the return period reaches to 10 years.
- Flood flow in the Bou Salem area basically comes from the Bou Heurtma River. Overflow starts at the low section on the right bank of the Bou Herutma River.

<u>20, 50 and 100 year Floods</u>

- Due to the abrupt change of bed slope about 5 km downstream of the Kasseb confluence (almost zero slope due to sedimentation in the reservoir on lower reaches and a riverbed with the slope of approximately 1/2,300 on upper reaches), the clutter of flow tend to occur around this area when discharge reaches to the scale of 20 year probability.

(2) Downstream of Sidi Salem Dam

Common to all probable floods

- The following areas are apt to suffer from inundation, even by 5-year and 10-year probable floods.
  - Downstream of Jendouba city (El Henna)
  - Upstream of Larrousia Dam including Mejez El Bab
  - El Mabtouh Area
  - Downstream of the Tobias Mobile Dam
- The inundation starting near the downstream of Jedeida (El Henna) progresses towards the El Mabtouh area in the north.
- Duration of inundation is generally long. In many areas, inundation continues a week or more.

20, 50 and 100 year Floods

- When the magnitude of flood reaches to 20 year probability, the inundation can be observed also in the following area
  - The low lying area situated on the northeast of the El Mabtouh area (Flood water flows into this area from El Mabtouh)
  - El Battan and Tebourba area.
- The temporal order of starting overflowing is (i) upstream of Larrousia Dam, (ii) down stream of Jendouba city, and then (iii) El Battan-Tebourba area.

A6.4.2 Inundation under After Project Condition (Improved Reservoir Operation Case)

The first step of the “After Project Condition” considers improved reservoir operation with present river channels. Discharges applied to this case as the boundary conditions are presented in **Figure A5.2.6 (3/3)**. The table below compares the inundated area of the before project condition and the first step of the “after project” case. Related inundation maps are compiled in **Data A7 of Databook**.

Inundated Area Before and After Project (Reservoir Operation) (unit: ha)

Zone	5-year	10-year	20-year	50-year
Upstream				
Before Project	2,700	5,800	9,600	15,000
After Project -Reservoir Operation	1,800	4,200	8,900	14,800
Downstream				
Before Project	29,900	37,400	48,900	56,500
After Project -Reservoir Operation	20,600	35,900	44,900	55,900
Upstream + Downstream				
Before Project	32,600	43,100	58,500	71,500
After Project -Reservoir Operation	22,400	40,100	53,800	70,700

Source: the Study team (Simulation result)

The major inundation characteristics of the after project cases are summarized below.

- With the improved reservoir operation followed by reduced outflow, the inundated area shrinks. However, this effect becomes less remarkable with the increase of the return period. This is directly connected to the regulated peak outflow discharges from the dams.
- Inundation still exists even with the improved reservoir operation.
- The overall characteristics of inundation behaviour, such as overflowing fragile reaches and flow directions, basically corresponds to the Before Project Case, except the inundated area.
- Long duration of inundation is observed even after the improvement of the reservoir operation due to mitigated but prolonged outflow from dams, especially on downstream of the Sidi Salem Dam.

A6.4.3 Inundation under After Project Case (Improved Reservoir Operation + River Improvement)

The second step of the after project case is a combination of improved reservoir operation and river improvement. Boundary inflow discharges to the model (dam outflow discharges in principle) for this case are also in **Figure A5.2.6 (3/3)**

Inundation of various river improvement alternatives has been simulated in order to explore the most cost effective river improvement plans. A 20-year flood for U2 and a 10-year flood for other zones was determined to be the most appropriate scale for the river improvement. (River improvement concepts and the selection of options are discussed in **Supporting Report D**.) **Figure A6.4.1** compares the inundation maps of the selected cases of before and after project conditions.

Some inundation still remains even after installing river improvement works. These areas contribute to mitigating peaks of downstream discharges. Such inundation, namely locations and extents, attribute to the concept of the river improvement planning. Details are described in **Supporting Report D**.

A6.5 Comments on Conceivable Inundation Analysis at the Future Stage

The inundation analysis simulation model (MIKE FLOOD model) for this Study was designed to fulfil adequate accuracy for the master plan study. The following issues are to be suggested for the future inundation analysis at the subsequent stages of the flood management studies in the Mejerda River basin.

- For this Study, the model was built applying the 500 m interval of cross sections and topography grid data with the size of 228m x 228m in principle. These sizes led adequately accurate results for the master planning level of inundation analysis. However, for the analysis of further details at the future stages, higher resolution of grid topography data (smaller grid size) and cross sections at shorter intervals need to be applied so that more sporadic hydraulic phenomena can be simulated.
- For the more detailed analysis of the future stages with smaller grid size and cross section intervals, models are suggested to be divided into more than two areas or to

be limited to selected target areas, instead of using the models for this study covering the entire up- or downstream areas.

- A new set of cross section survey might be required when the model will be updated in the future, because cross section shapes might change due to sedimentation or erosions. The roughness coefficients might also have to be updated in consideration of vegetation conditions.
- More structures may have to be included in the future model with higher resolution if necessary.

CHAPTER A7 SEDIMENT ANALYSIS

A7.1 General

One of the most considerable problems associated with sedimentation in the Mejerda basin has been believed to be reduced flow capacities due to sediment deposits in river channels.

In order to sustain an expected capacity conveying flood water, periodic maintenance dredging/excavation of the river channel is indispensable if sedimentation is actually superior to scouring in the river channel of the Mejerda. A general trend of sediment deposits in the river channel was analysed in this study in order to form a preliminary estimate of a long-term average of the required channel excavation/dredging volume, which will be applied for assessing necessary average maintenance costs as a part of the economic evaluation of the flood management master plan.

In this study, a general sedimentation trend in the river channel over time was evaluated through cross section geometry. This approach was selected to accomplish the above purpose for the master plan study using available data. Detailed sedimentation analyses would be needed at future stages for further discussions on sedimentation related issues, such as riverbed movement at a particular location, if necessary.

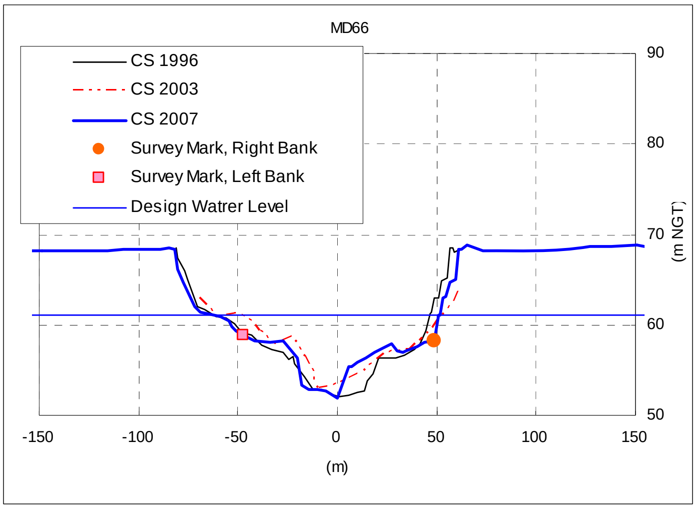
A7.2 Downstream of Sidi Salem Dam

A7.2.1 Methodology

The cross sectional survey results conducted in 1996, 2003 and 2007 by MARH have been compared through the following procedure to examine the amount and rate of change. The 2003 cross section data exist only for the stretch between the Sidi Salem and Larrousia Dams. The limited number of cross sections in 1959 was also available, but not used in this discussion due to shortages of availability and reliability.

1) Overlaying cross sections in different years

Locations of cross sections from different data sets surveyed in different years were compared on GIS maps, and sections situated at the same location or sufficiently close to each others were identified. Then, sections at an identical (or adjacent) location in different years were overlaid. The change in one cross section site is illustrated in the following figure, which shows the alternating periods of deposition and scour within the channel.



Source: the Study Team, based on cross section data from MARH

Example of Chronological Cross Sections

2) Computing cross section areas

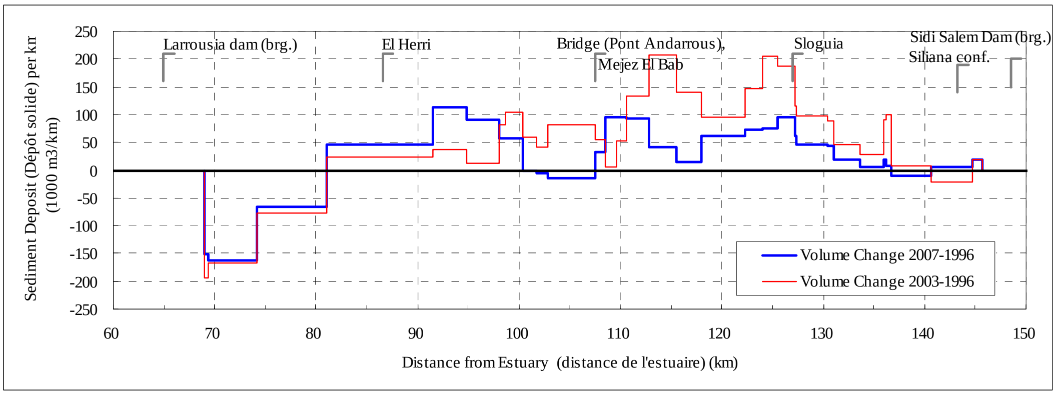
The area of cross sections (flow area) under a reference level (bank elevation, in principle, or design water level where riverbanks are considerably high), which was determined at each location, were computed.

3) Estimating volume of sedimentation or scouring

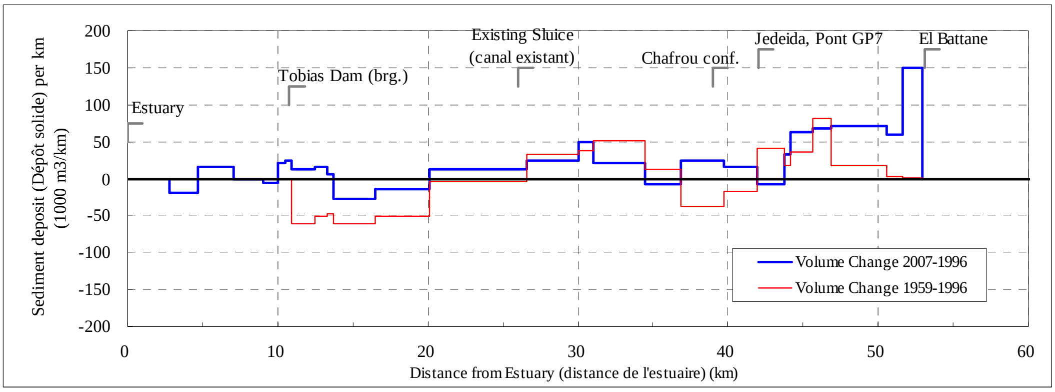
Irregular cross sections of the natural channel were represented by the channel width at the reference level, average and maximum depths, and cross sectional area. These variables were examined. Then, based on the computed cross sectional areas and distances between cross sections, sedimentation (or scouring) volumes in the river channel were derived.

A7.2.2 Preliminary Evaluation of Average Sedimentation Amount

Temporal changes obtained through the above procedure were investigated at the reach scales. The sedimentation (or scouring) volumes between two different years of cross sectional surveys (changes against the situation in 1996) were compared as in the charts below.



(a) Sidi Salem Dam – Larrousia Dam



Note: The change between 1959 and 1996 is shown only for reference. Reliability of the 1959 cross section data is not high.

(b) Larrousia Dam – Sidi Salem Dam

Source: the Study Team

Sediment Deposit (or Scouring) Volumes against River Channel Situation in 1996

The followings are findings observed;

- Comparison of existing data indicates the flow capacities of the river channel are not in a monotone decreasing trend. Changes vary with location along the river. Besides, even at the same location, the river channel has been scoured for certain periods and have accumulated deposits for other periods.
- In general, the existing records suggest that sedimentation prevails to scouring, and the flow areas tend to decrease accordingly.
- In the Mejerda River, deposits are often observed on riverbanks rather than a riverbed. Then, to restore flow capacities, scouring could occur at the riverbed. Hence, in the Mejerda River, deposition which cause a reduced flow capacity is not always equivalent to riverbed aggregation.
- Deposits from 1996 to 2003 generally show higher volume than from 1996 to 2007. This would be resulted from frequent floods from 2003 to 2005, after relatively drought period between 1996 and 2002. Normally, scouring could prevail receiving frequent floods, and contrariwise during dry years having few high discharges.

The average sediment amount between 1996 and 2007 was determined to be utilized for discussing long-term averages of sedimentation in the river channel on downstream of the

Sidi Salem Dam in this study. This period is preferable, because a series of cross sectional data for these years were adequately available and reliable, and because this period includes both flooding and drought years impartially.

The following table enumerates the average sediment amount during the periods between 1996 and 2007.

Estimated Average Sediment Amount from 1996 to 2007

Zone	Section		CA** (bv)	Distance	Volume 1996-2007 11 years	Volume /km/yr (Volume /km/an)	Volume /yr (Volume /an)	Volume /yr , 20% allowance added (Volume /an, 20% indemnité ajoutée)	Net volume (volume net)*	Equivalent height (Équivalent hauteur)
			km2	km	1000m3/km	$1000m^3$/km/yr ($1000m^3$/km/an)	million m^3/yr (million m^3/an)	million m^3/yr (million m^3/an)	million m^3/yr (million m^3/an)	mm/yr (mm/an)
D1	Sidi Salem	- Testour		10.1	0	0	0.000	0.000	0.000	
D1	Testour	- Slouguia		11.0	30	2.727	0.030	0.036	0.018	
D1	Slouguia	- Mejez El Bab		19.5	75	6.818	0.133	0.160	0.080	
D1	Mejez El Bab	- MD145, 100 km from estuary (100 km de l'estuaire)		7.9	0	0	0.000	0.000	0.000	
D1	MD145, 100 km from estuary (100 km de l'estuaire)	- 82 km from estuary, near El Herri (82 km de l'estuaire, près d'El Herri)		18.0	70	6.364	0.115	0.137	0.069	
D1	82 km from estuary, near El Herri (82 km de l'estuaire, près d'El Herri)	- Larrousia Reservior up end (jusqu'à la fin de Reservior Larrousia)		14.7	10	0.909	0.013	0.016	0.008	
D1	Larrousia Reservior up end (jusqu'à la fin de Reservior Larrousia)	- Larrrousia Dam (barrage)		2.3	0	0	0.000	0.000	0.000	
D1	D1 Subtotal (Total partiel)		2495	83.5			0.291	**0.349**	0.175	0.070
D2	Larrrousia Dam (barrage)	- El Battane		11.9	0	0	0.000	0.000	0.000	
D2	El Battane	- Jedeida		11.4	70	6.364	0.073	0.087	0.044	
D2	Jedeida	- Chafrou		2.7	10	0.909	0.002	0.003	0.002	
D2	Chafrou	- Existing Slouice (Existants canal)		12.9	20	1.818	0.023	0.028	0.014	
D2	Existing Slouice (Existants canal)	- Tobias		15.3	10	0.909	0.014	0.017	0.009	
D2	Tobias	- Estuary (Estuaire)		10.8	0	0	0.000	0.000	0.000	
D2	D2 Subtotal (Total partiel)		1475	65.0			0.112	**0.135**	0.068	0.046
	Total (Sidi Salem-Estuary)		3970	148.5			0.403	**0.484**	0.242	0.061

Note : * Porosity of bed material on downstream of Sidi Selem Dam (Porosité des matériaux du lit en aval du barrage Sidi Selem)
0.5
** Dam catchments are excluded. (Les bassins versants des barrages sont exclus.) (Sidi Salem, Siliana (and Rmil)

Source: the Study Team

The table also shows equivalent annual sedimentation rates which were converted from the volume to a height (mm/yr) using the following relations.

R : Sedimentation rate (mm/yr), $R = \dfrac{V}{A/1000000} \times 1000$

A : Catchment area excluding dam catchments (km^2)

V: Net sedimentation volume (m^3/yr), $V = (1-\lambda)V_m$

Vm : Sedimentation volume in river channels (m^3/yr)

λ : Porosity, $\lambda = 1 - \dfrac{\gamma d}{GsW} = 0.245 + 0.0864 d_{50}{}^{-0.21}$ (=0.52 $\approx$ 0.5)

γd : Dry density of riverbed material under saturated uncompacted conditions, $\gamma d = 2.00 - 0.229 d_{50}{}^{-0.1}$

d_{50} : Median percentile of the cumulate grain size distribution (cm) (40μm in this case, around 30 to 50μm in the downstream of the Mejerda (MARH))

Gs : Specific weight of sediment material (2.65)

W : Unit weight of water

The heights derived here should be smaller than denudation rates (mm/yr) of sedimentations accumulated in dam reservoirs, because reservoir sediments contain all of bedloads, suspended solids and wash loads, whereas wash loads cannot be contained in riverbed materials. According to the basin preservation study under this JICA Study, dams in the Mejerda basin trap most of all sediment delivered from the upstream watershed, and denudation rates were estimated at 0.4 mm/yr at the Siliana Dam and 0.2 mm/yr at the Sidi Salem Dam, for example. The considerably small figures of heights in the above table could make sense.

In summary, the long-term average sedimentation in the Mejerda basin can be enumerated below, according to the preliminary estimate under this study.

Zone	C.A* km^2	River Length km	Removal vol./yr mil. m^3/year	Rate mm/year
U1	1,154	89.1	0.16	0.070
U2	2,395**	63.9***	0.34	0.070
M	405	18****	0.06	0.070
D1	2,495	83.5	0.35	0.070
D2	1,475	65.0	0.13	0.046

Note:
* : Dam catchments are not included.
**: The Sidi Salem reservoir surface and the catchment area directly flowing to the Sidi Selam reservoir are excluded.
***: The river reaches under the Sidi Salem reservoir are not included.
****: Downstream of the Mellegue Dam

For the estimate of sediment volume in the river channel on upstream of the Sidi Salem Dam where past cross sectional survey results along the channel were not available, the sedimentation rate for Zone D1 (see Chapter A5 for the definition of “D1”) was applied because the D1 catchment shows similar geographical features to the upstream basins.

It should be noted that reduction of flow capacity in the Mejerda depends not only on sediment deposit, but also on growing bush trees in the river channel, according to investigations of several sources, including the above results and actual site conditions. For instance, the channel width of the Mejerda is often said to halve or reduced even more in these two or three decades, but these stories don’t separate impacts of sediments and vegetation. The increased channel roughness by thick bushes and shrubs has reduced the flow capacity of the river channel. It also reduced the sediment transport capacity of the river channel, and triggered further sedimentation.

Hence, in the Mejerda River basin, in order to secure conveyance of water and maintain design flow capacity, cutting / removing bushes in the river channels as well as sediment deposits is of importance.

A7.3 Upstream of Sidi Salem Dam

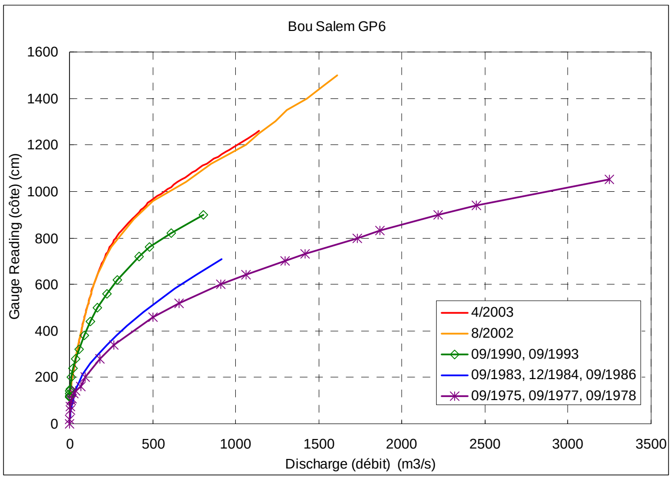
A7.3.1 Historical Changes of Flow areas at Gauging Stations

The alternation of the flow capacity on the upstream reaches was examined using historical rating curves at the Ghardimaou, Jendouba and Bou Salem stream gauging stations. Rating curves were utilized because past cross section data were not available on the upstream reaches.

The following table explains the changes of discharges at a depth of 400 cm at each station, and an example of rating curves at the Bou Salem station are presented in the subsequent chart. For example, the chart means that, at the Bou Salem station, the river section used to be able to convey about 380 m^3/s of flow at a depth of 400 cm in 1984, but only 72 m^3/s of water could flow at the same depth in 2002.

Discharge in Each Year vs Discharge in 1978 (at gauge reading 400cm)

Year	Ghardimaou	Jendouba	Bou Salem
1978	1.0	1.0	1.0
1983	0.67	0.87	0.82
2003	0.52	0.24	0.19



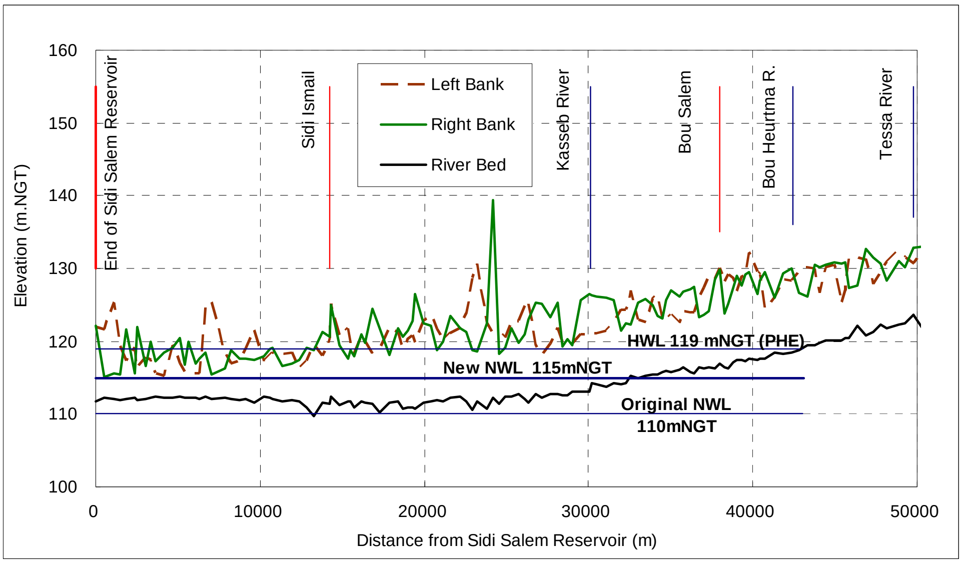
Historical Changes of Rating Curves at Bou Salem Gauging Station

These changes in rating curves entail a decreasing trend of flow capacities at the gauging station sites, although precise flow capacity cannot be computed directly from the rating curves because zero of the curves (normally at the lowest riverbed) floats and gauge readings are not connected to the NGT elevation system. Further, investigation of sets of the rating curves on the upper Mejerda could give the following implications.

- Decrease of flow section is larger at Bou Salem than that of Jendouba and Ghardimaou.
- Decrease at Bou Salem accelerated after the second half of 1980s

A7.3.2 Sedimentation at Upstream End of Sidi Salem Reservoir

The stretch near the upstream end of the Sidi Salem Reservoir for about 25 km is observed to suffer from the most remarkable sedimentation problem, according the cross section survey results in 2007 shown in **Figure A2.2.2 (1)**. The chart below is a magnified bed profile around this stretch along with the highest high water level (PHE) and normal water level (RN) of the reservoir. The deposit around this area is supposed to be the topset bed of "delta deposits" (a reservoir delta).



Riverbed Profile near the Upstream End of Sidi Salem Reservoir

The non-uniform analyses for the before and after sedimentation conditions were carried out to evaluate the potential impacts of the flat riverbed due to sedimentation in this stretch on the upstream water levels. Because of deficiency in available data regarding river geometries before the construction of the Sidi Salem Dam, a riverbed slope before the dam installation was assumed to be parallel to the present river banks as shown in **Figure A7.3.1**. The simulation was made also for two reservoir water levels of 110 mNGT (normal high water level of before 1990) and 115mNGT (present normal high water level).

The downstream end of the available cross section data set is the railway bridge site at about 45 km from the dam site, but water levels in the upper reaches strongly affected by riverbed elevations on further downstream of the surveyed reaches. Longer flat river reaches with sedimentation could result in higher water levels in upper stream. Due to uncertain riverbed elevations in lower parts, the simulation in this study considered assumed upper and lower limits of water levels.

Figure A7.3.1 presents estimated water surface profiles. The major findings from the simulation results are;

- The river reaches likely to be affected by the Sidi Salem reservoir water level extend to about 30km upstream from the railway bridge (around the Kasseb confluence). Sidi Ismail is situated within the affected reaches.
- This part of the river shows significant differences (could reach to maximum 3 to 5 m) of water levels before and after sedimentation cases.
- Upper reaches from the Kassab confluence show little or negligible impacts of reservoir sedimentation and the change of reservoir normal water levels, because these reaches are beyond the back water affected section.
- Bou Salem is located on such reaches receiving little or negligible impacts of reservoir sedimentation or normal water level.

In short, these simulation results imply that inundation conditions around Bou Salem and upper reaches are unlikely to be affected by the reservoir sedimentation or the rise of the normal water level of the Sidi Salem reservoir.

It is often heard that the Mejerda reaches near Bou Salem have become more likely to have flooding than before, and that this was originated from the rise of the reservoir normal water level. Such a story could not be explained from this non-uniform analysis result. Investigations could be made a combination of other facts.

- The historical cross sections and rating curves at the Bou Salem G/S indicate the decrease of flow area at the station, as mentioned above.
- The riverbed profile based on the 2007 topographic survey evidences high bed elevation between the Tessa and Kasseb confluences as in **Figure A2.2.2**.
- The recorded discharge data revealed that annual peak discharges and daily average discharges at the Bou Salem G/S altered after the installation of the Mellegue Dam as discussed in **Section A1.5.5**.

Going though these information from different sources, an assumption could be made that the river reaches near Bou Salem might become more likely to have flooding than before, but this change seems not to attribute to the rise of the reservoir water level. Rather, the progress of sedimentation could be a more dominant factor providing impacts on flooding, and the sedimentation could be led by the reduced discharges after the Mellegue Dam installation.

CHAPTER A8 SECTORAL RECOMMENDATIONS FOR THE SUBSEQUENT STAGES

The hydrological study under this JICA Study, including the runoff and inundation analyses, has been carried out to acquire adequate results for a master plan level of the study to grasp overall inundation situations in the entire basin for different scenarios. Future hydrological studies at subsequent study levels, such as a feasibility study, should be expected to provide more detailed information for particular areas. The following issues are recommended for subsequent hydrological studies at the future stages of the flood management studies in the Mejerda River basin.

(1) Inundation analysis simulation model (MIKE FLOOD model)

- For this Study, the model was built applying about 500 m intervals of cross sections and topography grid data with the size of 228m x 228m in principle. These sizes led adequately accurate results for the master planning level of inundation analysis. However, models at the future stages would necessitate higher resolution of grid topography data (smaller grid size) and cross sections at shorter intervals so as to simulate more sporadic hydraulic phenomena.
- For the more detailed simulations at the future stages applying smaller grid size and cross section intervals, each of models are suggested to be built to cover smaller area unlike the models for this study covering the entire up- or downstream Mejerda basin. A model will have to be limited to cover targeted areas, or the Mejerda basin should be divided into more than two areas.
- More structures which were not considered in this study may have to be included in new models, if necessary, so that local hydraulic situations can be evaluated in detail.

(2) Runoff analysis model

- Sub-catchments are suggested to be divided into smaller portions. Appropriate sizes of sub-catchments should be determined in connection with the extent and purposes of new inundation analysis models.

(3) Hydrological data

Detailed hydrological analyses at the future stages mentioned above will require updated hydrological data. The following improvements are suggested towards the future studies.

- In order to acquire reliable hourly rainfall, water level and discharge data which are essential for the subsequent hydrological studies, collection and storage of hourly data has to be improved. A new real time hydrological data collection and flood warning system (SYCHTRAC: Système de Collecte des Données Hydrologiques en Temps Réels et Annouce de Cures), which is currently being installed in the Mejerda River basin, is expected to bring about significant improvement of hydrological information management in the basin.
- Water level data observed by DGRE are currently expressed by independent gauge

readings. These need to be connected to the NGT elevation system, which has been widely applied to the Tunisian topographic information, such as altitudes in topographic maps, topographic survey results and structural design. Besides, this NGT information of gauge reading datum should be disclosed so that DGRE's water level information can easily be applied and utilized for practical plans and activities.

- Hydrological data in the Algerian territory of the Mejerda River basin basically are provided on a monthly basis at present. Acquiring daily and hourly level of hydrological data in the Algerian parts of the Mejerda basin would be necessary for more detailed hydrological analyses in the future stages. Exploring ways for acquiring data from sources other than Algerian agencies, such as from an international satellite observation system, could be an option.

Tables

Table A1.1.1 Availability of Daily Rainfall Data

(1) Stations in the Mejerda River Basin

ID	Station Name	ID
1485007801	AIN BEYA OUED RHEZALA	1485007801
1485013801	AIN DEBBA	1485013801
1485024404	AIN GUESIL	1485024404
1485026001	AIN HAMRAYA	1485026001
1485027603	AIN KERMA 1	1485027603
1485035001	AIN MERJA	1485035001
1485042103	AIN S'KOUM	1485042103
1485046704	AIN TABIA	1485046704
1485047109	AIN TAGA KEF GHEGAGA	1485047109
1485051102	AIN TOUNGA SE	1485051102
1485053501	AIN ZANA	1485053501
1485055303	AIN ZELIGUA	1485055303
1485059104	AKHOUAT GARE	1485059104
1485069224	AROUSSIA BARRAGE	1485069224
1485073801	BADROUNA BOUSALEM	1485073801
1485076402	BARRAGE KASSEB	1485076402
1485076704	BARRAGE LAKHMES	1485076704
1485079124	BATANE ECOLE	1485079124
1485079902	BEAUCE TUNISIENNE	1485079902
1485082302	BEJA INRAT	1485082302
1485100924	BORJ EL AMRI	1485100924
1485110303	BORJ EL AIFA	1485110303
1485113301	BORDJ HAMDOUNA	1485113301
1485122603	BEN ARAR	1485122603
1485126801	BEN METIR 2 SM	1485126801
1485140301	BOU HEURTMA BGE	1485140301
1485143201	BOU SALEM DELEGATION SM	1485143201
1485160801	CHEMTOU RAOUDET SM	1485160801
1485160901	CHEMTOU FERME	1485160901
1485161622	CHERFECH CRGR	1485161622
1485167203	CITE DU MELLEGUE SM	1485167203
1485168802	COOPERATIVE EL AZIMA	1485168802
1485185601	JANTOURA	1485185601
1485204103	DJERISSA DELEGATION	1485204103
1485250803	DEHMANI ELEVAGE	1485250803
1485251003	DEHMANI MUNICIPALITE	1485251003
1485260303	FATH TESSA	1485260303
1485261924	FEJ KHEMAKHEM	1485261924
1485265901	FERNANA	1485265901
1485266501	FEIJA EL SM	1485266501
1485286401	GARDIMAOU DRE	1485286401
1485290002	GOUBELLAT CHEIKH OUD	1485290002
1485309602	EL HERY	1485309602
1485350803	KALAA KHASBA DELEGATION	1485350803
1485352022	KALAAT ANDALOUS	1485352022
1485352503	KALAAT ESSENAM DELEGATION	1485352503
1485360503	KEF.B.I.R.H	1485360503
1485361903	KEF CMA	1485361903
1485380302	KSAR BOU KLEIA	1485380302
1485383903	KSOUR ECOLE	1485383903
1485387502	KSAR TYR LES ALLOBROGES	1485387502
1485410204	MAKTHAR P.F	1485410204
1485429202	MEJEZ EL BAB PF	1485429202
1485452402	MONTARNAUD 1	1485452402
1485461102	MUNCHAR ECOLE	1485461102
1485462002	MZOUGHA SIDI KHALLED	1485462002
1485490001	OUED EL LEBEN	1485490001
1485498101	OUED MLIZ INRAT	1485498101
1485499003	OUED MELLEGUE K 13	1485499003
1485505304	OUED RMIL	1485505304
1485508004	OUED TINE	1485508004
1485509102	OUED ZARGA FME DENGUEZLI	1485509102
1485519305	PORTO FARINA GHAR EL MELEH	1485519305
1485528801	RAGHAY SUPERIEUR	1485528801
1485550203	SAKIET SIDI YOUSSEF SM	1485550203
1485586204	SENED EL HADDED	1485586204
1485588703	SERS AGRICOLE	1485588703
1485588803	SERS DELEGATION	1485588803
1485625004	SIDI BOU ROUIS SM	1485625004
1485638004	SIDI HAMADA	1485638004
1485667022	SIDI THABET DOMAINE HARAS	1485667022
1485676404	SILIANA AGRICOLE	1485676404
1485676502	SILIANA LAOUJ	1485676502
1485680401	SKHIRA BOU SALEM	1485680401
1485683202	SLOUGUIA	1485683202
1485699001	SK EL ARBA(JENDOUBA)SM	1485699001
1485701801	BOU SALEM DRE	1485701801
1485702201	SK EL KHEMIS B.S.CFPA	1485702201
1485711801	SRAYA ECOLE	1485711801
1485732803	TAJEROUINE AIN ZOUAGHA	1485732803
1485755802	TEBOURSOUK SM	1485755802
1485764303	TESSA SIDI MEDIEN	1485764303
1485764602	TESTOUR SM	1485764602
1485767609	TALA PF	1485767609
1485767809	TALA SM	1485767809
1485769002	THIBAR SM	1485769002
1485805903	ZAAFRANE UCP	1485805903
1485815801	ZAOUEM SM	1485815801
1485827203	ZOUARINE GARE	1485827203

(2) Stations in the adjacent areas to the Mejerda basin

ID	Station Name	ID
1483018801	AIN DRAHAM	1483018801
1483182424	DEKHILA	1483182424
1483238801	DAR FATMA	1483238801
1483242401	DAR ECHFA	1483242401
1483292005	GOUSSAT EL BEY	1483292005
1483354224	KHANGUET	1483354224
1483368824	KHAZEM	1483368824
1483463805	NEFET	1483463805
1483474501	OULED MFADDA	1483474501
1483489001	OUED BARBARA	1483489001
1483510101	OUED ZEEN P.F	1483510101
1484105824	BORJ CHAKIR	1484105824
1484129007	BOUCHA ECOLE	1484129007
1484130704	BOU ARADA II	1484130704
1484131104	BOU ARADA DRE	1484131104
1484169704	COOP GHORBANE	1484169704
1484541604	ROBAA GN	1484541604
1484610807	SIDI ARFA	1484610807
1484762007	TELLET ERRAIB	1484762007
1486332509	HIR MNIHLA	1486332509
1486366404	KESRA B9	1486366404
1486366604	KESRA FORET	1486366604
1486393609	LADJERED PF	1486393609
1486406904	MAJBAR	1486406904
1486476809	OUM JDOUR	1486476809
1486506411	OUSLATIA FORET	1486506411
1486543104	ROHIA DELEGATION SM	1486543104
1486547804	SAADIA DU BARGOU SM	1486547804
1486761404	TELLA	1486761404
1486809409	BIR CHAABEN EX ZELFANE	1486809409

Legend: ■ : Completed; ▨ : Partially completed; □ : Totally missing

Data Source : DGRE

Table A1.1.2 Availability of Daily Discharge Data

ID	Station Name	ID
1485001110	RARAI SUPERIEUR	1485001110
1485001160	RARAI PLAINE	1485001160
1485101210	MELLEGUE K13	1485101210
1485101222	K22 MOYEN DANS BARRAGE	1485101222
1485104380	PONT ROUTE (RMEL)	1485104380
1485105060	PONT ROUTE (SARREATH)	1485105060
1485106125	SIDI ABDELKADER	1485106125
1485201310	ZOUARINE	1485201310
1485201355	SIDI MEDIENNE	1485201355
1485202110	PONT ROUTE (SOUANI)	1485202110
1485203780	IZID BARRAGE	1485203780
1485302020	KEF RHIRA	1485302020
1485303510	FERNANA	1485303510
1485400110	GHARDIMAOU	1485400110
1485400160	JENDOUBA	1485400160
1485400180	BOU SALEM GP6	1485400180
1485501635	JEBEL LAOUDJ COTE 140	1485501635
1485504670	ENTREE PLAINE SILIANA	1485504670
1485602240	PONT GP6	1485602240
1485793040	AMONT	1485793040
1485793050	AVAL	1485793050
1485794010	BAZINA	1485794010
1485900110	PONT TRAJAN	1485900110
1485900130	SLOUGUIA	1485900130
1485900140	MEJEZ ELBAB	1485900140
1485900141	EL HERRI	1485900141
1485900175	JEDEIDA VILLE	1485900175
1485900180	JEDEIDA PVF	1485900180

Legend:
: Completed
: Partially completed
: Totally missing

Data source: DGRE

Table A1.3.1 Average Monthly Values of Climate Indexes

Monthly Mean Air Temperature (Tempereture Mayonne Mensuelle) Unit: oC (en oC)

Station		Location (Position)		Altitude	Period		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Ave
ID	Name (Nom)	Latitude	Longitude	m	from (de)	to (à)	(Sep)	(Oct)	(Nov)	(Dec)	(Jan)	(Fev)	(Mar)	(Avr)	(Mai)	(Juin)	(Juil)	(Aout)	(Moy)
11515111	TUNIS_CARTHAGE	36 o 50 '	10 o 14 '	4	1985	2006	25.3	21.9	16.8	13.2	11.8	12.3	14.2	16.5	20.5	24.6	27.4	28.3	19.4
22323111	BEJA	36 o 44 '	9 o 11 '	158	1985	2006	24.5	20.4	14.9	11.1	9.8	10.4	12.4	14.8	19.5	23.9	27.1	28.0	18.1
22525111	JENDOUBA	36 o 29 '	8 o 48 '	143	1985	2006	25.0	20.7	15.1	11.3	10.0	10.8	12.8	15.3	20.3	24.9	28.0	28.6	18.6
23434111	SILIANA	36 o 4 '	9 o 22 '	443	1985	2006	23.4	19.6	13.9	10.2	8.7	9.5	11.5	14.2	19.3	23.9	26.9	27.2	17.3
23232111	LE-KEF	36 o 8 '	8 o 42 '	842	1986	2006	23.2	18.9	12.8	9.1	7.8	8.6	11.1	13.8	19.0	23.6	26.6	26.9	16.8

Monthly Mean Maximum Air Temperature (Tempereture Maximale Mayonne) Unit: oC (en oC)

Station		Location (Position)		Altitude	Period		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Ave
ID	Name (Nom)	Latitude	Longitude	m	from (de)	to (à)	(Sep)	(Oct)	(Nov)	(Dec)	(Jan)	(Fev)	(Mar)	(Avr)	(Mai)	(Juin)	(Juil)	(Aout)	(Moy)
11515111	TUNIS_CARTHAGE	36 o 50 '	10 o 14 '	4	1985	2006	30.5	26.8	21.2	17.4	16.0	16.8	19.2	21.8	26.2	30.6	33.6	34.3	24.5
22323111	BEJA	36 o 44 '	9 o 11 '	158	1985	2006	31.8	27.2	20.5	16.2	14.9	16.2	19.0	22.0	27.6	32.5	35.8	36.4	25.0
22525111	JENDOUBA	36 o 29 '	8 o 48 '	143	1985	2006	32.1	27.4	20.7	16.5	15.2	16.5	19.3	22.2	28.1	33.2	36.6	36.9	25.4
23434111	SILIANA	36 o 4 '	9 o 22 '	443	1985	2006	30.5	25.9	19.3	15.3	13.9	15.1	17.9	21.2	27.0	32.4	35.7	35.6	24.1
23232111	LE-KEF	36 o 8 '	8 o 42 '	842	1986	2006	30.3	25.5	18.4	14.3	13.0	14.4	17.6	20.8	26.8	31.9	35.3	35.4	23.7
64646311	THALA				1985	2004	26.1	21.4	14.5	10.4	9.2	10.8	13.5	17.0	22.6	28.3	31.8	31.5	19.7

Monthly Mean Minimum Air Temperature (Temperature minimale mayonne) Unit: oC (en oC)

Station		Location (Position)		Altitude	Period		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Ave
ID	Name (Nom)	Latitude	Longitude	m	from (de)	to (à)	(Sep)	(Oct)	(Nov)	(Dec)	(Jan)	(Fev)	(Mar)	(Avr)	(Mai)	(Juin)	(Juil)	(Aout)	(Moy)
11515111	TUNIS_CARTHAGE	36 o 50 '	10 o 14 '	4	1985	2006	20.2	17.0	12.3	9.0	7.5	7.8	9.3	11.3	14.9	18.6	21.3	22.3	14.3
22323111	BEJA	36 o 44 '	9 o 11 '	158	1985	2006	17.3	13.6	9.2	6.1	4.7	4.7	5.8	7.7	11.4	15.4	18.3	19.6	11.2
22525111	JENDOUBA	36 o 29 '	8 o 48 '	143	1985	2006	17.8	14.0	9.5	6.1	4.9	5.1	6.4	8.4	12.4	16.7	19.4	20.3	11.8
23434111	SILIANA	36 o 4 '	9 o 22 '	443	1985	2006	16.4	13.2	8.4	5.1	3.7	3.9	5.2	7.4	11.5	15.4	18.1	18.8	10.6
23232111	LE-KEF	36 o 8 '	8 o 42 '	842	1986	2006	16.1	12.3	7.2	4.0	2.6	2.7	4.6	6.8	11.2	15.3	17.8	18.4	10.0
64646311	THALA				1985	2004	15.1	12.0	6.9	3.8	2.4	2.9	4.4	6.3	10.6	15.0	18.1	18.5	9.7

Monthly Evaporation (Evaporation Piche mensuelle) Unit: mm (en mm)

Station		Location (Position)		Altitude	Period		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
ID	Name (Nom)	Latitude	Longitude	m	from (de)	to (à)	(Sep)	(Oct)	(Nov)	(Dec)	(Jan)	(Fev)	(Mar)	(Avr)	(Mai)	(Juin)	(Juil)	(Aout)	(Moy)
11515111	TUNIS_CARTHAGE	36 o 50 '	10 o 14 '	4	1985	2006	151.1	109.1	93.0	77.5	70.3	78.3	108.2	125.3	155.2	194.1	229.2	208.2	1608.3
22323111	BEJA	36 o 44 '	9 o 11 '	158	1985	2006	181.8	128.9	85.3	60.5	53.6	61.7	82.1	100.5	153.0	213.0	269.4	263.0	1668.7
22525111	JENDOUBA	36 o 29 '	8 o 48 '	143	1985	2001	181.0	117.5	78.1	58.4	49.2	58.5	86.3	110.9	163.4	221.8	298.0	268.6	1687.4
23434111	SILIANA	36 o 4 '	9 o 22 '	443	1985	2006	174.8	129.9	84.9	64.4	62.7	72.5	97.7	117.6	183.5	242.3	294.0	265.0	1778.1
23232111	LE-KEF	36 o 8 '	8 o 42 '	842	1986	2006	177.6	135.7	81.3	60.1	57.8	69.2	98.2	124.0	185.0	234.6	300.9	266.7	1754.1

Monthly Mean Relative Humidity (Humidite mayonne mensuelle) Unit: % (en %)

Station		Location (Position)		Altitude	Period		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Ave
ID	Name (Nom)	Latitude	Longitude	m	from (de)	to (à)	(Sep)	(Oct)	(Nov)	(Dec)	(Jan)	(Fev)	(Mar)	(Avr)	(Mai)	(Juin)	(Juil)	(Aout)	(Moy)
11515111	TUNIS_CARTHAGE	36 o 50 '	10 o 14 '	4	1985	2006	65.9	69.7	71.3	74.9	75.0	72.7	70.2	68.0	65.8	61.6	60.4	61.5	68.0
22323111	BEJA	36 o 44 '	9 o 11 '	158	1986-1994, 1999-2006		58.7	65.5	71.3	77.2	77.3	74.7	71.5	69.0	63.8	56.8	51.8	50.6	65.7
22525111	JENDOUBA	36 o 29 '	8 o 48 '	143	1985	2006	60.2	67.4	72.4	76.6	77.5	74.7	72.6	70.0	64.1	56.5	51.5	52.0	66.3
23434111	SILIANA	36 o 4 '	9 o 22 '	443	1985	2006	60.8	65.0	70.3	74.4	74.7	72.4	70.1	67.0	61.1	53.5	49.3	50.4	64.2
23232111	LE-KEF	36 o 8 '	8 o 42 '	842	1990	2006	62.8	65.8	71.1	75.3	76.0	73.0	69.8	67.9	61.9	54.9	49.9	52.9	65.0

Monthly Sunshine Duration (Insolation mensuelle) Unit: hr (en heure)

Station		Location (Position)		Altitude	Period		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
ID	Name (Nom)	Latitude	Longitude	m	from (de)	to (à)	(Sep)	(Oct)	(Nov)	(Dec)	(Jan)	(Fev)	(Mar)	(Avr)	(Mai)	(Juin)	(Juil)	(Aout)	(Moy)
11515111	TUNIS_CARTHAGE	36 o 50 '	10 o 14 '	4	1986	2006	249.7	219.2	166.8	153.1	156.5	172.6	216.3	235.9	282.1	304.7	344.2	321.0	2822.8
22323111	BEJA	36 o 44 '	9 o 11 '	158	1986	2006	225.6	195.5	146.9	125.8	126.9	144.4	191.0	212.3	256.0	277.6	318.5	284.1	2519.0
22525111	JENDOUBA	36 o 29 '	8 o 48 '	143	1985	2006	242.3	217.7	162.7	147.0	150.6	165.3	205.6	216.3	255.3	267.2	317.2	297.1	2643.9
23434111	SILIANA	36 o 4 '	9 o 22 '	443	1986	2006	239.4	204.5	159.1	140.6	146.1	158.8	204.5	226.3	268.7	295.0	342.3	310.2	2695.2
23232111	LE-KEF	36 o 8 '	8 o 42 '	842	1990	2006	242.4	218.4	170.8	151.2	160.7	171.1	215.3	227.5	275.5	303.5	347.0	303.9	2787.9

Monthly Mean Wind Velocity (Vitesse moyenne du vent) Unit: m/s (en m/s)

Station		Location (Position)		Altitude	Period		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Ave
ID	Name (Nom)	Latitude	Longitude	m	from (de)	to (à)	(Sep)	(Oct)	(Nov)	(Dec)	(Jan)	(Fev)	(Mar)	(Avr)	(Mai)	(Juin)	(Juil)	(Aout)	(Moy)
11515111	TUNIS_CARTHAGE	36 o 50 '	10 o 14 '	4	1993	2002	3.7	3.3	3.8	4.0	3.9	4.3	4.1	4.5	4.0	3.8	4.0	3.4	3.9
22323111	BEJA	36 o 44 '	9 o 11 '	158	1993-1995,1998-2002		3.1	2.6	2.7	2.7	3.0	3.2	3.1	3.4	3.1	3.3	3.3	3.0	3.0
22525111	JENDOUBA	36 o 29 '	8 o 48 '	143	1993	2002	2.0	1.8	2.1	2.3	2.0	2.3	2.0	2.1	2.0	2.1	2.2	2.0	2.0

Maximum Instantaneous Wind Velocity (Vent Maximum instantaneous) Unit: m/s (en m/s)

Station		Location (Position)		Altitude	Period		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Ave
ID	Name (Nom)	Latitude	Longitude	m	from (de)	to (à)	(Sep)	(Oct)	(Nov)	(Dec)	(Jan)	(Fev)	(Mar)	(Avr)	(Mai)	(Juin)	(Juil)	(Aout)	(Moy)
11515111	TUNIS_CARTHAGE	36 o 50 '	10 o 14 '	4	1985	2004	20.2	19.1	20.9	23.8	22.1	23.6	22.5	22.3	20.8	20.0	20.4	19.1	21.2
22323111	BEJA	36 o 44 '	9 o 11 '	158	1986	2004	18.2	16.0	16.5	19.4	18.6	19.0	19.1	18.5	16.9	16.4	18.2	17.7	18.7
22525111	JENDOUBA	36 o 29 '	8 o 48 '	143	1985	2004	19.5	17.9	18.5	18.5	18.0	20.3	18.6	18.5	18.2	19.4	19.6	19.9	18.9
23434111	SILIANA	36 o 4 '	9 o 22 '	443	1985	2004	20.5	17.5	19.0	18.9	19.7	20.4	19.8	20.8	19.4	19.6	19.8	21.2	19.9
23232111	LE-KEF	36 o 8 '	8 o 42 '	842	1990	2004	19.4	18.4	18.0	18.0	16.7	18.7	18.7	19.5	18.2	19.6	18.0	19.4	20.3
64646311	THALA				1985	2004	25.4	24.2	27.5	27.5	26.6	29.4	27.8	27.9	25.2	23.3	24.1	25.0	26.2

Table A1.4.1 Annual, 2 Year and 3 Year Basin Rainfall in the Mejerda River Basin

(1) Annual Rainfall

Year	Annual Rainfall* (mm/y)	% to Average	Rainfall deficit	% to Average	Meterological Drougts dry	Meterological Drougts very dry
	a	b (a/Ave.)	c (a-Ave.)	d (c/Ave.)	-50%<d<-30%	d<-50%
1968/1969	389.9	77.6	-112.4	-0.22		
1969/1970	691.4	137.6	189.1	0.38		
1970/1971	563.2	112.1	60.9	0.12		
1971/1972	603.0	120.0	100.7	0.20		
1972/1973	721.1	143.6	218.8	0.44		
1973/1974	390.1	77.7	-112.2	-0.22		
1974/1975	482.5	96.1	-19.8	-0.04		
1975/1976	565.0	112.5	62.7	0.12		
1976/1977	470.5	93.7	-31.8	-0.06		
1977/1978	429.0	85.4	-73.3	-0.15		
1978/1979	419.1	83.4	-83.2	-0.17		
1979/1980	484.6	96.5	-17.7	-0.04		
1980/1981	510.5	101.6	8.2	0.02		
1981/1982	512.5	102.0	10.2	0.02		
1982/1983	460.1	91.6	-42.2	-0.08		
1983/1984	452.8	90.1	-49.5	-0.10		
1984/1985	515.8	102.7	13.5	0.03		
1985/1986	378.8	75.4	-123.5	-0.25		
1986/1987	635.5	126.5	133.2	0.27		
1987/1988	347.0	69.1	-155.3	-0.31	dry	
1988/1989	352.8	70.2	-149.5	-0.30		
1989/1990	412.9	82.2	-89.4	-0.18		
1990/1991	637.5	126.9	135.2	0.27		
1991/1992	569.2	113.3	66.9	0.13		
1992/1993	417.3	83.1	-85.0	-0.17		
1993/1994	316.3	63.0	-186.0	-0.37	dry	
1994/1995	358.6	71.4	-143.7	-0.29		
1995/1996	676.1	134.6	173.8	0.35		
1996/1997	376.7	75.0	-125.6	-0.25		
1997/1998	569.5	113.4	67.2	0.13		
1998/1999	515.3	102.6	13.0	0.03		
1999/2000	412.8	82.2	-89.5	-0.18		
2000/2001	464.9	92.6	-37.4	-0.07		
2001/2002	350.2	69.7	-152.1	-0.30	dry	
2002/2003	779.9	155.3	277.6	0.55		
2003/2004	701.0	139.6	198.7	0.40		
2004/2005	628.2	125.1	125.9	0.25		
2005/2006	526.5	104.8	24.2	0.05		
Ave.	502.3	100.0				
Max.	779.9	155.3				
Min.	316.3	63.0				

(2) 2 and 3 Year Rainfall

Year	2 year Rain (mm)	3 year Rain (mm)
1968/1969		
1969/1970	1081.3	
1970/1971	1254.6	1644.5
1971/1972	1166.2	1857.6
1972/1973	1324.1	1887.3
1973/1974	1111.2	1714.2
1974/1975	872.6	1593.7
1975/1976	1047.5	1437.6
1976/1977	1035.5	1518.0
1977/1978	899.5	1464.5
1978/1979	848.1	1318.6
1979/1980	903.7	1332.7
1980/1981	995.1	1414.2
1981/1982	1023.0	1507.6
1982/1983	972.6	1483.1
1983/1984	912.9	1425.4
1984/1985	968.6	1428.7
1985/1986	894.6	1347.4
1986/1987	1014.3	1530.1
1987/1988	982.5	1361.3
1988/1989	699.8	1335.3
1989/1990	765.7	1112.7
1990/1991	1050.4	1403.2
1991/1992	1206.7	1619.6
1992/1993	986.5	1624.0
1993/1994	733.6	1302.8
1994/1995	674.9	1092.2
1995/1996	1034.7	1351.0
1996/1997	1052.8	1411.4
1997/1998	946.2	1622.3
1998/1999	1084.8	1461.5
1999/2000	928.1	1497.6
2000/2001	877.7	1393.0
2001/2002	815.1	1227.9
2002/2003	1130.1	1595.0
2003/2004	1480.9	1831.1
2004/2005	1329.2	2109.1
2005/2006	1154.7	1855.7
Ave.	1007.0	1503.1
Max.	1480.9	2109.1
Min.	674.9	1092.2

(3) Ranking of Annual, 2 Year and 3 Year Rainfall

from 1968/1969 to 2005/2006

Order	Annual Rain* Year	Annual Rain* mm/year	2 years Rain Year	2 years Rain mm in 2 years	3 years Rain Year	3 years Rain mm in 3 years
1	1993/1994	316.3	1994/1995	674.9	1994/1995	1092.2
2	1987/1988	347.0	1988/1989	699.8	1989/1990	1112.7
3	2001/2002	350.2	1993/1994	733.6	2001/2002	1227.9
4	1988/1989	352.8	1989/1990	765.7	1993/1994	1302.8
5	1994/1995	358.6	2001/2002	815.1	1978/1979	1318.6
6	1996/1997	376.7	1978/1979	848.1	1979/1980	1332.7
7	1985/1986	378.8	1974/1975	872.6	1988/1989	1335.3
8	1968/1969	389.9	2000/2001	877.7	1985/1986	1347.4
9	1973/1974	390.1	1985/1986	894.6	1995/1996	1351.0
10	1999/2000	412.8	1977/1978	899.5	1987/1988	1361.3
11	1989/1990	412.9	1979/1980	903.7	2000/2001	1393.0
12	1992/1993	417.3	1983/1984	912.9	1990/1991	1403.2
13	1978/1979	419.1	1999/2000	928.1	1996/1997	1411.4
14	1977/1978	429.0	1997/1998	946.2	1980/1981	1414.2
15	1983/1984	452.8	1984/1985	968.6	1983/1984	1425.4
16	1982/1983	460.1	1982/1983	972.6	1984/1985	1428.7
17	2000/2001	464.9	1987/1988	982.5	1975/1976	1437.6
18	1976/1977	470.5	1992/1993	986.5	1998/1999	1461.5
19	1974/1975	482.5	1980/1981	995.1	1977/1978	1464.5
20	1979/1980	484.6	1986/1987	1014.3	1982/1983	1483.1
21	1980/1981	510.5	1981/1982	1023.0	1999/2000	1497.6
22	1981/1982	512.5	1995/1996	1034.7	1981/1982	1507.6
23	1998/1999	515.3	1976/1977	1035.5	1976/1977	1518.0
24	1984/1985	515.8	1975/1976	1047.5	1986/1987	1530.1
25	2005/2006	526.5	1990/1991	1050.4	1974/1975	1593.7
26	1970/1971	563.2	1996/1997	1052.8	2002/2003	1595.0
27	1975/1976	565.0	1969/1970	1081.3	1991/1992	1619.6
28	1991/1992	569.2	1998/1999	1084.8	1997/1998	1622.3
29	1997/1998	569.5	1973/1974	1111.2	1992/1993	1624.0
30	1971/1972	603.0	2002/2003	1130.1	1970/1971	1644.5
31	2004/2005	628.2	2005/2006	1154.7	1973/1974	1714.2
32	1986/1987	635.5	1971/1972	1166.2	2003/2004	1831.1
33	1990/1991	637.5	1991/1992	1206.7	2005/2006	1855.7
34	1995/1996	676.1	1970/1971	1254.6	1971/1972	1857.6
35	1969/1970	691.4	1972/1973	1324.1	1972/1973	1887.3
36	2003/2004	701.0	2004/2005	1329.2	2004/2005	2109.1
37	1972/1973	721.1	2003/2004	1480.9		
38	2002/2003	779.9				

Note : * Arithmetic mean of 82 stations in the Mejerda Basin

Table A1.4.2 Probable 6 Day Rainfalls at Major Stations

6day rainfall

Unit : mm in 6 days

Sub-basin	Upper Mejerda, Left Bank				Mellegue		Tessa	Siliana		Lower Mejerda		
Station :	1485528801	1485013801	1485126801	1485265901	1485499003	1485361903	1485251003	1485059104	1485755802	1485683202	1485309602	1485079124
Return period	RAGHAY SUPERIEUR	AIN DEBBA	BEN METIR 2 SM	FERNANA OUED RHEZALA	OUED MELLEGUE K 13	KEF CMA	DEHMANI MUNICIPALITE	AKOUAT GARE	TEBOURSOUK SM	SLOUGUIA	HERY EL	BATANE ECOLE
2 year	80	200	170	140	50	65	70	65	90	60	65	60
5 year	100	260	240	180	70	95	95	85	115	85	90	90
10 year	120	300	290	210	90	115	100	95	135	105	100	105
20 year	140	340	340	240	100	130	130	110	160	135	110	125
50 year	180	390	420	290	120	155	150	120	200	180	130	155
100 year	200	420	480	320	140	170	170	130	230	220	140	180
Distribution	Log Pearson Type III				Log Normal		Log Normal	GEV		GEV		

Table A1.5.1 Annual Peak Discharges

Station		Ghardimaou (1 490 km2)			Jendouba (2 414 km2)			Bou Salem (16 483 km2)			Mejez El Bab (21 185 km2)			K13 (9 000 km2)		
Year (Annee)	Dam started Operation (installation des barrages)	Date	Q annual max (instant.) m3/s	Source	Date	Q annual max (instant.) m3/s	Source	Date	Q annual max (instant.) m3/s	Source	Date	Q annual max (instant.) m3/s	Source	Date	Q annual max (instant.) m3/s	Source
1897/1898					1898/3/8	724	1									
1898/1899					1899/3/14	88.4	1									
1899/1900					1900/1/21	521	1									
1900/1901					1900/11/13	275	1									
1901/1902					1902/4/24	142	1									
1902/1903					1903/3/31	136	1									
1903/1904					1904/1/28	184	1									
1904/1905					1905/2/19	94.3	1									
1905/1906					1906/2/8	508	1									
1906/1907					1907/2/17	1610	1									
1907/1908					1908/3/23	639	1									
1908/1909					1908/12/22	508	1									
1909/1910					1910/2/12	335	1									
1910/1911					1910/12/31	159	1									
1911/1912					1911/11/13	105	1									
1912/1913					1913/2/23	617	1									
1913/1914					1914/2/15	171	1									
1914/1915					1915/4/13	199	1									
1915/1916					1915/12/16	203	1									
1916/1917					1916/11/27	405	1									
1917/1918					1917/11/29	191	1									
1918/1919					1919/1/28	292	1									
1919/1920					1920/2/4	159	1									
1920/1921					1921/4/8	125	1									
1921/1922					1922/2/25	381	1									
1922/1923																
1923/1924					1924/1/3	123	1								80	8
1924/1925					1924/12/10	168	1							1925/8/16	118	1
1925/1926					1926/2/12	251	1	1925/9/29	452	1				1926/8/28	253	1
1926/1927					1927/1/11	342	1	1927/1/10	431	1				1927/5/6	388	1
1927/1928					1928/4/4	285	1	1928/4/4	1220	1				1928/5/3	1270	1
1928/1929					1929/2/18	488	1	1929/3/27	1760	1				1928/9/15	460	1
1929/1930					1930/2/17	114	1							1930/2/16	317	1
1930/1931					1931/2/10	311	1	1931/2/10	578	1				1931/4/14	1030	1
1931/1932					1931/12/14	488	1	1931/12/14	2060	1				1931/12/13	341	1
1932/1933					1933/1/23	177	1	1933/1/23	496	1				1932/9/28	371	1
1933/1934					1934/3/5	206	1	1934/3/6	307	1				1934/4/25	277	1
1934/1935					1935/1/3	709	1	1935/1/3	894	1				1934/11/26	186	1
1935/1936					1936/2/15	168	1	1935/9/15	150	1				1935/9/15	425	1
1936/1937					1936/11/16	342	1	1936/11/16	1420	1				1936/11/15	520	1
1937/1938					1938/2/5	140	1	1938/2/5	310	1				1938/8/27	99.8	1
1938/1939					1939/2/28	268	1	1939/2/5	566	1				1939/4/16	539	1
1939/1940					1940/1/26	1400	1	1940/1/26	1780	1				1940/1/26	98.4	1
1940/1941					1941/2/9	140	1	1941/5/24	231	1				1941/5/23	283	1
1941/1942					1942/3/1	1130	1	1942/3/1	943	1				1941/10/3	1060	1
1942/1943					1944/2/17	91.6	1	1943/4/25	150	1				1942/9/18	127	1
1943/1944								1943/11/6	351	1				1943/11/5	825	1
1944/1945					1945/2/7	209	1	1944/9/10	196	1				1944/9/9	431	1
1945/1946					1946/3/18	342	1	1946/1/27	743	1				1946/1/27	863	1
1946/1947					1946/12/17	626	1	1946/12/17	911	1				1947/8/25	412	1
1947/1948					1947/10/12	80.8	1	1947/10/11	1700	1	1947/10/12	1280	1	1948/2/28	2000	1
1948/1949					1949/1/16	331	1	1949/1/7	718	1	1948/11/13	891	1	1949/1/6	923	1
1949/1950		1950/3/4	185	1	1950/3/5	162	1	1950/3/5	383	1	1950/3/5	310	1	1950/4/16	398	1
1950/1951		1951/1/30	82.9	1				1951/5/6	191	1	1951/5/7	158	1	1951/6/2	569	1
1951/1952		1951/12/30	372	1				1951/12/31	651	1	1951/10/6	561	1	1951/10/5	1000	1
1952/1953		1953/1/28	504	1				1952/12/7	904	1	1952/12/8	981	1	1953/8/5	493	1
1953/1954	Mellegue	1953/11/5	326	1				1954/2/22	478	1	1954/2/22	496	1	1953/10/21	244	1
1954/1955		1955/2/8	350	1				1954/12/15	322	1	1954/12/15	298	1	1955/8/25	548	1
1955/1956		1956/2/8	226	1				1956/2/8	465	1	1956/2/8	612	1	1955/10/24	1060	1
1956/1957		1957/1/27	150	1				1957/2/3	255	1	1957/1/24	241	1	1957/5/2	446	1
1957/1958		1958/1/18	330	1				1958/1/15	515	1	1957/11/17	632	1	1957/10/6	3340	1
1958/1959		1959/4/2	660	1				1959/3/14	1140	1	1959/3/15	1490	1	1959/6/7	1070	1
1959/1960		1960/5/5	210	1				1960/5/6	254	1	1960/5/7	202	1	1960/5/5	336	1
1960/1961		1961/1/27	112	1				1961/1/28	337	1	1961/1/28	255	1	1960/10/5	297	1
1961/1962		1962/2/19	412	1				1962/2/13	603	1	1962/2/13	675	1	1962/2/13	300	1
1962/1963		1963/4/20	529	1				1963/4/21	672	1	1963/4/21	746	1	1963/6/24	418	1
1963/1964		1964/1/30	266	1				1964/1/30	587	1	1964/1/31	756	1	1963/9/6	720	1
1964/1965		1965/1/22	282	1				1965/1/22	449	1	1964/10/31	686	1	1964/10/31	1230	1
1965/1966		1966/4/23	188	1				1966/4/23	685	1	1966/4/24	768	1	1966/5/14	392	1
1966/1967		1967/3/21	93.5	1				1967/3/9	119	1	1967/2/10	186	1	1967/4/22	627	1
1967/1968		1967/12/13	165	1				1968/1/23	167	1	1968/1/22	348	1	1967/9/12	950	1
1968/1969		1969/1/4	58.2	1	1969/1/4	106	1	1969/1/4	118	1	1969/1/5	268	1	1969/3/26	130	1
1969/1970		1969/12/25	650	1	1969/12/25	508	1	1969/9/28	1490	1	1969/9/28	1440	1	1969/9/27	4480	1
1970/1971			236	1		220	1		381	1		545	1		199	1
1971/1972			185	1		314	1		174	1		296	1		190	1
1972/1973			2370	1		2420	1		3180	1		3500	1		1280	1
1973/1974			48	1		61	1		86	1		212	1		315	1
1974/1975			518	1		724	1		620	1		689	1		1350	1
1975/1976	Bou Heurtma		167	1		221	1		210	1		428	1		775	1
1976/1977			1013	1		970	1		743	1		880	1		519	8
1977/1978															472	8
1978/1979								1979/4/18	410	2,3					1350	8
1979/1980								1979/11/4	484	2,3					487	8
1980/1981	Sidi Salem							1981/2/7	145	2,3					381	8
1981/1982								1982/3/23	211	2,3					544	8
1982/1983								1982/12/27	327	2,3					1120	8
1983/1984								1984/2/5	583	2,3					415	8
1984/1985								1985/1/1	917	2,3					485	8
1985/1986								1986/3/16	81	2,3					365	8
1986/1987		1987/4/14	350	3	1987/2/14	415	3	1987/2/14	788	2,3					441	8
1987/1988		1988/3/9	51.3	3	1988/3/7	123	3	1988/3/7	152	2,3					881	8
1988/1989		1989/2/16	51.3	3	1989/2/16	31	3	1988/10/7	321	2,3					1240	8
1989/1990		1989/10/8	10.8	3	1990/3/24	16.2	2	1989/9/3	320	2,3						
1990/1991		1991/3/19	382	3	1991/3/19	425	3	1990/11/17	595	2,3	1991/1/29	304	3	1990/11/16	971	3
1991/1992		1992/5/25	300	3	1992/4/11	653	3	1992/5/26	776	2,3					1300	8
1992/1993		1993/1/1	123	2,3	1993/1/1	105	3	1993/1/2	100	2,3	1993/1/14	250	3	1992/11/7	870	2,3
1993/1994		1993/2/10	322	2	1994/2/10	287	2	1994/2/11	272	2,3				1994/8/1	61.1	2
1994/1995		1995/1/13	64.3	2,3	1995/3/6	109	2,3	1995/6/16	93	2,3				1995/6/10	992	2
1995/1996		1996/2/8	295	2,3	1996/2/8	412	2,3	1995/9/23	671	2,3	1996/2/29	263	3	1995/9/17	345	2
1996/1997		1997/8/26	83	2,3	1997/1/13	133	2,3	1996/9/10	144	2,3				1997/6/29	434	2,3
1997/1998		1997/12/7	315	2,3	1997/12/28	195	2,3	1998/1/22	421	2,3				1997/9/20	487	2,3
1998/1999		1998/11/28	303	2,3	1999/1/3	332	2,3	1999/1/4	434	2,3				1998/9/24	549	2,3
1999/2000		2000/5/26	737	2,3	2000/5/27	327	2,3	2000/5/27	977	2,3				2000/5/26	4480	2,3
2000/2001		2001/2/17	397	5	2001/2/17	224	5	2001/1/22	112	5				2000/9/5	556	2,5
2001/2002		2002/8/27	630	5	2002/8/27	177	5	2002/8/25	290	5				2001/10/1	919	5
2002/2003		2003/1/11	1090	6	2003/1/12	1070	6	2003/1/12	1020	6		730	4	2003/1/11	2600	5
2003/2004		2004/1/1	1470	4		1020	4		889	4		350	4		2480	4
2004/2005		2005/1/20	838	4		616	4		529	4		224	4			
		max	2370		max	2420		max	3180		max	3500		max	4480	
		min	10.8		min	16.2		min	80.6		min	158		min	61.1	
		Mean	394		Mean	381		Mean	598		Mean	638		Mean	782	
		Median	300		Median	268		Median	458.5		Median	520.5		Median	490	
		m=Mean-Median	94		m=Mean-Median	113		m=Mean-Median	139.5		m=Mean-Median	117.5		m=Mean-Median	292	
		m/Median	0.313		m/Median	0.422		m/Median	0.304		m/Median	0.226		m/Median	0.596	

Note : shade : affected by dam operation

Source :
1 : Monigraphies Hydrologiques, le bassin de la Mejerda, 1981
2 : DGRE, Annuaires Hydroriques
3 : DGRE, instantaneous discharge data during floods (Qinst_bv5.txt)
4 : Compiled files of flood discharges. (Compiled by the Study team based on various data from DGRE and DGBGTH)
2 : DGRE, Annuaires Hydroriques (Electric version, 1998/99-2002/03)
6 : DGRE text file, instantaneous discharge data during floods (debinsmej0304.txt)
8 : Mellegue 2 Study Report

Table A3.1.1 Major Floods and Events in the Mejerda River Basin

Year	Month	Description
1907	Feb.	**Flood**
1909 -		Mabtouh Canal (30m) constructed
1928	Feb.	Flood
1929	Mar.	**Flood**
1931	Dec.	Flood
1936	Nov.	**Flood**
1940	Jan.	**Flood**
1947	Oct.	**Flood**
1948	Nov.	Flood
1952	Jan. or Feb.	**Flood**
1953*		Opened the floodway of the Mejerda at the estuary
1954	Mar.	**Mellegue Dam started operation**
1955*		Short cut construction at Bizerte
1965*		**Larrousia Dam started operation**
1958*		Short cut construction at upstream of Bizerte
1959	Mar. – Apr.	**Flood**
1969	Sep. – Oct.	**Flood**
1973	Mar.	**Flood**
1976		**Bou Heurtma Dam started operation**
1981		**Sidi Salem Dam started operation**
1984		Mejerda Cap Bon Canal (from the Larrousia Dam) started operation
1987		**Siliana Dam started operation**
1990		**Tobias Dam (gated weir) started operation**
1997, 1999		**Sidi Salem Dam: NHWL rising** from 110 to 115 NGTm
2000	May	**Flood**
2003	Jan. – Feb.	**Flood**
2003	Sep.	Flood
2004	(Dec. '03-) Jan. – Feb.	**Flood**
2005	Jan. – Feb.	Flood

Note : * : Year to be confirmed
Bold: Notable floods and events

AT-8

Table A4.1.1 Annual Inflow at Dam Sites

Unit : million m3,

Dam / year	Zouitina	Sarrath	Mellegue	Tessa	Ben M'Tir	Bou Heurtma	Kasseb	Beja	Sidi Salem	Khaled	Lakhmes	Siliana	R'Mil	El Kebir	Zerga	El Moula	Sidi Barak	Ziatine	Gamgoun	El Harka	Sejnane	Douimis	Melah	Joumine	Ghezala	Tine	year	Annual Inflow Total Mejerda	Annual Inflow Total North	Grand Total 1year
	Mejerda													Extreme North																
1946	143.7	13.5	92.1	19.2	73.5	222.5	80.6	28.7	906.8	5.1	2.5	48.9	6.5	42.2	29.2	31.8	278.4	37.6	13.2	14.8	168.4	16.3	35.4	259.8	16.0	44.8	1946	1643.6	987.7	2631.3
1947	54.7	36.6	335.5	49.2	19.8	75.6	26.9	9.6	647.2	13.0	5.9	32.4	7.5	14.3	9.9	12.0	117.6	16.3	5.7	6.4	74.9	6.1	13.3	80.3	6.0	13.8	1947	1314.0	376.7	1690.7
1948	119.0	31.8	284.4	42.9	78.5	250.3	64.6	23.0	1389.5	11.3	34.6	155.1	32.8	35.7	24.8	28.2	260.1	32.4	11.4	12.8	135.6	13.0	28.1	203.8	12.7	35.1	1948	2517.9	833.6	3351.5
1949	89.4	13.3	89.4	18.8	43.9	148.9	54.1	19.3	685.2	5.0	9.2	57.7	7.3	33.8	23.5	26.5	241.7	27.7	9.7	10.9	106.0	10.1	22.0	159.6	10.0	27.5	1949	1241.5	709.0	1950.6
1950	53.5	17.3	131.7	24.1	23.8	87.6	37.1	13.2	419.9	6.4	7.2	38.2	10.2	14.1	9.7	11.7	113.2	15.5	5.4	6.1	70.1	5.8	12.5	75.9	5.6	13.1	1950	870.1	358.6	1228.6
1951	118.3	34.5	313.5	46.5	57.4	193.6	60.8	21.7	1231.4	12.3	9.4	58.2	10.3	38.5	26.7	30.5	283.7	34.0	12.0	13.4	136.7	13.4	29.1	215.8	13.1	37.2	1951	2167.9	883.9	3051.8
1952	129.2	24.7	210.3	33.8	56.6	187.5	70.8	25.3	1333.5	8.9	11.9	59.3	12.8	40.3	27.9	31.5	287.4	35.5	12.5	14.0	147.1	14.4	31.4	232.5	14.2	40.1	1952	2164.5	928.7	3093.2
1953	147.5	17.7	135.7	24.6	77.3	249.9	71.0	25.3	1260.8	6.5	21.7	75.0	19.7	43.2	29.9	33.7	307.1	37.4	13.1	14.7	152.4	15.1	32.8	245.1	14.8	42.3	1953	2132.6	981.4	3114.0
1954	62.6	12.8	84.6	18.2	26.9	99.5	39.4	14.0	421.6	4.8	2.6	16.0	3.1	15.4	10.7	12.9	126.5	16.3	5.7	6.4	70.3	5.9	12.8	80.6	5.8	13.9	1954	806.1	383.3	1189.4
1955	120.0	20.3	163.1	27.9	65.1	209.1	84.6	30.2	1033.3	7.4	17.8	96.6	18.9	36.7	25.4	28.9	265.2	34.3	12.1	13.5	148.3	15.5	33.7	242.7	15.2	58.9	1955	1894.2	930.4	2824.6
1956	89.6	14.6	103.9	20.6	35.9	124.9	48.1	17.2	568.9	5.4	1.2	10.3	1.7	29.0	20.1	22.5	204.0	29.3	10.3	11.5	137.7	14.6	31.6	197.8	14.3	75.7	1956	1042.3	798.3	1840.5
1957	107.8	27.1	235.4	36.8	53.9	166.9	55.4	19.7	1104.0	9.7	15.0	40.2	12.6	37.8	26.2	29.6	271.6	35.0	12.3	13.8	151.1	14.3	31.1	224.3	14.0	37.6	1957	1884.4	898.6	2783.1
1958	128.0	19.6	156.7	27.2	67.4	243.4	55.0	19.6	1236.5	7.2	25.6	78.1	21.9	33.6	23.3	26.9	253.0	31.3	11.0	12.3	129.3	12.4	27.0	185.4	12.2	41.2	1958	2086.2	799.0	2885.2
1959	69.2	18.3	142.5	25.4	24.8	112.4	42.8	15.3	788.0	6.7	5.4	29.8	6.4	30.8	21.3	25.1	239.9	22.3	7.9	8.8	62.4	6.3	13.6	95.2	6.2	23.0	1959	1286.9	562.7	1849.5
1960	61.2	9.9	53.6	14.4	25.2	70.0	37.1	13.2	448.5	3.8	1.5	9.2	1.8	17.9	12.4	12.2	93.5	11.4	4.0	4.5	47.1	4.7	10.1	32.1	4.6	40.1	1960	749.5	294.5	1044.0
1961	58.6	15.7	114.7	22.0	39.8	84.2	34.4	12.3	549.2	5.8	7.1	32.4	6.9	12.4	8.6	9.3	81.0	11.1	3.9	4.4	50.5	6.7	14.6	101.1	6.6	43.9	1961	983.0	354.0	1336.9
1962	100.4	16.5	123.6	23.1	45.5	164.5	60.8	21.7	665.0	6.1	2.3	30.1	4.2	36.6	25.3	33.6	355.6	39.4	13.9	15.5	144.8	16.1	35.0	275.8	15.8	57.2	1962	1263.6	1064.5	2328.1
1963	61.1	27.6	240.3	37.4	30.6	103.2	32.6	11.6	677.5	9.9	21.1	89.5	20.8	21.2	14.7	15.4	129.7	16.6	5.9	6.5	71.2	5.9	12.7	62.3	5.8	23.2	1963	1363.1	391.0	1754.1
1964	78.1	16.7	126.0	23.4	45.8	152.8	43.0	15.3	934.9	6.2	17.9	78.4	17.3	29.5	20.5	30.8	357.0	40.6	14.3	16.0	154.0	14.3	30.9	208.6	14.0	42.2	1964	1555.6	972.7	2528.3
1965	67.8	14.0	97.0	19.8	27.3	96.4	43.4	15.5	521.0	5.2	2.5	23.7	4.7	34.0	23.6	30.6	319.8	26.7	9.4	10.5	58.7	4.5	9.7	50.7	4.4	10.1	1965	938.3	592.7	1531.0
1966	57.1	15.7	115.2	22.0	22.2	81.1	34.5	12.3	408.3	5.8	2.7	22.1	3.0	20.7	14.3	16.5	154.7	23.8	8.4	9.4	117.5	8.9	19.3	108.2	8.7	15.0	1966	802.0	525.3	1327.3
1967	49.8	22.4	186.0	30.8	12.2	44.0	37.1	13.2	555.1	8.1	5.2	55.9	9.1	10.5	7.2	8.3	77.5	10.1	3.5	4.0	43.6	3.5	7.6	45.8	3.4	7.0	1967	1028.9	232.0	1261.0
1968	55.5	10.3	58.0	15.0	11.3	45.3	30.9	11.0	298.1	4.0	1.0	9.2	1.6	13.4	9.3	10.9	103.3	14.5	5.1	5.7	67.1	4.7	10.3	39.5	4.7	14.4	1968	551.1	302.7	853.9
1969	101.7	81.2	804.9	107.1	45.9	161.1	46.8	16.7	1595.0	28.3	69.3	264.6	67.1	37.2	25.8	27.3	232.8	28.9	10.2	11.4	120.1	13.2	28.7	224.4	12.9	46.1	1969	3389.5	818.9	4208.5
1970	91.3	17.7	136.5	20.5	41.1	158.1	52.0	18.5	692.0	5.4	14.5	73.6	15.3	48.7	33.7	30.1	197.5	32.6	11.4	12.8	168.1	14.1	30.7	179.4	13.9	41.2	1970	1336.4	814.3	2150.7
1971	81.6	24.1	203.7	39.9	37.5	111.9	53.5	19.1	771.5	10.5	8.2	70.5	12.6	29.4	20.4	22.3	197.9	20.3	7.1	8.0	67.2	6.6	14.2	60.4	6.4	46.1	1971	1444.4	506.3	1950.8
1972	115.2	48.1	456.8	209.2	47.4	176.7	68.1	24.3	2012.5	55.2	49.3	251.2	47.6	53.9	37.3	62.7	775.0	65.8	23.2	25.9	150.7	18.0	39.1	300.7	17.7	81.2	1972	3561.7	1651.2	5212.8
1973	96.0	10.9	65.0	37.9	19.8	51.3	15.2	5.4	370.8	10.0	32.3	72.5	21.4	5.9	4.1	5.2	53.5	9.3	3.3	3.6	49.3	5.4	11.7	52.6	5.3	41.9	1973	808.5	251.0	1059.6
1974	78.4	21.8	178.9	31.3	36.0	129.7	34.9	12.4	532.6	8.3	14.0	32.0	8.4	17.0	11.8	14.2	137.7	19.4	6.8	7.6	89.9	9.7	21.1	146.7	9.5	43.8	1974	1118.5	535.3	1653.8
1975	48.2	19.6	156.0	86.6	18.0	87.0	23.3	8.3	587.2	22.9	22.5	87.3	21.1	13.3	9.2	11.1	108.6	20.1	7.1	7.9	110.2	9.4	20.3	108.5	9.2	35.1	1975	1187.8	469.9	1657.6
1976	49.7	22.2	183.3	45.5	32.3	94.0	32.8	11.7	663.3	12.0	18.3	59.0	10.8	14.9	10.3	12.3	119.6	15.1	5.3	5.9	63.6	6.2	13.4	61.3	6.1	40.2	1976	1234.9	374.1	1609.0
1977	57.4	33.1	140.1	22.3	45.6	119.9	42.8	15.3	579.8	5.9	4.7	23.5	4.9	30.1	20.9	22.8	200.9	20.7	7.3	8.2	69.1	7.6	16.6	128.7	7.5	13.0	1977	1095.2	553.4	1648.5
1978	76.5	25.1	180.9	15.7	37.6	100.5	37.1	13.2	603.8	4.1	4.0	12.4	2.7	25.5	17.6	15.0	88.1	17.2	6.0	6.7	96.4	7.5	16.3	79.8	7.4	5.2	1978	1113.6	388.7	1502.3
1979	49.0	16.0	108.5	37.8	48.0	118.7	43.3	15.4	529.5	10.0	3.2	12.9	5.2	20.3	14.1	18.9	201.6	26.0	9.1	10.2	111.7	10.4	22.6	163.6	10.2	25.4	1979	997.5	644.0	1641.5
1980	75.3	10.8	146.2	26.2	111.5	189.5	141.6	50.5	1128.1	6.9	3.8	67.3	10.3	23.7	16.4	20.1	198.9	23.6	8.3	9.3	94.1	8.5	18.3	137.3	8.3	35.6	1980	1968.0	602.4	2570.4
1981	68.5	23.5	224.9	14.5	45.3	118.9	84.4	30.1	825.0	3.8	2.9	26.6	6.3	26.4	18.2	21.1	197.8	23.6	8.3	9.3	94.2	8.1	17.6	118.7	8.0	4.7	1981	1474.5	555.9	2030.5
1982	74.7	15.8	111.4	30.2	41.8	129.5	44.9	16.0	720.7	8.0	6.3	55.3	16.8	20.4	14.1	16.5	155.6	25.4	8.9	10.0	130.4	14.1	30.5	232.2	13.8	69.4	1982	1271.3	741.3	2012.6
1983	87.2	11.4	95.5	15.6	54.0	179.9	46.0	16.4	834.5	4.1	4.2	15.0	2.3	23.1	16.0	18.7	177.6	21.1	7.4	8.3	83.8	5.6	12.1	52.1	5.5	7.4	1983	1366.0	438.7	1804.6
1984	84.6	46.4	138.8	30.3	61.0	218.3	55.9	19.9	960.7	8.0	5.9	21.5	9.2	40.2	27.8	28.2	227.2	29.1	10.2	11.5	124.7	10.1	22.0	102.5	9.9	51.6	1984	1660.4	694.9	2355.3
1985	33.4	14.6	103.2	20.5	27.0	73.1	26.4	9.4	371.8	5.4	3.5	24.8	4.6	10.1	7.0	8.6	85.7	12.2	4.3	4.8	56.9	4.4	9.6	53.3	20.0	9.8	1985	717.8	286.5	1004.3
1986	117.9	17.0	128.1	23.6	98.0	245.3	80.1	28.6	1276.9	6.2	7.4	49.2	10.2	25.2	17.4	20.4	193.0	25.0	8.8	9.8	108.3	9.7	21.0	140.2	20.6	25.7	1986	2088.5	625.1	2713.6
1987	51.2	18.5	144.2	25.6	26.0	53.7	29.9	10.7	418.6	6.8	2.0	15.4	2.4	5.5	3.8	4.8	49.0	7.8	2.8	3.1	39.4	2.8	6.1	29.0	0.8	5.3	1987	804.9	160.3	965.2
1988	39.9	20.2	162.7	27.9	20.3	23.1	17.3	6.2	94.3	7.4	2.9	7.6	2.3	3.9	2.7	3.6	97.9	6.6	2.3	0.6	35.8	2.3	5.0	19.5	1.1	3.7	1988	432.0	184.9	616.9
1989	7.3	30.9	275.0	41.8	3.7	9.4	7.8	2.8	140.5	11.0	4.9	15.0	5.8	6.3	4.4	5.6	37.0	9.1	3.2	0.5	108.2	3.2	7.0	34.9	7.4	6.4	1989	556.0	233.1	789.1
1990	75.4	32.8	295.1	67.7	91.7	164.1	78.1	27.9	690.7	17.9	20.7	59.8	9.0	45.3	288.5	40.6	125.7	37.0	13.0	14.5	146.8	13.0	59.1	195.0	30.1	30.8	1990	1630.9	1039.4	2670.4
1991	52.9	21.1	172.0	18.8	32.8	57.2	37.0	13.2	330.3	5.0	11.5	29.2	6.4	12.7	50.4	16.7	43.6	11.7	4.1	4.6	41.2	3.1	20.1	40.4	4.4	25.5	1991	787.3	278.7	1066.0
1992	36.8	15.5	113.3	14.3	23.0	52.4	26.4	9.4	261.9	3.8	19.6	29.9	5.3	21.5	63.1	11.4	64.4	21.7	7.6	8.5	96.2	5.9	13.6	46.7	4.9	8.7	1992	611.6	374.2	985.9
1993	48.3	8.3	36.8	5.5	27.2	54.3	24.5	8.8	156.7	1.4	1.9	3.7	4.5	3.4	23.4	12.9	33.9	3.9	1.4	1.5	15.4	1.3	4.9	18.0	0.5	2.3	1993	381.7	122.7	504.4
1994	14.7	22.5	187.1	22.9	12.9	22.1	16.4	5.9	162.7	6.0	2.3	7.4	1.6	4.4	32.2	6.2	40.6	12.6	4.4	5.0	84.3	4.7	5.2	24.0	1.8	4.4	1994	484.4	229.8	714.2
1995	66.6	43.6	409.7	275.7	47.0	77.2	50.3	17.9	556.3	72.8	6.9	53.0	11.6	214.4	148.5	22.7	6.3	18.6	6.5	33.2	137.8	16.6	17.4	103.9	13.1	19.0	1995	1688.7	757.9	2446.6
1996	48.4	11.8	74.2	74.2	17.7	34.8	20.3	7.2	136.4	19.6	2.8	18.5	4.0	40.9	28.3	8.8	31.2	2.8	1.0	11.6	20.1	0.9	7.3	21.1	1.9	3.9	1996	469.9	179.7	649.6
1997	82.6	17.5	133.6	55.4	49.7	113.2	49.2	17.5	462.4	14.6	2.8	15.1	3.3	191.0	132.3	84.1	28.8	18.2	6.4	21.0	135.4	9.7	16.3	95.9	11.7	17.5	1997	1016.8	768.3	1785.1
1998	55.8		108.2	46.4	49.4	145.4	54.6	19.5	456.2	12.2	6.4	34.4	7.5	155.8	107.9	69.0	23.4	8.9	3.1	55.8	61.9	6.8	*	77.8	4.5	14.2	1998			
1999	47.4		355.2		10.5	39.0	13.7	4.9	257.9		2.1	15.0	15.9	19.8	13.7	9.2	3.3	3.0	1.1		23.5			10.9	1.3		1999			
2000	63.5		131.6		34.1	86.1	38.1	13.6	304.1		4.7	23.5	15.3				212.4				75.0			60.8	3.0		2000			
2001	17.7		292.2		13.6	22.0	13.0	4.6	159.8		3.7	19.1	11.1				61.0				13.4			11.0	0.4		2001			
2002	64.6											40.7					217.5								3.7		2002			
2003	186.9											122.2					487.2								23.2		2003			
2004	105.8											56.4					289.2								10.1		2004			
2005	110.7											71.8					380.7								18.9		2005			

Source : EAU 2000, GEORE, Mssing data are filled by Study Team.

Note : * Inflow data at dam sites other than Melah dam can be available after 1997, but did not presented in the table because the reference period for the frequencey analysis were selected from 1946/47 to 1997/98.

Table A4.1.2 Annual Inflow, 2 Consecutive Year Inflow and 3 Consecutive Year Inflow

(a) Chronicled Inflow

year	Inflow: 1 year (M m3)	% of ave (%)	Consecutive years: 2 years (M m3)	Consecutive years: 3 years (M m3)	Interval 2 years (M m3)	Interval 3 years (M m3)
1946	2631.3	137.6				
1947	1690.7	88.4	4322.0			
1948	3351.5	175.3	5042.2	7673.5	5042.2	
1949	1950.6	102.0	5302.0	6992.7		6992.7
1950	1228.6	64.3	3179.2	6530.7	3179.2	
1951	3051.8	159.6	4280.5	6231.0		
1952	3093.2	161.8	6145.0	7373.7	6145.0	7373.7
1953	3114.0	162.9	6207.1	9259.0		
1954	1189.4	62.2	4303.3	7396.5	4303.3	
1955	2824.6	147.7	4013.9	7127.9		7127.9
1956	1840.5	96.3	4665.1	5854.5	4665.1	
1957	2783.1	145.6	4623.6	7448.2		
1958	2885.2	150.9	5668.2	7508.8	5668.2	7508.8
1959	1849.5	96.7	4734.7	7517.8		
1960	1044.0	54.6	2893.6	5778.7	2893.6	
1961	1336.9	69.9	2381.0	4230.5		4230.5
1962	2328.1	121.8	3665.1	4709.1	3665.1	
1963	1754.1	91.7	4082.2	5419.2		
1964	2528.3	132.2	4282.4	6610.5	4282.4	6610.5
1965	1531.0	80.1	4059.2	5813.3		
1966	1327.3	69.4	2858.3	5386.5	2858.3	
1967	1261.0	65.9	2588.3	4119.2		4119.2
1968	853.9	44.7	2114.9	3442.1	2114.9	
1969	4208.5	220.1	5062.3	6323.3		
1970	2150.7	112.5	6359.1	7213.0	6359.1	7213.0
1971	1950.8	102.0	4101.4	8309.9		
1972	5212.8	272.6	7163.6	9314.2	7163.6	
1973	1059.6	55.4	6272.4	8223.1		8223.1
1974	1653.8	86.5	2713.3	7926.2	2713.3	
1975	1657.6	86.7	3311.4	4371.0		
1976	1609.0	84.2	3266.7	4920.5	3266.7	4920.5
1977	1648.5	86.2	3257.6	4915.2		
1978	1502.3	78.6	3150.8	4759.9	3150.8	
1979	1641.5	85.8	3143.8	4792.3		4792.3
1980	2570.4	134.4	4211.9	5714.2	4211.9	
1981	2030.5	106.2	4600.9	6242.4		
1982	2012.6	105.3	4043.0	6613.4	4043.0	6613.4
1983	1804.6	94.4	3817.2	5847.7		
1984	2355.3	123.2	4160.0	6172.5	4160.0	
1985	1004.3	52.5	3359.7	5164.3		5164.3
1986	2713.6	141.9	3717.9	6073.2	3717.9	
1987	965.2	50.5	3678.7	4683.1		
1988	616.9	32.3	1582.1	4295.7	1582.1	4295.7
1989	789.1	41.3	1406.0	2371.2		
1990	2670.4	139.7	3459.5	4076.4	3459.5	
1991	1066.0	55.8	3736.4	4525.5		4525.5
1992	985.9	51.6	2051.9	4722.3	2051.9	
1993	504.4	26.4	1490.3	2556.3		
1994	714.2	37.4	1218.6	2204.5	1218.6	2204.5
1995	2446.6	128.0	3160.8	3665.2		
1996	649.6	34.0	3096.2	3810.5	3096.2	
1997	1785.1	93.4	2434.8	4881.4		4881.4

Max	5212.81
Min	504.43
Mean	1912.08
Media	1769.61

(b) Ranking

1 year (N= 52)

Rank	Year	Inflow (M m3)	Thomas T	Thomas F	% of ave (%)
1	1993	504.43	0.9811	0.0189	26.4
2	1988	616.93	0.9623	0.0377	32.3
3	1996	649.65	0.9434	0.0566	34.0
4	1994	714.21	0.9245	0.0755	37.4
5	1989	789.09	0.9057	0.0943	41.3
6	1968	853.88	0.8868	0.1132	44.7
7	1987	965.16	0.8679	0.1321	50.5
8	1992	985.85	0.8491	0.1509	51.6
9	1985	1004.34	0.8302	0.1698	52.5
10	1960	1044.04	0.8113	0.1887	54.6
11	1973	1059.56	0.7925	0.2075	55.4
12	1991	1066.03	0.7736	0.2264	55.8
13	1954	1189.39	0.7547	0.2453	62.2
14	1950	1228.63	0.7358	0.2642	64.3
15	1967	1260.97	0.7170	0.2830	65.9
16	1966	1327.29	0.6981	0.3019	69.4
17	1961	1336.94	0.6792	0.3208	69.9
18	1978	1502.29	0.6604	0.3396	78.6
19	1965	1530.99	0.6415	0.3585	80.1
20	1976	1609.05	0.6226	0.3774	84.2
21	1979	1641.50	0.6038	0.3962	85.8
22	1977	1648.53	0.5849	0.4151	86.2
23	1974	1653.79	0.5660	0.4340	86.5
24	1975	1657.62	0.5472	0.4528	86.7
25	1947	1690.69	0.5283	0.4717	88.4
26	1963	1754.11	0.5094	0.4906	91.7
27	1997	1785.12	0.4906	0.5094	93.4
28	1983	1804.64	0.4717	0.5283	94.4
29	1956	1840.54	0.4528	0.5472	96.3
30	1959	1849.52	0.4340	0.5660	96.7
31	1949	1950.55	0.4151	0.5849	102.0
32	1971	1950.75	0.3962	0.6038	102.0
33	1982	2012.56	0.3774	0.6226	105.3
34	1981	2030.46	0.3585	0.6415	106.2
35	1970	2150.67	0.3396	0.6604	112.5
36	1962	2328.13	0.3208	0.6792	121.8
37	1984	2355.34	0.3019	0.6981	123.2
38	1995	2446.60	0.2830	0.7170	128.0
39	1964	2528.25	0.2642	0.7358	132.2
40	1980	2570.40	0.2453	0.7547	134.4
41	1946	2631.33	0.2264	0.7736	137.6
42	1990	2670.37	0.2075	0.7925	139.7
43	1986	2713.57	0.1887	0.8113	141.9
44	1957	2783.07	0.1698	0.8302	145.6
45	1955	2824.55	0.1509	0.8491	147.7
46	1958	2885.17	0.1321	0.8679	150.9
47	1951	3051.84	0.1132	0.8868	159.6
48	1952	3093.18	0.0943	0.9057	161.8
49	1953	3113.96	0.0755	0.9245	162.9
50	1948	3351.47	0.0566	0.9434	175.3
51	1969	4208.47	0.0377	0.9623	220.1
52	1972	5212.81	0.0189	0.9811	272.6

Max	5212.81
Min	504.43
Mean	1912.08
Median	1769.61

2 years (interval) (N= 25)

Year	Inflow (M m3)	Thomas T	Thomas F	interval (2 yrs) *	**One cycle once in N years
1994	1218.6	0.9615	0.0385	1/26.0	52.0
1988	1582.1	0.9231	0.0769	1/13.0	26.0
1992	2051.9	0.8846	0.1154	1/8.7	17.3
1968	2114.9	0.8462	0.1538	1/6.5	13.0
1974	2713.3	0.8077	0.1923	1/5.2	10.4
1966	2858.3	0.7692	0.2308	1/4.3	8.7
1960	2893.6	0.7308	0.2692	1/3.7	7.4
1996	3096.2	0.6923	0.3077	1/3.3	6.5
1978	3150.8	0.6538	0.3462	1/2.9	5.8
1950	3179.2	0.6154	0.3846	1/2.6	5.2
1976	3266.7	0.5769	0.4231	1/2.4	4.7
1990	3459.5	0.5385	0.4615	1/2.2	4.3
1962	3665.1	0.5000	0.5000	1/2.0	4.0
1986	3717.9	0.4615	0.5385	1/1.9	3.7
1982	4043.0	0.4231	0.5769	1/1.7	3.5
1984	4160.0	0.3846	0.6154	1/1.6	3.3
1980	4211.9	0.3462	0.6538	1/1.5	3.1
1964	4282.4	0.3077	0.6923	1/1.4	2.9
1954	4303.3	0.2692	0.7308	1/1.4	2.7
1956	4665.1	0.2308	0.7692	1/1.3	2.6
1948	5042.2	0.1923	0.8077	1/1.2	2.5
1958	5668.2	0.1538	0.8462	1/1.2	2.4
1952	6145.0	0.1154	0.8846	1/1.1	2.3
1970	6359.1	0.0769	0.9231	1/1.1	2.2
1972	7163.6	0.0385	0.9615	1/1.0	2.1
Typical	2088.1		0.115	1/8.7	17.4

approximate

*The amount might not exceeds once in X cicles of 2 years

**This 2 year cycle could occure in average once in N years

3 years (interval) (N= 17)

Year	Inflow (M m3)	Thomas T	Thomas F	interval (3 yrs) +	++One cycle once in N years
1994	2204.5	0.9444	0.0556	1/18.0	54.0
1967	4119.2	0.8889	0.1111	1/9.0	27.0
1961	4230.5	0.8333	0.1667	1/6.0	18.0
1988	4295.7	0.7778	0.2222	1/4.5	13.5
1991	4525.5	0.7222	0.2778	1/3.6	10.8
1979	4792.3	0.6667	0.3333	1/3.0	9.0
1997	4881.4	0.6111	0.3889	1/2.6	7.7
1976	4920.5	0.5556	0.4444	1/2.3	6.8
1985	5164.3	0.5000	0.5000	1/2.0	6.0
1964	6610.5	0.4444	0.5556	1/1.8	5.4
1982	6613.4	0.3889	0.6111	1/1.6	4.9
1949	6992.7	0.3333	0.6667	1/1.5	4.5
1955	7127.9	0.2778	0.7222	1/1.4	4.2
1970	7213.0	0.2222	0.7778	1/1.3	3.9
1952	7373.7	0.1667	0.8333	1/1.2	3.6
1958	7508.8	0.1111	0.8889	1/1.1	3.4
1973	8223.1	0.0556	0.9444	1/1.1	3.2
Typical	3132.1		0.09	1/11.1	33.3

approximate

+ The amount might not exceeds once in X cicles of 2 years

++This 3 year cycle could occure in average once in N years

Typical drought 1960	1044.0	Million m3
% of average	54.6	%

Table A5.1.1 Computation of Probable Discharge at Mellegue Sarrath Confluence (BP-AM)

			Return Period						
			2-year	5-year	10-year	20-year	50-year	100-year	200-year
K13									
Catchment area (km2) :	9000 km2								
Peak Discharge	*1	m3/s	470	940	1430	2080	3340	4710	6620
Specific discharge	*2	m3/s/km2	0.052	0.104	0.159	0.231	0.371	0.523	0.736
BP-AM (Mellegue & Sarrath Confluence)									
Converted from Discharge at K13									
Catchment area (km2) :	6224 km2								
Peak Discharge	*3	m3/s	442	934	1369	2116	3299	4419	6224
Specific discharge	*2'	m3/s/km2	0.071	0.15	0.22	0.34	0.53	0.71	1

Source : JICA Study Team

Note : *1 : Probable analysis result of observed peak discharges at K13 by Study team

*2 and *2' : Specific dischage was derived based on catchment area-spedific dischage relation curves developed from probable analysis results of various hydrographs at different gauging stations in existing studies.

*3 : Derived from *2'.

Table A5.2.1 Probable Basin Average 6 day Rainfall and Basin Average 6 day Rainfall during the Experienced Major Floods

(1) Probable Basin Average 6 day Rainfall (1968/69 - 2005/06) (mm)

(2) Probable Peak Discharge at K13 and Ghardimaou (m3/s)

	HY-M	HY-U1	HY-U2	HY-D1	HY-D2	HYd-Bh	K13	Ghardimaou
	Mellgue, Mejerda Conf	Mellgue, Mejerda Conf	Sidi Salem	Larrousia Dam	Estuary	BouHeurtma Dam		
Catchment	4561	1154	10414	14172	15968	390	9000	1480
Return Period	km2	km2	km2	km2	km2	km2	km2	km2
2	55	75	60	56	55	143	470	250
5	82	101	84	80	79	185	940	520
10	104	121	100	98	96	215	1430	790
20	128	141	118	116	113	246	2080	1150
30	143	155	129	127	124	264	2200	1410
50	164	171	143	141	137	289	3340	1830
100	195	196	163	162	156	324	4710	2550
200	230	224	184	184	175	361	6620	3540
Disribution	LP3	LP3	LP3	LP3	LP3	LP3	GEV	GEV

Note : Basin average rainfall of HY-U2 will be applied to HY-D1 and HY-D2 as their values are similar.
LP3 : Log Pearson Type III, GEV : Generalized Extream Value

(3) Basin Average 6 Day Rainfall during Experienced Major Floods

(4) Peak Discharge at K13 and Ghardimaou (m3/s)

Flood	date				6day rain / Return period	HY-M	HY-U1	HY-U2	HY-D1	HY-D2	BouHeurtma Dam	K13	Ghardimaou
						Mellgue, Mejerda Conf	Jendouba	Sidi Salem	Larrousia Dam	Estuary			
1973 Mar Fl.	6 day rainfall	1973/3/24	to	1973/3/29	mm/6days	115	130	121	120	111	213	1280	2370
					year	15	15	22	25	20	10	8	80
2000 May Fl.	6 day rainfall	2000/5/22	to	2000/5/27	mm/6days	74	121	70	62	64	32	4480	737
					year	4	10	3	2.5	3	<1.01	90	10
2003 Jan Fl.	6 day rainfall	2003/1/8	to	2003/1/13	mm/6days	110	89	98	100	94	112	2600	1090
					year	12	4	10	12	10	1.01-2	30	18
	6 day rainfall	2003/1/16	to	2003/1/21	mm/6days	27	88	46	41	41	155	692	334
					year	1.01-2	4	1.01-2	1.01-2	1.01-2	3	3	3
	6 day rainfall	2003/1/22	to	2003/1/27	mm/6days	41	72	62	56	51	121	154	419
					year	1.01-2	1.01-2	2	2	1.01-2	1.01-2	<1.01	4
	6 day rainfall	2003/1/31	to	2003/2/5	mm/6days	16	61	37	32	31	118	80	131
					year	<1.01	1.01-2	1.01-2	1.01-2	1.01-2	1.01-2	<1.01	1.01-2
2004 Jan Fl.	6 day rainfall	2003/12/8	to	2003/12/13	mm/6days	139	175	139	142	140	223	2480	938
					year	28	50	40	50	60	13	28	15
	6 day rainfall	2003/12/19	to	2003/12/24	mm/6days	28	54	40	32	35	116	-	-
					year	1.01-2	1.01-2	1.01-2	1.01-2	1.01-2	1.01-2		
	6 day rainfall	2003/12/29	to	2004/1/3	mm/6days	42	51	51	40	43	146	645	1470
					year	1.01-2	1.01-2	1.01-2	1.01-2	1.01-2	2	3	32
	6 day rainfall	2004/1/20	to	2004/1/25	mm/6days	14	24	30	23	23	127	-	190
					year	<1.01	<1.01	1.01	1.01	1.01	1.01-2		<1.01

Note : - : Negligibly small

Table A5.2.2 Parameters for Deriving Unit Hydrograph from Dimensionless Unit Hydrograph and Peak Discharge of Derived Unit Hydrograph

Sub-catchment	Base point (downstream end of zone)	description	Remarks	Catchment Area Km2	Lag time Tcv hour	Parameters for Lag Time C (Footfill area)	n	Elevation highest mNGT	Lowest mNGT	Elevation difference (Entire reaches) h m	ft	Overall slope Sst ft/mile	i	Mainstream length (Entire reaches) L m	mile	Mainstream length (centroid-down end) Lca m	mile	Unit hydrograph qmax m3/s	q volume M m3
HY-AM	BP-AM	Mellegue & Sarrath Conf.	(Algeria)	(6224)															
HY-AU1	BP-AU1	Ghardimaou	(Algeria)	(1507)															
HY-U2p11	BP-M	Mj & Mel Conf	= HY-U1	1,154	8.085	0.72	0.38	520	126	394	1292.65	20.91768	1/252	99,450	61.80	69,180	42.99		
HY-U2p12	BP-U2up	Bou Salem (Mj & Bh Conf)		1,664	6.125	0.72	0.38	340	115	225	738.19	15.74092	1/335	75,470	46.90	38,090	23.67	983	17.56
HY-U2p13	BP-D2	Sidi Salem Dam		1,630	9.212	0.72	0.38	115	66	49	160.76	3.114772	1/1,695	83,060	51.61	45,060	28.00	653	17.22
HY-Mp2	BP-M	Mejerda & Mellgue Conf.		405	5.028	0.72	0.38	210	126	84	275.59	9.846103	1/536	45,044	27.99	30,030	18.66	282	4.28
HY-D2tp11	BP-D1up2	Mejerda&Siliana Conf.		1,626	5.557	0.72	0.38	360	63	297	974.41	24.62495	1/214	63,680	39.57	43,710	27.16	1,053	17.24
HY-D2tp12	BP-D1	Larrousia Dam		1,092	8.802	0.72	0.38	63	25	38	124.67	2.580508	1/2,046	77,750	48.31	38,875	24.16	441	11.55
HY-D2tp13	BP-D2	Estuary		1,473	7.926	0.72	0.38	25	-3	28	91.86	2.257038	1/2,339	65,500	40.70	32,750	20.35	678	15.58
HYd-Bh	BPd-Bh	BouHeurtma Dam	Dam CA	390	2.195	0.72	0.38	825	188	637	2089.90	91.17018	1/58	36,890	22.92	12,602	7.83	630	4.28
HYd-Ts	BPd-Ts	Tessa Dam	Dam CA	1,420	5.247	0.72	0.38	940	340	600	1968.50	45.08843	1/117	70,260	43.66	46,088	28.64	896	15.00
HYd-Sr	BPd-Sr	Sarrath Dam	Dam CA	1,850	5.684	0.72	0.38	1250	525	725	2378.61	41.12921	1/128	93,070	57.83	41,021	25.49	1,190	19.61
HYd-Mg	BPd-Mg	Mellegue Dam	Dam CA	4,156	11.615	0.72	0.38	1250	210	1040	3412.07	28.77064	1/184	190,856	118.60	109,686	68.16	1,327	43.98
HYd-Sl	BPd-Sl	Siliana Dam	Dam CA	1,040	4.658	0.72	0.38	950	360	590	1935.70	46.66839	1/113	66,750	41.48	36,068	22.41	829	10.99

Unit Ex. Rain : 10mm
Duration : 1 hr

Table A5.2.3 Probable Floods

(1) Runoff Analysis Result : Peak Runoff from Sub-catchments *1

Runoff Zone	CA km2	Peak Discharge (m3/s) 2-y	5-y	10-y	20-y	50-y	100-y	200-y
Dam Sites								
BouHeurtma Dam	390	240	490	745	1083	1731	2427	3391
Siliana Dam	1040	164	334	508	738	1180	1654	2312
Tessa Dam	1420	213	434	660	960	1535	2151	3006
Sarrath Dam (HY-M)	1850	278	567	863	1255	2005	2811	3927
Sarrath Dam (HY-U2)	1850	270	551	838	1220	1950	2733	3818
Runoff from sub Catchment								
HY-U1 (HY-U1)	1154	189	386	587	854	1365	1913	2673
HY-Mp1 (HY-M)	2306	304	621	944	1374	2196	3078	4300
HY-Mp1 (HY-U2)	2306	296	603	918	1335	2134	2991	4180
HY-Mp2	405	63	129	196	284	455	637	890
HY-U2p11 (U2)	1154	158	323	492	715	1143	1602	2239
HY-U2p12	1664	234	478	727	1057	1690	2368	3309
HY-U2p13	1630	195	398	606	881	1409	1974	2759
HY-D2p11	1626	240	490	746	1085	1734	2430	3396
HY-D2p12	1092	134	273	415	604	966	1353	1891
HY-D2p13	1473	188	383	582	847	1354	1898	2652

(2) Probable Flood Calculation Result (No dam, MIKE BASIN simulation Result)

Runoff Zone	CA km2	Peak Discharge (m3/s) 2-y	5-y	10-y	20-y	50-y	100-y	200-y
Bou Salem (Mej&BH conf.)	16500		733	1501	2252	3339	5267	7107
Sidi Salem Dam site	18150		675	1376	2066	3035	4820	6547
Estuary	23397		546	1092	1638	2397	3790	5201

Note : ( ) Basin Average Rainfall Applied

(3) Design Peak Discharges (Inflow from Algeria)

Station	CA km2	Peak Discharge (m3/s) 2-y	5-y	10-y	20-y	50-y	100-y	200-y
BP-AM (Mellegue) *1	6224	470	940	1430	2080	3340	4710	6620
BP-AU2 (Ghardimaou) *1	1507	250	520	790	1150	1830	2550	3540

(4) Probable Peak Discharges in Existing Studies

Station	CA km2	Peak Discharge (m3/s) 2-y	5-y	10-y	20-y	50-y	100-y	200-y	1000-y	10000-y	Design flood
Dam Sites											
BouHeurtma Dam *3	390							(Return period unknown)			3300
Tessa Dam *3	1420			1250			2500		3500	5500	5500
Sarrath Dam *3	1850						3800		8000		8000
Mellegue Dam *3	10309						4500		11300		6000
Siliana Dam *3	1040							(Return period unknown)			5100
Sidi Salem *3	18150							(Return period unknown)			6700
Mellegue 2 *3	10100			1700			5000		11000	25500	11000
estimated upper limit*3	10100			3100			8000		16500	35000	
Gauging station sites											
K13 *1	9000	470	940	1430	2080	3340	4710	6620			
K13 *3	9000			1600			4700		10400	24000	
estimated upper limit*3	9000			2900			7600		15500	33000	
Bou Salem (w/o Mellegue)*1	16330	530	1080	1560	2110	2970	3720	4580			
Bou Salem (w/o Mellegue)*2	16330	556		1625			4050				
Mejez El bab (w/oMellegue) *	21008	650		1790			4000				

Source : *1 : Computation by the Study Team
*2 : Monographies
*3 : Various dam data and Existing study reports

Table A5.2.4 Specific Discharges of Probable Floods

(1) Runoff Analysis Result : Peak Runoff from Sub-catchments *1

Runoff Zone	CA km2	Spedific Discharge (m3/s/km2) 2-y	5-y	10-y	20-y	50-y	100-y	200-y
Dam Sites								
BouHeurtma Dam	390	0.615	1.256	1.910	2.777	4.438	6.223	8.695
Siliana Dam	1040	0.158	0.321	0.488	0.710	1.135	1.590	2.223
Tessa Dam	1420	0.150	0.306	0.465	0.676	1.081	1.515	2.117
Sarrath Dam (HY-M)	1850	0.150	0.306	0.466	0.678	1.084	1.519	2.123
Sarrath Dam (HY-U2)	1850	0.146	0.298	0.453	0.659	1.054	1.477	2.064
Runoff from sub Catchment								
HY-U1 (HY-U1)	1154	0.164	0.334	0.509	0.740	1.183	1.658	2.316
HY-Mp1 (HY-M)	2306	0.132	0.269	0.409	0.596	0.952	1.335	1.865
HY-Mp1 (HY-U2)	2306	0.128	0.261	0.398	0.579	0.925	1.297	1.813
HY-Mp2	405	0.156	0.319	0.484	0.702	1.123	1.573	2.198
HY-U2p11 (U2)	1154	0.137	0.280	0.426	0.620	0.990	1.388	1.940
HY-U2p12	1664	0.141	0.287	0.437	0.635	1.016	1.423	1.989
HY-U2p13	1630	0.120	0.244	0.372	0.541	0.864	1.211	1.693
HY-D2p11	1626	0.148	0.301	0.459	0.667	1.066	1.494	2.089
HY-D2p12	1092	0.123	0.250	0.380	0.553	0.885	1.239	1.732
HY-D2p13	1473	0.128	0.260	0.395	0.575	0.919	1.289	1.800

(2) Probable Flood Calculation Result (No dam, MIKE BASIN simulation Result)

Runoff Zone	CA km2	Spedific Discharge (m3/s/km2) 2-y	5-y	10-y	20-y	50-y	100-y	200-y
Bou Salem (Mej&BH conf.)	16500		0.044	0.091	0.136	0.202	0.319	0.431
Sidi Salem Dam site	18150		0.037	0.076	0.114	0.167	0.266	0.361
Estuary	23397		0.023	0.047	0.070	0.102	0.162	0.222

Note : ( ) Basin Average Rainfall Applied

(3) Design Peak Discharges (Inflow from Algeria)

Station	CA km2	Spedific Discharge (m3/s/km2) 2-y	5-y	10-y	20-y	50-y	100-y	200-y
BP-AM (Mellegue) *1	6224	0.08	0.15	0.23	0.33	0.54	0.76	1.06
BP-AU2 (Ghardimaou) *1	1507	0.17	0.35	0.52	0.76	1.21	1.69	2.35

(4) Probable Peak Discharges in Existing Studies

Station	CA km2	Spedific Discharge (m3/s/km2) 2-y	5-y	10-y	20-y	50-y	100-y	200-y
Dam Sites								
BouHeurtma Dam *3	390							
Tessa Dam *3	1420			0.880			1.761	
Sarrath Dam *3	1850						2.054	
Mellegue Dam *3	10309						0.437	
Siliana Dam *3	1040							
Sidi Salem *3								
Mellegue 2 *3	10100			0.168			0.495	
estimated upper limit*3				0.307			0.792	
Gauging station sites								
K13 *1	9000	0.052	0.104	0.159	0.231	0.371	0.523	0.736
K13 *3	9000			0.178			0.522	
estimated upper limit*3	9000			0.322			0.844	
Bou Salem (w/o Mellegue)*1	16330	0.032	0.066	0.096	0.129	0.182	0.228	0.280
Bou Salem (w/o Mellegue)*2	16330	0.034		0.100			0.248	
Mejez El bab (w/oMellegue) *1	21008	0.031		0.085			0.190	

Source : *1 : Computation by the Study Team
*2 : Monographies
*3 : Various dam data and Existing study reports