Part 2

PHASE-I STUDY:

UNDERSTANDING OF PRESENT CONDITIONS AND FORMULATION OF FRAMEWORK FOR THE MASTER PLAN

CHAPTER 3 FIELD SURVEYS

3.1 River Profile and Cross Section Survey

The river profile and cross-section survey was conducted for the following sites and routes where flood control measures need to be planned:

(1) Mainstream of the Mejerda River (from the Sidi Salem dam reservoir to the border between Tunisia and Algeria),

(2) Major tributaries (Mellegue, Tessa, Bou Heutma, Kasseb, Beja Rivers and others), and

(3) Prospective sites of flood control structures, such as retarding basins, bypass channels, ground-sills, bridges, dikes and revetments.

Out of these survey areas, the item (1) survey, the mainstream of the Mejerda River and the item (2) survey, major tributaries, were conducted during the first and the second work in Tunisia, respectively. The item (3) survey was conducted during the third work in Tunisia.

The technical specifications of the items (1) to (3) survey are as stated below.

Item (1) Survey: Technical Specifications

Survey area	Mainstream of the Mejerda River (Upstream section from the Sidi Salem reservoir to the border with Algeria)
Work quantity	1) River profile survey: about 180 km 2) Cross-sectional survey: 360 sections (about 500m interval along the river center, average width of about 330 m)
Technical Specifications	1) Selection of survey points by use of the existing maps with scales of 1:25,000 – 50,000 2) River profile along the stream flow line (the deepest river channel) 3) Provision of one wooden/steel bar each on both sides of each river cross-section
Survey outputs	1) Drawings of control survey networks and locations of profile and cross-sections (plan) 2) Drawings of river profile and river cross-sections 3) Survey records and reports 4) Survey drawings shall be of Auto CAD format. 5) Both paper drawings and digital files shall be submitted.

Item (2) Survey: Technical Specifications

Survey area	Major tributaries situated between the Sidi Salem Reservoir and Jendouba: Mellegue, Tessa, Rarai, Bajer, Bou Heurtma, Kasseb and Beja Rivers
Work quantity	1) River profile survey: about 140.6 km 2) Cross-sectional survey: 476 sections (about 250/500m intervals along the river center, average width of about 300 m)
Technical Specifications	1) Selection of survey points by use of the existing maps with a scale of 1:25,000 2) River profile along the stream flow line (the deepest river channel) 3) Provision of one steel bar each on both sides of each river cross-section
Survey outputs	1) Drawings of control survey networks and locations of profile and cross-sections (plan) 2) Drawings of river profile and river cross-sections 3) Survey records and reports 4) Survey drawings shall be of Auto Cad format. 5) Both paper drawings and digital files shall be submitted.

Item (3) Survey: Technical Specifications

Survey area	Prospective sites of flood control structures in and along the mainstream of the Mejerda River (from the estuary to the border between Tunisia and Algeria)
Work quantity	1) River profile survey: about 54.8 km 2) Cross-sectional survey: 72 sections (about 250m/100m intervals along the river/canal center, average width of about 200 m)
Technical Specifications	1) Selection of survey points by use of the existing maps with scales of 1:25,000 – 50,000 2) River profile along the stream flow line (the deepest river/canal bed) 3) Provision of one steel bar each on both sides of each river cross-section
Survey outputs	1) Drawings of control survey networks and locations of profile and cross-sections (plan) 2) Drawings of river profile and river cross-sections 3) Survey records and reports 4) Survey drawings shall be of Auto CAD format. 5) Both paper drawings and digital files shall be submitted.

The survey results have been usefully reflected in the study work, particularly to the study on discharge capacities of river channels, flood inundation analysis and river improvement works for flood control measures.

3.2 Flood Inundation and Damage Survey

The flood inundation and damage survey has been conducted to collect data and information in the field regarding flood inundation and damage due to previous major floods in the Mejerda River basin. The major flood events considered for this survey are those that occur in 1973, 2000, 2003, 2004 and 2005.

The survey consists of the following two major activities:

- Collection of data/information from related government agencies/offices, and
- Questionnaire survey to residents/ shops/ farmers/ industries.

The execution of both above activities was designed to obtain information on actual flood damage from two different sources. Regarding the data collection through questionnaire survey, prepared questionnaire forms were different for residents, shops, farmers and industries. Nevertheless, all forms basically contained questions about the following items:

- General information of respondents, such as address and major income sources,
- Inundation conditions including inundation date, water level, and duration,
- Flood damage and inconvenience caused,
- Experiences of inundation, such as behaviour after its occurrence.

The questionnaire survey was conducted to 300 respondents in total at the cities/major towns which had experienced significant inundation damage due to past major floods. The survey results have been effectively referred to and employed in the Study, particularly the study work on flood inundation analysis, river improvement works for flood control measures and evaluation of project benefit for economic analysis of project.

3.3 Inventory Survey on Water Management Facilities

3.3.1 General

The inventory survey on water management facilities was carried out to collect data and information, including physical characteristics, concerning water resources management and flood control facilities operated within the Mejerda River basin. The following items are included in the inventory survey:

Classification	Survey Item
Pluviometric and hydrometric measurement and monitoring	(A1) Rain gauging stations in the catchment (A2) Rain gauging stations in adjacent catchments (B) Stream gauging stations (C) Gauging stations used for flood early warning system (D) Water quality monitoring locations
Hydraulic structures and obstructions	(E) Dams (F) Crossing structures: bridge piers, pipelines, siphons (G) Weirs and other water level control structures
Channel improvement works	(H) Channel lining, flow diversion channels, and levees
Erosion/ sediment control	(I) Storm water detention for erosion control (hill dams) (J) Flow attenuation check dams for soil conservation
Irrigation and drainage	(K) Location of canal inlets/outlets and flood protection gates
Groundwater resources	(L1) Wells (L2) Shallow aquifers (L3) Deep aquifers

Classification	Survey Item
Water use	(M) Water intake facilities (N) Potable water facilities operated by SONEDE (O) Bulk water transfer facilities operated by SECADENORD (P) List of irrigated schemes (Q) Population of communes and sectors (R) Towns supplied with potable water from SONEDE
Wastewater treatment	(S) List of wastewater treatment schemes operated by ONAS
Land use	(T) Forestry land use (U) Agricultural land use (V) Land use by sub-catchment area
Environment	(W) List of wetlands and protected areas

The information gathered during the inventory survey was used to understand the existing conditions in the basin, and to prepare master plan solutions aimed at improving flood control and early flood warning systems.

3.3.2 Description of Survey

The inventory survey on water management facilities was carried out in two stages.

(1) Stage 1

The first stage consisted of identifying the existing facilities located within the Mejerda River basin and collecting corresponding data related to its physical characteristics. Most of the data for said inventory survey were obtained from the MARH's GEORE database. Locations of all inventory items and land use data have been geo-referenced to UTM coordinates.

Population data and projections are as published by INS based on the most recent census taken in 2004. Boundaries for communes have been collected, but the sector boundaries within communes (the smallest unit of population) were not obtained as it required special permission from the Ministry of Defense.

The approximate locations of levees were indicated by MARH on the topographic maps. However, heights and its existing conditions are unavailable. Limited information on heights of levees can be obtained from the cross sectional surveys that were carried out under the Study.

(2) Stage 2

In the second stage, the inventory survey was conducted for collecting information pertaining to the operation and maintenance of the physical infrastructure that plays an important role in flood management.

The collection of data was conducted in cooperation with DGBGTH. Finding a reliable source of information for some operation and maintenance data proved to be difficult. In the end, the survey was only able to obtain limited O&M data for several inventory items, namely, rain gauging stations, stream gauging stations, large dams, hydraulic control structures, levees, small hill dams and check dams.

3.3.3 Synopsis of Operation and Maintenance

The survey result indicates that routine maintenance is almost non-existent and clearly suffers from a lack of funding. It also reveals that there is little or no preventive maintenance carried out.

Key findings of the O&M survey are outlined in **Table 3.3.1**, and summarized below.

(1) Rain gauging stations

MARH reports that there is a serious lack of maintenance caused by shortage of manpower and funds. The collection of rainwater is often blocked by dirt or debris, preventing accurate recording of rainfall. Main stations are equipped with automated data loggers. However, power supplies (electrical utility, batteries, solar panels, etc.) are unreliable. Loss of power for extended periods results in loss of system configuration data and rainfall data.

(2) Stream gauging stations

Similar to rain gauging stations, MARH reported a serious lack of maintenance of the stream gauging stations due to shortage of manpower and funds. Although said stations are equipped with automated data loggers, its power supplies (electrical utility, batteries, solar panels, etc.) are unreliable as well. Hence, long duration power failure causes system risks such as loss of system configuration and water level data.

Data loggers are not regularly downloading data at required intervals. It is noted that when the storage disk is full, the system is unable to record any new data. Sometimes, the disk remains full for several days resulting in gaps in the recorded data.

(3) Large dams

Dams are inspected annually by specialist consultants. They monitor survey markers to check for settlement and piezometers for leakage. Bathymetric surveys are carried out approximately every five years to measure sediment accumulation and update storage volume curves.

Maintenance consists mainly of a program for planned repair or replacement due to the following defects and related components:

- leaks from gates and valves
- corrosion of valves and outlet piping
- failure of motorized valve operators and controls
- damaged concrete on spillways and abutments

There is little or no preventive maintenance carried out. Budget requested for planned maintenance are submitted for approval each fiscal year.

(4) Hydraulic control structures at Laroussia and Tobias

A number of recent repairs have been reported, namely dredging of sediment, replacement of lifting chains on gates, corrosion protection for the sheet piling and corrosion protection for gates and outlet valves.

(5) Levees

Levees are inspected about five times per year, usually after heavy rainfalls and high flows. Typical problems include erosion during peak flows and man-made breaches. Levees at Kalaat Andalous were damaged and repaired in 2005, 2006 and 2007.

3.4 Interview Survey on Public Acceptance of Flood Risk

As part of public involvement in the early stages of the decision making process, a survey on residents' acceptance of flood risks was undertaken in the field work phase of the Study. The survey is based on a detailed questionnaire designed for localities along the Mejerda River basin that have experienced flood damages. The 2003 flood is taken as a reference because it is still vivid in people memory, and caused significant damage in recent time. The questionnaire is designed to grasp the views and opinions of the local residents on the flood risks in the Mejerda River basin. This is intended to assess people's perception on flood danger so as to find out whether they can tolerate with the flooding or how it threatens them. In countries such as Indonesia, people are terrified of flooding as it occurs almost every year, causing considerable damage. Therefore, people in Asia (particularly Indonesia, Bangladesh and Thailand) could be more motivated in participating in flood protection activities due to frequent occurrence of flood. In Africa meanwhile, the perception seems different since its people experience flood events very rarely and thus do not feel threatened with its occurrence. Hence, they may not be willing to participate in taking related structural measures or responsibilities.

That is why the surveys are conducted to determine people's perception on flood risks so that one can plan adequate and necessary measures for protection.

The survey includes questions on general data related to location and social profile of the respondent, and several detailed questions to assess the respondent's perception on flood risk. Said questions are itemized as follows:

1) General data (Question 1 to Question 3)
2) Social profile of the respondent (Question 4)
3) Experience and type of flood damage (Question 5)
4) Fear of flood (Question 6)
5) Perception of flood risk (Question 7)
6) Acceptability of flood damage risk (Question 8)
7) Structural measures for reducing flood damage (Question 9)
8) Non structural measures for reducing flood damage (Question 10)
9) Reliance on government for reducing flood damage (Question 11)
10) Appreciation of self-responsibility to flood damage risk (Question 12)
11) Priority to structural and non structural measures to flood damage risk (Question 13).

Some items of interest in the questionnaire deal particularly with:

1. The acceptability of flood damage risk to assist in determining corresponding plan

adequate to the level of flood risks, which should be applied to the flood control plan for the Mejerda River basin.

2. The appreciation of self-responsibility to flood damage risk to measure the willingness of people to participate in flood control measures or be responsible enough for them and to plan adequately for measures to raise the level of awareness of self-responsibility, if needed
3. The level of reliance on agencies concerned with flood control as these agencies alone cannot solve all the related problems especially for rare flood events. All parties concerned should play their designated roles in order to mitigate flood risks and damage. Proper measures involving capacity building of parties concerned and good coordination work should be planned for effective control of the damage due to these rare flood events, such as that occurred in 2003.

The details of this survey have been reported in **Supporting Report J** and major achievements are as compiled in **Table 8.1.1.** The achievements have been used as information for decision making process for the plan formulation, especially to determine the level of flood risk to be applied to the flood control plan for the Mejerda River basin.

CHAPTER 4 HYDROLOGY AND HYDRAULICS

4.1 Hydrological Investigations

4.1.1 General

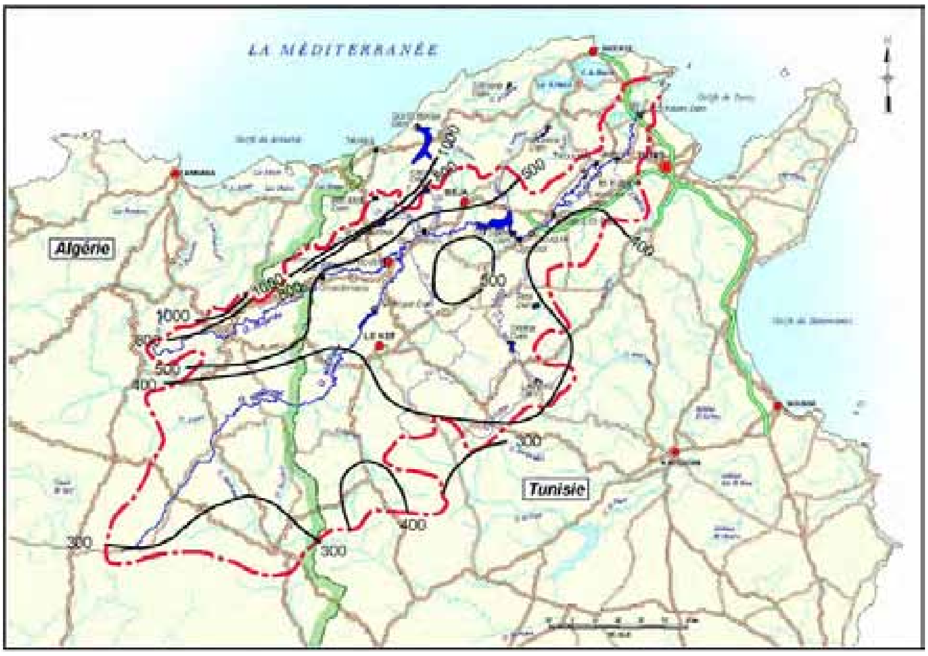
The current hydrological conditions in the study area have been examined to acquire necessary hydrological background information. The findings of previous hydrological works in past projects have been reviewed and some of the results have been incorporated into the Study.

Meteorological and hydrological data in the Mejerda River basin and adjacent areas were collected from the two major responsible agencies, i.e., the Ministry of Agriculture and Hydraulic Resources (MARH), mainly DGRE and DGBGTH and the National Institute of Meteorology (INM). The major data collected were climate data, daily and hourly rainfall, daily and hourly discharges and limited hydrological data in Algeria. The collected rainfall and stream discharge data have been scrutinized before being used in subsequent analyses.

4.1.2 Rainfall Characteristics in the Study Area

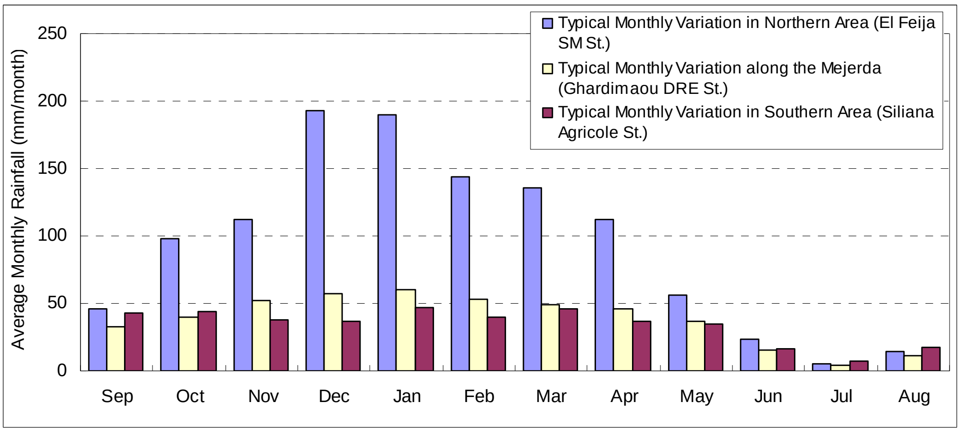
(1) Spatial and seasonal variations

Generally, the average annual rainfall shows a decrease trend 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, from over 1,000 mm in the north to around 300mm in the southern parts, as shown in the map below.



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

This difference is mainly due to notable abundant rainfall during the wet season in the northern parts. As indicated in the following chart, the wet season (Oct. to Apr.) rainfall in the northern parts of the study area (the left bank areas of the Mejerda basin) increases significantly, especially in December and January. These months meanwhile do not indicate a distinct peak in the southern areas where right bank tributaries, including the Mellegue River, are situated.



Source : the Study Team, developed based on DGRE daily rainfall data (Average of 1950/51-2005/06)

Monthly Variation of Rainfall in Different Regions

The occurrence of intensive rainfalls also has regional variations. In the northern areas, an annual maximum daily rainfall is more likely to occur from November to January, whereas in the southern areas, it could occur throughout September to June.

(2) Annual variations

Table 4.1.1 presents annual rainfalls, consecutive two year rainfalls and consecutive three year rainfalls, during the period from 1968/69 to 2005/06. The following table shows the five lowest precipitation records during the said period. This result matches with the fact that the two most serious droughts in the basin during the 80s to the 90s, occurred in 1987-88-89 and 1993-94-95.

Five Lowest Precipitation Records (Basin 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 rainfalls correspond to the years with remarkable floods as compiled below.

Five Highest Precipitation Records

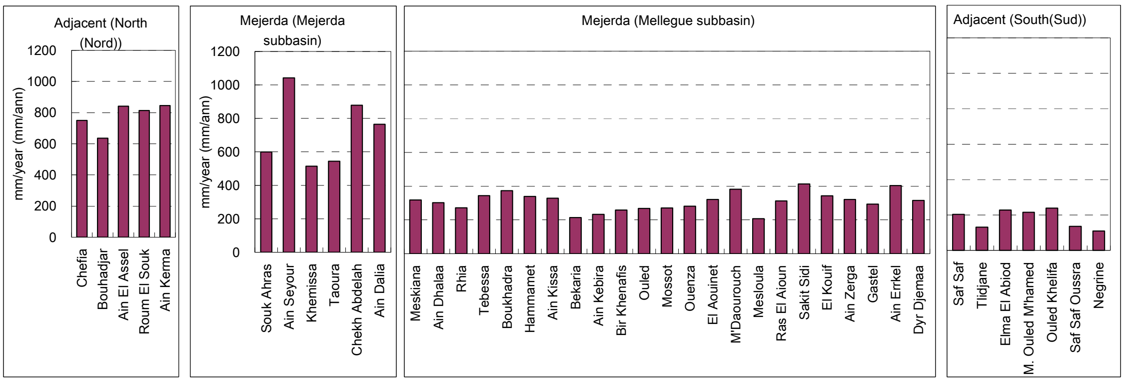
Rank	Period	Annual Basin Rainfall (mm/year)	Notable Flood during the period
1	2002/2003	780	Jan. 2003
2	1972/1973	721	Mar. 1973
3	2003/2004	701	Jan.-Feb. 2004
4	1969/1970	691	Sep.-Oct. 1969
5	1995/1996	676	-

Source : the Study Team

(3) Monthly and annual rainfalls in the Algerian territory of the Mejerda River basin

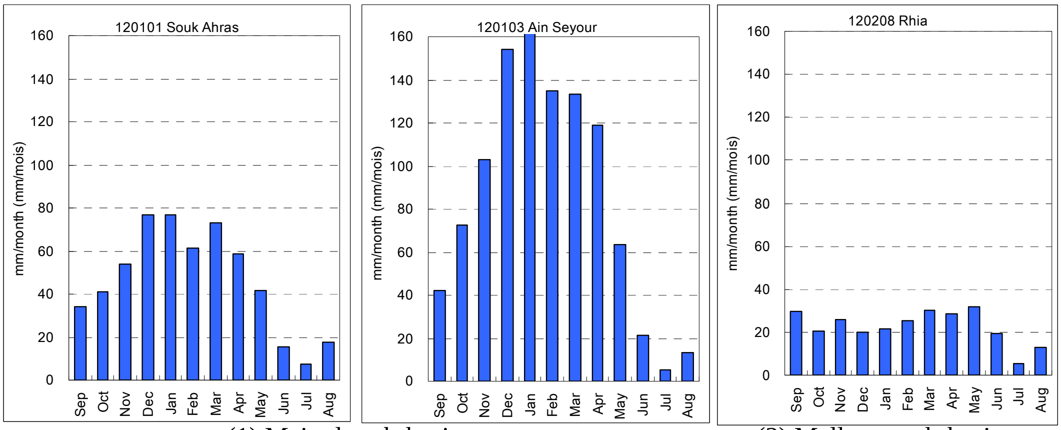
The following charts present examples of monthly and annual rainfalls at some stations in different parts of the Algerian territory of the Mejerda River basin. Details could not be discussed thoroughly due to limited data. However, existing data suggest that the annual rainfall and monthly variation in the Algerian territory show similar characteristics to those in the Tunisian territory; that is,

- The north edge receives the highest annual rainfall, and the annual rainfall generally declines towards the south.
- Stations in the northern parts indicate more significant peaks of monthly rainfall in the wet season (Oct. – Apr.) than those in the southern parts.



Period: First year of operation– 2003/2004 (at respective stations)
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

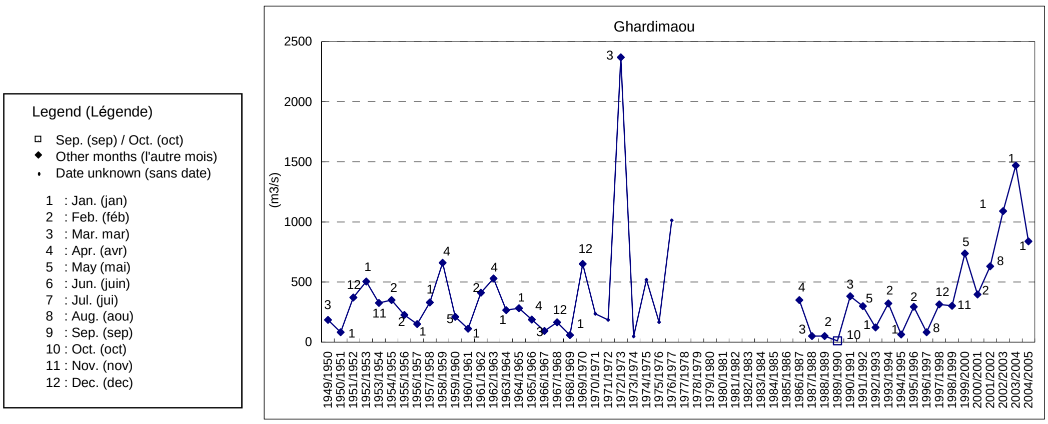
Average Monthly Rainfall at Typical Stations in Algerian Territory of the Mejerda River Basin

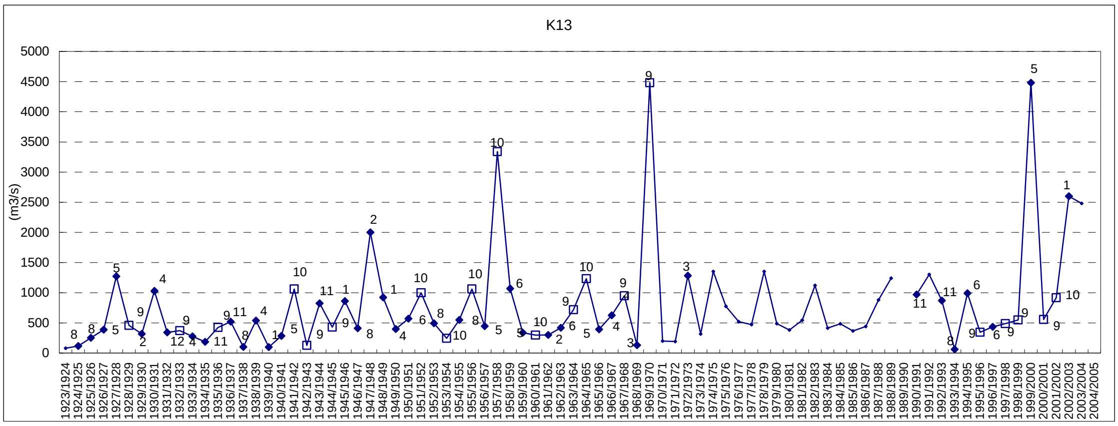
4.1.3 Flood Flow Characteristics

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 **Figure 4.1.1** for their locations). The following characteristics can be observed from the charts.

- At the K13 station, September and October are prominent in the occurrence of annual peak discharges throughout 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 the months when annual peak discharge prevails (24 out of 41 records), including the ones caused by recent major floods. Unlike the K13 station, the annual peak discharges at Ghardimaou station are seldom observed in September and October.

The peaks at the two stations could often happen in the same month (during the same series of flooding) as the charts indicate. Coincidence of the two peaks at the two stations would result in serious floods in the Mejerda River basin, such as the ones in March 1973 and January 2003.





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

Recorded Annual Maximum Discharges and Months of their Occurrence

The frequency analysis of annual peak discharges at major stations was made in the existing study (“Monograhies Hydrologiques”) using the data up to 1975/76. Excess probabilities of flood were updated in the Study by adding available recent data (1976/77 to 2003/2004), and applying statistical methodologies which have become popular after the 1980s, such as the GEV (Generalized extreme value). **Table 4.1.2** shows the available observed annual peak discharge data at the major stations.

The following table summarises the results at the Ghardimaou and Mellegue K13 stations, two of the most important stations for determining flood conditions in the Mejerda River basin. The differences between the figures in the existing study and by the Study were due to the consideration of additional recent data and the application of the new probability distribution.

Probable Peak Discharges Unit : m^3/s

Return period	Ghardimaou		Mellegue K13	
	Existing study	By the Study	Existing study	By the Study
2 yr	250	250	480	470
5 yr	500	520	1000	940
10 yr	750	790	1510	1430
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 return period demonstrate a rough estimate only. Computation of such a small probability using the data covering a period shorter than 100 years might give low reliability results.

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

4.2 Existing River System

4.2.1 Present River System and Riverbed Profiles

(1) River system and catchment area

Figure 4.2.1 schematically shows the present river system and the major tributaries in the Mejerda River basin. Upstream parts of the Mejerda, the Mellegue, and the 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 (and upst. tributaries)	Length	River Name (and upst. tributaries)	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

Two outlets of the Mejerda River used to exist, which includes the original river channel towards the north and an artificial floodway towards the east constructed in the 1950's, during the French administration. However, the original channel of the Mejerda River was closed at the branch in 1990, and was converted to an irrigation canal conveying the water taken at the Tobias Dam (movable weir) to its command areas. The current river outlet of the Mejerda River is the artificial floodway constructed in the 1950's.

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, and Grid elevation (DEM) data.

The following table summarizes the calculated catchment area. The result confirmed that one third of the entire Mejerda River basin lies in Algeria.

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 total catchment area of the Mejerda River basin is 23,700km^2.

Runoff from 323 km^2 of the total catchment area, located at the downstream end of the original Mejerda River, directly flows into the sea based on the topographic condition.

Out of said total catchment area, 19,400 km^2 (approximately 80%) extends upstream of the existing dams, which is called "controlled catchment area". The primary contributor is the Sidi Salem Dam with a 18,100 km^2 catchment area. The remaining 1,300 km^2 is covered by the Siliana and R'Mil Dams.

(2) Riverbed profiles and slopes

(i) Upper reaches of Mejerda River: upstream end of Sidi Salem Reservoir - Algerian border (158 km)

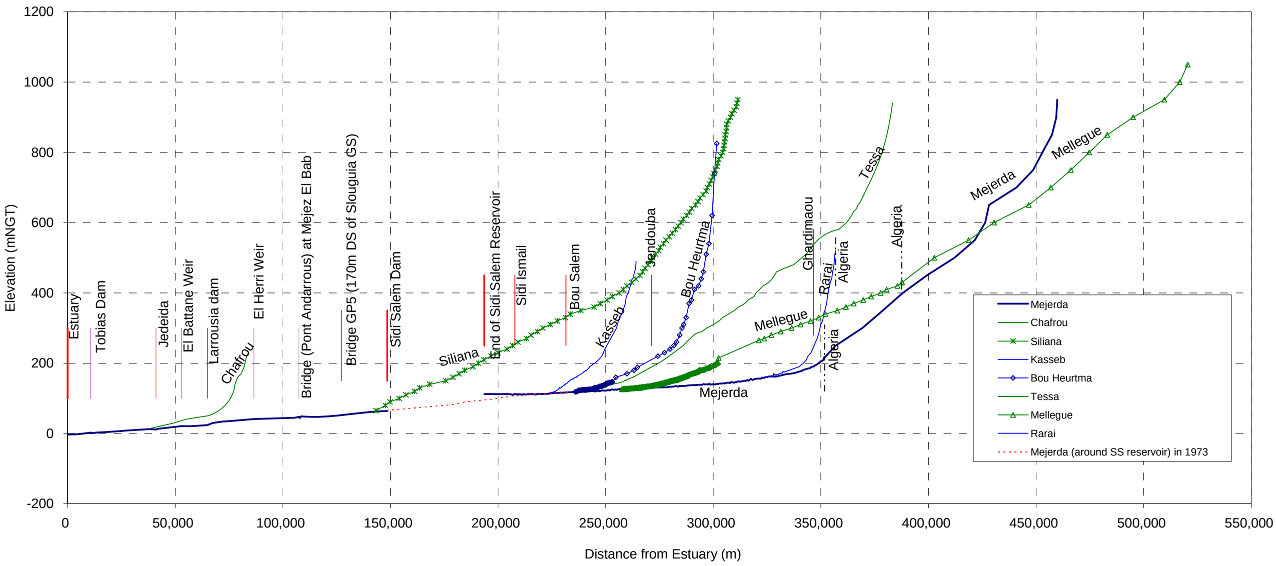
The riverbed profile is shown in **Figure 4.2.2** which was prepared based on the topographic survey results conducted in 2007 as part of the Study. As per the profile, the stretch near the Sidi Salem Reservoir for about 25 km has a nearly flat slope. This implies significant sediment deposit occurs around the upstream end of the reservoir.

(ii) Lower reaches of Mejerda River: downstream from the Sidi Salem Dam (148 km)

Figure 4.2.3 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 range 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 due to the sedimentation trapped by the dam. Andarous Bridge at Mejez El Bab, the old weir at El Battane and the Tobias Dam also are investigated to have caused fluctuation of the bed, but seems as just local phenomena.

(iii) Tributaries

The following figure provides an overview of riverbed slopes of the Mejerda River and its tributaries. The figure reveals steeper slopes of the left bank tributaries on the upper reaches (the Rarai, the Bou Heurtma and the Kasseb Rivers).



Source: the Study Team, prepared based on 2007 topographic survey results as well as available 1/50,000 and 1/25,000 topographic maps

Profiles of the Mejerda River and its Major Tributaries

4.2.2 Flow Capacity

(1) Methodology

Flow capacity of the existing river channels was computed by the non-uniform flow calculation method. River geometry data were acquired from the cross section survey results in 2007 conducted by MARH and the Study Team. The flow capacity was derived from a bankfull discharge of each cross section, while the capacities of several reaches were determined taking the minimum value in each reach.

(2) Upstream areas from Sidi Salem Dam

Figure 4.2.2 presents the computed flow capacity along with bed slopes. Although the capacities vary among the different reaches, in general, the capacity of the Mejerda mainstream could be said to range from 200 to 600 m^3/s. The river sections whose capacities are smaller than those of other sections generally coincide with reaches which have experienced extended inundation during the past major floods.

(3) Downstream areas from Sidi Salem Dam

Figure 4.2.3 shows the longitudinal profile and the estimated flow capacity on the downstream reaches of the Mejerda River (lower reaches from the Sidi Salem Dam). Considerably small flow capacity is found 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 as well as existing data of experienced floods.

4.3 Hydrological Characteristics of Floods in the Mejerda River Basin

4.3.1 General

The Mejerda River basin has experienced a number of floods. This section discusses characteristics of the following recent major floods from a hydrological view point.

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

Hydrological data, such as flood hydrographs at the major stream gauging stations, related to the above floods are complied in **Annex 4.1** and **Data Book A4**.

4.3.2 Overall Flood Characteristics

In the Mejerda River basin, significant floods have occurred in any month from autumn to spring (September to May) as experienced floods signify. High precipitation at the middle of the wet season (Dec. to Jan.) would trigger flooding. However, despite the relatively small basin subjected to monthly rainfall in spring and autumn, violent floods can be observed also in these seasons. This relates to a combination of the following hydrological features in the basin discussed in **Section 4.1**;

- High discharge with large peaks from the right bank tributaries are more likely to be observed in September and October, whereas large floods from the left bank tributaries and the Mejerda mainstream (at Ghardimaou) tend to be observed from December to February.
- In the right bank tributary areas, intensive rainfall could occur throughout from autumn to spring.
- The right bank tributaries tend to bring floods with sharp and acute hydrographs.

A coincidence of a peak of inflow to the Mejerda River from Algeria, that to the Mellegue River and abundant rainfall on the Tunisian side of the basin often resulted in devastating floods, such as the ones in 1973 and 2003.

4.3.3 Hydrological Characteristics of the March 1973 Flood

The March 1973 Flood caused extensive inundation in the entire reaches of the Mejerda River as in **Figure 4.3.2**. At the time of this event, the Sidi Salem Dam did not exist yet and the Mejerda River possessed two outlets (the original river and the floodway at Tobias). Hydrological features of this flood are distinguished by a high single peak of rainfall, inflow and discharge.

The probability of the flood peak at Ghardimaou is estimated at 1/80. The heavy rainfalls with probabilities of 1/15 to 1/25 (6 day basin rainfall) covered the entire Mejerda River basin. Flood runoff derived from 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 exceeded their flow capacities at many reaches of the rivers.

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), based on the short duration rainfall.

4.3.4 Hydrological Characteristics of the May 2000 Flood

The May 2000 Flood caused severe inundation along the Mellegue River and upper reaches of the Mejerda River. Prominent hydrological features of this flood are:

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

The estimated probability of the peak discharge at Mellegue K13 reached 1/90, while the peak at Ghardimaou fell into the range between 1/5 and 1/10. 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 since its reservoir water level had been already kept high so as to be ready for water supply (for the coming dry season) when the inflow arrived. The outflow from the Mellegue Dam exceeded the flow capacities of the downstream river channels, and consequently overflowed. Inundation was limited to upstream areas of the Sidi Salem Dam, since it successfully mitigated the peak.

4.3.5 Hydrological Characteristics of the January 2003 Flood

This flood is characterized by:

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

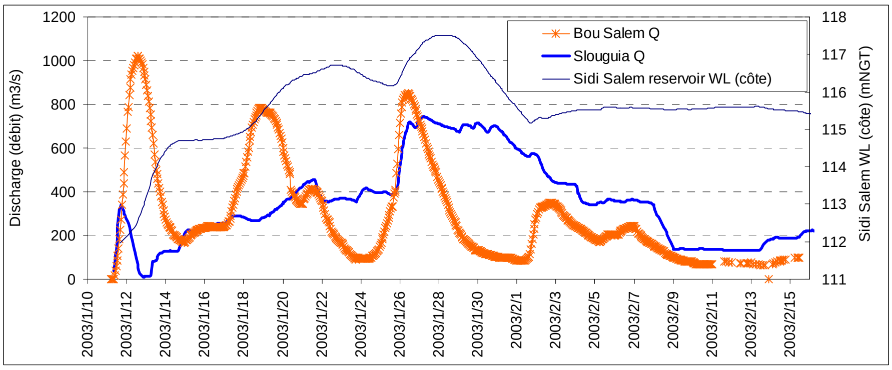
A probability of the peak discharge at Ghardimaou is estimated at around 1/20, but a probability of the flood volume (197 million m^3, total for 30 days with four peaks) fell to about 1/70.

The contrast between the May 2000 and January 2003 floods illustrates one of distinctive features of the latter flood event. As shown in the table below, the peaks of inflow to the Sidi Salem Reservoir of the two floods were nearly identical. However, the January 2003 Flood inflow with high multiple peaks could not avoid the large peak outflow unlike the May 2000 Flood.

Inflows and Outflows at Sidi Salem Dam during the May 2000 and Jan 2003 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. The Sidi Salem Reservoir effectively mitigated peaks of the first and second waves of the flood inflow, but needed to increase releasing discharge of up to 740 m^3/s when the third peak arrived. The presence of the fourth peak prolonged high level of the release.

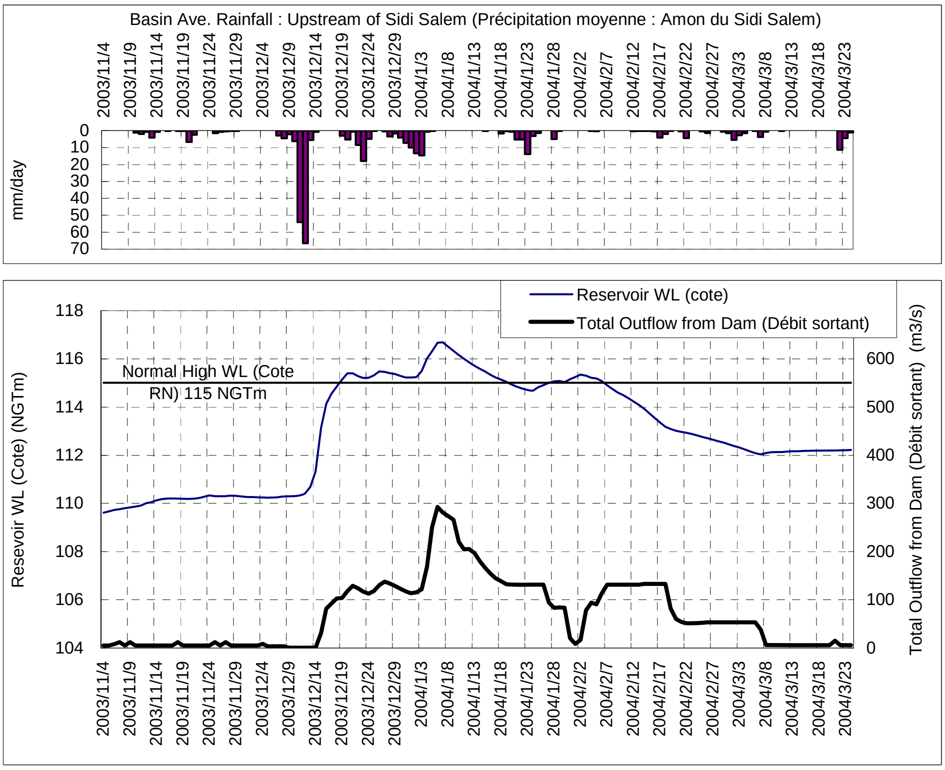
A consequence of the multiple peaks was the long duration of inundation on both upstream and downstream areas of the Sidi Salem Dam. The inundation continued for a month or longer in certain areas, especially in the downstream areas.

4.3.6 Hydrological Characteristics of the January 2004 and 2005 Floods

Hydrological features of these floods are also;

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

During the January 2004 Flood, the peak of outflow from the Sidi Salem Dam was observed on the 6th of January 2004, despite the small to moderate rainfall around this day. This was rather caused by significant antecedent rainfalls (around 50 year probability of 6 day rainfall) during the 10th to 13th of December 2003, followed by the rising of the high reservoir water level. When the moderate rain occurred during the 29th of December to 3rd of January, water needed to be released to maintain the normal high water level (Cote RN) as the following charts indicate. Hence, high water levels of the Mejerda River were observed on the downstream areas despite small rainfall around that day. Similar phenomena were observed in the 2005 Flood.



source : the Study Team, based on data from MARH

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

4.3.7 Implication of Hydrological Characteristics of Past Major Floods

The past major 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 simultaneous occurrence of all or some of high inflow peaks to the Mejerda and the Mellegue River from the Algerian parts and significant rainfall in the Tunisian part of the basin, and
- Multiple peaks of inflow and precipitation

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

- Reservoir water level receiving water from flood
- Outflow discharges of dams, and
- Capacity of river channels and river structure

4.4 Low Flow Analysis

4.4.1 Methodology and Data Used

(1) General

The purpose of low flow analysis under the 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 the Study focuses on flood control, it follows and applies existing plans, theories and concepts regarding water supply whenever available. 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 from 1946/47 to 1989/90 was derived in EAU2000, based on available DGRE observation data and past study results.

Then, EAU2000 treated the sum of annual inflows at 16 dam sites located in the "Nord+Mejerda" (Extreme 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'Mil Dams, were classified into the separate area, and some other dams in the 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

Frequency analysis on the total annual inflow (total at the 16 dams) was made using data for 44 years from 1946/47 to 1989/90 in EAU2000, while the year with a 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 from EAU2000 with as much available data as can be obtained until year 2003.

(3) Computation of inflow by the Study

The Study incorporates 26 dam sites enumerated in the above table into the estimate of available water resources for the Mejerda River basin. The 26 dams either constitute a water supply network system in the extreme north and Mejerda River basin, or independently provide water to their own local command areas 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, mainly using daily discharges observed by DGRE.

Through the data verification and filling work, the absence of the inflow data in 1998/1999 at the Melah Dam site in the Extreme-North Area was found (see Table A4.1.1 in Supporting Report A). This missing data could not be filled using other available data, although the data during and after 1998/1999 were available from many other dam sites. Consequently, the annual inflow data from 1946/47 to 1997/1998 were determined applicable to the frequency analysis, because this period already satisfies the purpose of such analysis taking the following facts into account:

- This period of more than 50 years can be considered sufficient for purposes of frequency analysis of the annual inflow volumes.
- This period covers the two historical droughts (1987-88-89 and 1993-94-95).
- Rainfall data of up to the year 2006 provided by MARH shows that the years after 1997/1998 were relatively wet as discussed in Sub-section 4.1.2. Especially after 2000, the wet years with frequent significant floods led to high annual inflows. For the purpose of the frequency analysis of the dam inflow data discussing the required water supply water amount, setting the period up to 1997/1998 without containing notable wet years can bring about the safer side of planning.

Subsequently, 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.

4.4.2 Frequency Analysis

Table 4.4.1 presents rankings of the annual, two and three consecutive year inflows from 1946/47 to 1996/97. Extreme drought cases in the table agree with the years which suffered from the two significant droughts that occurred in 1987-88-89 and 1993-94-95.

The probability was computed using samples of the annual inflow for 56 years. Following EAU2000, the probability of non-exceedance 0.2 (F=0.2) was determined as standard of a dry year. The monthly variations and regional distributions of the inflow data sets for the years near F=0.2, which are 1960/61, 1973/74 and 1991/92, were examined as to whether they do not exhibit significant biases. As a result, 1960/1961 was judged to be typical, and was selected as a “typical dry year” for the Study.

The probabilities of two and three consecutive year inflows were also analyzed. The computed probabilities are compiled in **Table 4.4.1** and the following table presents frequency estimates 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 million m^3 of the inflow was estimated to occur once in 8.7 cycles in average. This implies that one cycle of 2-year inflow with this amount would occur once in 17 to 18 (8.7 x 2) years on average.

Frequency of Three Lowest 2 Consecutive Year* Inflows and Synthetic 2 Year Inflow

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
Synth.	1960/61 x 2 years	2088	0.115	8.7	17-18

Note : * : One cycle is two consecutive years without allowing overlap and discard of any years.

CHAPTER 5 IDENTIFICATION AND STUDY OF PROBLEMS/ ISSUES ON FLOOD CONTROL

5.1 Water Supply Operations

5.1.1 Background

(1) Objectives

The joint use of reservoir storage for water supply and flood control purposes creates a problem on storage allocation. Water supply operations require as much water as possible to minimize the risk of shortages during dry years. On the other hand, flood control operations require that water levels be reduced to store some or all of the inflow from a flood event. Such competitive uses can share the same storage space. However, seasonal water supply needs and risks of shortage must be clearly defined in order to determine the storage volume that can be allocated for flood control, and when it can be allocated.

The main objectives of the study on water supply operation are:

- To confirm the storage volume reserved for water supply at each reservoir,
- To confirm what water supply shortage risk criteria is used by MARH to regulate water levels, and
- To determine the amount of storage that can be used for flood control at each reservoir.

(2) Existing water supply operations

At present, the reservoir storage is kept as close as possible to the designed normal water level of most reservoirs. Reservoir operations are focused on storing as much water as possible to satisfy demands in case of sequential drought years.

Water demands for the coming agricultural season are submitted by various CRDA's to MARH every March. Potable water demands estimated by SONEDE are added to agricultural demand and compared to the volumes stored at each reservoir. Priority is given to meeting the potable water demands. MARH prepares a plan for allocation of resources for each reservoir and decides if demand restrictions in the agricultural sector are necessary. In the case of sequential dry years, demand restrictions can also be applied to potable water demands.

(3) Constraints to flood control operations

The following main constraints to flood control operations are all related to the fact that criteria for water supply operations are not well defined:

- There are no standard criteria for water supply security.
- There are no firm operating rules and no rule curves for water supply operations.
- The boundary between water supply and flood control storages is not well defined.
- Reservoir yield and associated failure risk for water supply is not defined.

(4) Previous studies

Attempts to develop operating rules and optimize the allocation of resources have been made in two previous studies: EAU 2000 and GEORE.

EAU 2000 published in 1993 included a complex analysis of reservoirs using stochastic dynamic programming (SDP) techniques to optimize the allocation of resources. The objective function of the analysis was to minimize the difference between demand and supply. The analysis produced monthly reservoir yields for two initial storage scenarios (50% full and empty) and three annual inflow conditions (typical dry year, average year, typical wet year) giving a total of six different possible yield scenarios. The documents made available for the Study do not clearly discuss or define the probabilities associated with each one of these yield scenarios. Furthermore, the analysis was only concerned with quantity and did not consider the need to balance salinity in the Cap Bon Canal. The results of the study, which have since become outdated, were never used by MAHR for water supply operations.

The GEORE project sponsored by GTZ in the late 80's created a computer based optimization model intended to be used as a tool to optimize reservoir operations for water supply. Unfortunately, since the model was complex and the data were intensive, MAHR was unable to utilize the model for technical and financial reasons. The model has since become outdated because it does not include many of the newly constructed and proposed dams.

A further review of EAU 2000 and EAU XXI indicates that these documents are planning documents for the future development of water resources. Future water demands are estimated and compared to potential surface water and groundwater resources. The limits for conventional water resources are identified and the need for the development of new non-conventional resources is identified e.g. desalination of brackish water or re-use of treated wastewater for agriculture. The studies do not provide plans or criteria for water supply operations.

(5) Study methodology

Reservoir storage volumes for water supply must be defined in order to proceed with the flood control analysis. Since essential information on water supply is not available from MARH, the Study has carried out a simple water balance calculation to estimate how much storage volume should be reserved for water supply at each reservoir.

The water balance is carried out for a regional system of 26 reservoirs (existing and future) that are linked together to supply potable and agricultural water demands. The water balance calculation is carried out for different drought scenarios.

The calculation identifies how much water must be stored at the beginning of the hydrological year (September) to meet water demands without deficits. Additional flood control storage is identified if the storage required for water demands is less than the full active storage.

5.1.2 Surface Water Resources

(1) Northern Tunisia Water Supply Scheme

The total annual rainfall is not sufficient to provide a stable year-round water source for agricultural crops and to satisfy other water demands. Therefore, a network of reservoirs and transfer schemes has been constructed in northern Tunisia to store rainwater and fill the gap between wet years and drought years. Many of the structures have already been completed while others are being constructed or planned in order to store as much of the surface water runoff as possible.

This water resources development and transfer scheme is referred to in this study as the Northern Tunisia Water Supply Scheme. It consists of two main branches:

i) The Mejerda River branch depicted schematically in **Figure 5.1.1** (with main supply reservoirs of Sidi Salem, Ben Metir, Kasseb) and
ii) The Sejnane-Joumine branch coming from the extreme north as depicted in **Figure 5.1.2** (with main supply reservoirs of Sejnane, Joumine and Sidi Barrak)

Each branch supplies water to the Cap Bon Canal which provides water to Greater Tunis and areas to the south (Cap Bon, Sfax, Sahel, and Kairouan). Since the Cap Bon Canal is supplied by two branches, the whole of scheme must be considered when evaluating storage allocation for water supply and flood control at reservoirs in the Mejerda River basin.

Water is transferred into the Mejerda River basin from the Barbara basin (Zouitina and Melilla Dams) upstream of the Bou Heurtma Reservoir. At the lower end of the catchment, the Mejerda River is partially diverted into the Mejerda-Cap Bon Canal to meet water needs in arid regions to the south. The river is diverted by a control structure located at Laroussia.

(2) Reservoir yields and timeframes for implementation

Reservoir yields and timeframes for implementation provided by DGBGTH are presented in **Table 5.1.1**.

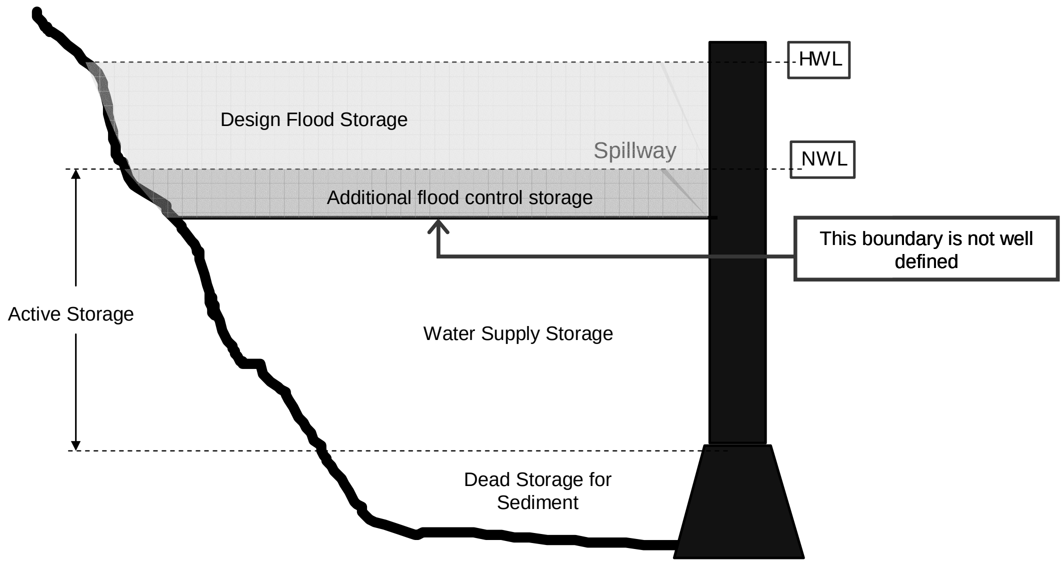
There is no information on how the yields are calculated and MARH does not have a record of the yield-probability curves usually developed during engineering studies for estimating reservoir capacity. Therefore, it is not possible to evaluate yields for various shortage risks. The 80% level of water supply security quoted by MARH, as shown in **Table 5.1.1**, is consistent with those normally found for irrigation schemes in developing countries.

(3) Reservoir characteristics

A total of eight reservoirs (Mellegue, Ben Metir, Lakhmes, Kasseb, Bou Heurtma, Sidi Salem, Siliana, R'Mil) are in operation in the Mejerda River basin providing an average of 576 million m^3/year or 59% of the total resources mobilized by dams in northern Tunisia. An additional 80 million m^3 per year can be transferred into the basin from the Barbara complex.

The main reservoir characteristic which is of interest to water supply operations is the active storage volume. An active storage is located between the normal water level and the top of dead storage.

Dead or inactive storage is the volume reserved for the storage of sediment. As a rule the reservoir may not be drawn down below the top of the dead storage. The active storage volume decreases in time as the reservoir is filled with sediment.



Typical Storage Allocation

The calculation of active storage for 27 dams in northern Tunisia is presented in **Table 5.1.2**.

5.1.3 Water Demands

(1) Total Water Demand

The reservoir system must satisfy the following monthly demands.

Water Demand Applied to the Reservoir System

(Unit 10^6 m^3)

Demand 2010	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**Total**
Agriculture	51.2	27.2	15.9	0.9	0.4	7.7	36.2	67.3	123.	88.0	101.	96.2	616.1
Potable Water	28.3	28.0	25.5	23.0	22.4	18.0	22.1	22.4	25.5	27.4	34.2	34.2	311.1
Environmental	0.0	0.0	6.0	6.0	6.0	6.0	6.0	0.0	0.0	0.0	0.0	0.0	30.0
Total	79.5	55.2	47.4	29.9	28.8	31.8	64.3	89.7	149.	115.	135.	130.	957.1
Demand 2020	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**Total**
Agriculture	54.4	29.4	17.1	0.8	0.4	8.3	39.8	74.2	135.	93.8	107.	100.	661.4
Potable Water	37.2	36.8	33.6	30.3	29.5	23.7	29.1	29.5	33.6	36.0	45.0	45.0	409.3
Environmental	0.0	0.0	6.0	6.0	6.0	6.0	6.0	0.0	0.0	0.0	0.0	0.0	30.0
Total	91.6	66.2	56.6	37.1	35.8	38.1	74.8	103.	168.	129.	152.	145.	1100.7
Demand 2030	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**Total**
Agriculture	51.1	27.6	16.0	0.8	0.6	9.3	39.7	72.1	129.	92.2	106.	96.9	641.6
Potable Water	46.2	45.7	41.6	37.5	36.5	29.4	36.0	36.5	41.6	44.6	55.8	55.8	507.4
Environmental	0.0	0.0	6.0	6.0	6.0	6.0	6.0	0.0	0.0	0.0	0.0	0.0	30.0
Total	97.3	73.3	63.7	44.3	43.1	44.7	81.7	108.	170.	136.	162.	152.	1179.0

Source: the Study Team

The total water demand will increase at an average growth rate of 1% from 957 Mm^3/year in 2010 to 1,179Mm^3/year in 2030

At present more water resources are allocated to irrigation than to potable water demand (32% for potable water in 2010). Strong growth will quickly close the gap and by 2030, potable water demand will require a significantly larger share of the resources (43%). The increase in potable water demand, which is more prioritized, will put more pressure on reservoir operations making it increasingly difficult to provide resources to agriculture during long periods of drought.

(2) Salinity Thresholds

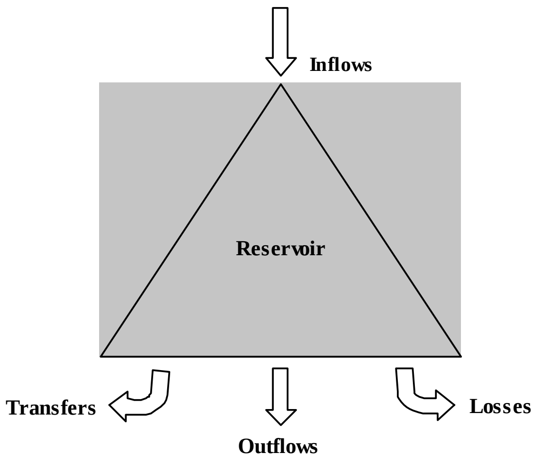
Each demand center has a different salinity threshold depending on the type of use. Upper limits for salinity determined by MARH are presented in **Table 5.1.3**. Salinity in the Cap Bon Canal is controlled by SECADENORD by mixing a large amount of freshwater from the extreme north at Bejaoua to dilute the saline water from Laroussia. The target salinity in the canal is normally maintained between 1.0 g/l and 1.5 g/l with preference given to the lower limit when resources are plentiful.

5.1.4 Reservoir Water Balance

(1) Calculation model

Storage requirements at each reservoir are computed using a simplified water balance calculation, automated on a spreadsheet model. The calculation is based on a hydrological mass balance at each reservoir accounting for all inflows, less all outflows and losses at each reservoir. Reservoirs are linked together and the outflow from upstream reservoirs is collected at the next downstream reservoir. Storage at the end of each time period is computed from:

$$S_i = S_{i-1} + I_i + Tr_{in} - Tr_{out} - R_i - W_i - L_i - E_i - DS_i$$



Water Balance Model

Where:

S_{i-1} is the storage at the end of the previous time period (initial storage for the first time period)

I_i is the natural inflow for time period i
Tr_{in} is the amount arriving by pipeline from upstream reservoirs for time period i
Tr_{out} is the amount withdrawn by pipeline from the reservoir for time period i
R_i is the release for downstream demands for time period i
W_i is the withdrawal for local water demands for time period i
L_i is the infiltration loss for time period i
E_i is the evaporation loss (less rainfall) in time period i
DS_i is the amount released for desilting in time period i

(2) Calculation procedure

The time step is one month. The storage at the end of the time period (S_i) is compared with the maximum reservoir storage (S_{max}). If S_i is greater than S_{max} then the storage is set to a maximum,

$$S_i = S_{max}$$

and the Spill is computed as

$$S_{pi} = S_{max} – S_i$$

The release is also updated to include the spill,

$$R_i = R_i + S_{pi}$$

If the storage is less than the dead storage then the storage is set to the dead storage,

$$S_i = S_{min}$$

and the deficit is computed as

$$D_i = (S_{min} – S_i)$$

The water balance calculation is used to identify how much water must be stored at each reservoir to satisfy water demands in the coming year. The volumes determined in this way are called “target storage” volumes. The water balance computation is for all reservoirs and all demand centers included in the regional system.

The calculation begins in September to coincide with the start of the hydrological year. September is also a convenient starting point since it provides target storage volumes prior to the critical flood control months of Dec-Jan-Feb-Mar-Apr.

The initial storage volume S_i at each dam is set to 100% of the active volume for the first iteration.

The calculation is done monthly using drought inflow series representing different drought scenarios

If all demands are met then the calculation is repeated with a smaller value of initial storage. This procedure is repeated to find the initial storage volume in September that will satisfy demands without depleting the reservoir completely. Where possible, a 20% buffer is maintained as an emergency reserve.

(3) Inflows

Initially five drought scenarios were considered for the preliminary water balance:

Drought Scenarios Initially Considered

Drought scenarios			Total Inflow* Mm^3	Total as % of average**	Type
1:	1 year	1960	1,044	55%	Dry
2:	2 year	synthetic	2,088	55%	Dry
3:	2 year	Historic 1987-88	1,582	41%	Very dry
4:	3 year	synthetic	3,132	55%	Dry
5:	3 year	Historic 1992-94	22,04.5	38%	Very dry

* inflow to 27 dams in Northern Tunisia **average inflow from 1946-1997=1912Mm^3/year
Source: the Study Team

MARH defines hydrological drought as follows:

- a year is “dry” when inflows are less than 70% of the average
- a year is ”very dry” when inflows are less than 50% of the average

The average inflow to the system for the period of record (1946-97) is 1,912Mm^3 per year.

Year 1960/61 was selected as the typical dry year because it has a frequency of 1 in 5 years (T=0.2). This frequency is selected to be consistent with the “typical dry year” defined in the EAU 2000 study.

The historical droughts are quite severe. Preliminary analysis indicates that most reservoirs would need to be 100% at the start of the agricultural season in order to meet the demands. In addition, demand restrictions need to be implemented in the second and third year to prevent complete water depletion in the reservoir. This is confirmed by demand restrictions actually applied by MARH during these historical drought events (Guide de la Secheresse Dec 1999).

After discussion with MARH it was decided to retain the following three scenarios for the water balance calculation.

Drought Scenarios Selected for Water Balance

Drought scenarios			Recurrence interval
1:	1 year	typical	1/5
2:	2 year	synthetic	1/9*
3:	3 year	synthetic	1/11**

Notes: * One cycle is 2 years. ** One cycle is 3 years.
Source: the Study Team

The Ministry also requested a separate analysis of the two-year drought with a 20% demand restrictions applied to irrigation in the second year.

5.1.5 Storage Allocation

The water balance calculation has identified that the Northern Tunisia Water Supply Scheme will experience deficits during two and three-year drought events. These deficits are summarized in the following Table.

Comparison of Storage Deficits for Selected Drought Scenarios

Drought scenario	Demand Restriction	Year	Deficits Northern Tunisia (Mm^3/year)**		
			2010	2020	2030
1 year	none	1	0	0	0
2 year	none	1	0	0	0
	20% agriculture	2	6.0	19.1	68.6
2 year	none	1	0	0	0
	none	2	6.7	21.1	75.2
3 year	none	1	0	0	0
	none	2	6.7	11.4	62.4
	none	3	84.5	267.1	377.8

** 27 dams in the Northern Tunisia Water Supply Scheme
Source: the Study Team

For the two-year drought, the deficits are localized and limited to the following reservoirs where the local agricultural demand exceeds the capacity of the reservoir:

- Mellegue II
- Lakhmes, Siliana and R'Mil

It is therefore possible to allocate additional storage for flood control at other dams without affecting the water supply in other parts of the system for a typical two-year drought.

Meanwhile, the three-year drought cannot be managed unless significant system wide demand restrictions are applied to potable water and agricultural irrigation. Under this scenario, the reservoirs at most dams in the system would need to be kept as full as possible at the beginning of September in order to minimize water shortages. Therefore additional flood control storage is not advisable.

Storage allocation and additional flood control volumes are identified through this water balance analysis for dams in the Mejerda River basin. Additional flood control storage is defined as the volume between designed normal water level and the top of water supply storage.

Seven dams in the Mejerda River basin have been selected for flood control analysis based on their storage capacities and catchment areas. These are: the Bou Heurtma, Mellegue, Mellegue II, Sidi Salem, Sarrath, Siliana, and Tessa Dams, as discussed in **5.3**. The total additional flood control storage provided for the seven dams by each scenario is presented below.

Comparison of Flood Control Storage for Drought Scenarios

Drought scenario	Demand restrictions	Additional flood control storage (Mm^3)**		
		2010	2020	2030
1 year	none	321	299	215
2 year	20% agriculture year 2	169	104	69
2 year	None	168	99	33
3 year	None	78	<10	<10

** for 7 dams in Mejerda Basin with significant flood control potential, Source: the Study Team

The space available for flood control decreases with time because the demand for water is increasing, while the active storage at each reservoir decreases as a result of sedimentation.

Demand restrictions provide a relatively small increase in flood control storage, however the negative impact on agriculture is likely to be significant.

5.2 Flood Damage and Existing Measures

5.2.1 Flood Damage in Past Significant Floods

(1) Flood prone areas

The flood prone areas suffering from habitual flooding are located mainly in the low undulated plains along the mainstream of the Mejerda River. Through the field reconnaissance and interviews with the governmental agencies concerned, it was revealed that Jendouba, the Mellegue confluence, Bou Salem, Sidi Smail, Slouguia, Medjez El Bab, El Herri, Tebourba, El Battan, Jedeida, El Henna, the Chafrou confluence and El Mabtou have become flood prone towns/areas, which were seriously damaged by the past significant floods such as those that occurred in May 1973 and January to February 2003.

(2) Results of flood inundation and damage survey

(a) Objective and target respondents

In order to grasp the recent conditions of flood damage and inundation occurrence, the "Flood Inundation and Damage Survey" was carried out from December 2006 to March 2007. The survey was delegated to Eco Ressources Inc., one of the Tunisian consulting firms. Using interview sheets designed for farmers, residents, shops and industries, verbal interview through direct visits was conducted to a total 300 respondents. The questionnaire sheets consist of four sections, i.e. I: General Information, II: Flood Damage, III: Experience of Inundation and Lessons, IV: Evacuation and Early Warning. Through the survey, valuable information was collected which can be referred to for the master plan formulation. The number of respondents according to target municipalities is tabulated below:

Number of Target Respondents for Flood Inundation and Damage Survey

	Name of City	Code	Governorate	Number of Respondents				
				Total	Farmers	Residents	Shops	Industries
1	Nebeur	NB	Le Kef	**15**	4	11	0	0
2	Jendouba	JN	Jendouba	**40**	19	16	4	1
3	Bou Salem	BS	Jendouba	**40**	10	20	8	2
4	Sidi Ismail	SI	Beja	**10**	10	0	0	0
5	Zone Amont SS	ZA	Beja	**5**	5	0	0	0
6	Testour	TS	Beja	**20**	20	0	0	0
7	Slouguia	SL	Beja	**30**	30	0	0	0
8	Mejez El Bab	MB	Beja	**40**	7	20	7	6
9	Mouatisse- El Herri	EH	Beja	**20**	20	0	0	0
10	Tebourba	TB	Manouba	**20**	9	8	2	1
11	Jedeida	JD	Manouba	**20**	10	9	1	0
12	El Battane	EB	Manouba	**20**	15	5	0	0
13	Chaouat - Sidi Thabet	CS	Manouba - Ariana	**20**	20	0	0	0
	Total			**300**	**179**	**89**	**22**	**10**

(b) Serious floods

The most serious flood events were asked from each respondent. In the upstream area such as Jendouba, people most commonly responded that the serious flood was in 1973 and 2000. On the other hand, downstream of Bou Salem, except Slouguia, respondents from all municipalities replied that the 2003 Flood was the most severe. As discussed earlier, the flood events in 1973 and 2003 were extraordinary events in terms of rainfall amount and runoff volume from the catchment.

Most Serious Floods Experienced

Farmers

No.	Code	Answers as most severe flood			Total
		1973	2000	2003	
1	NB	0	1	3	4
2	JN	9	9	1	19
3	BS	3	0	7	10
4	SI	0	0	10	10
5	ZA	0	0	5	5
6	TS	4	0	16	20
7	SL	21	0	9	30
8	MB	3	0	4	7
9	EH	3	0	17	20
10	TB	5	0	4	9
11	JD	6	0	4	10
12	EB	10	0	5	15
13	CS	6	0	14	20
Total		70	10	99	179
		39%	6%	55%	100%

Residents

No.	Code	Answers as most severe flood			Total
		1973	2000	2003	
1	NB	0	0	11	11
2	JN	8	7	1	16
3	BS	2	0	18	20
4	SI	-	-	-	0
5	ZA	-	-	-	0
6	TS	-	-	-	0
7	SL	-	-	-	0
8	MB	7	0	13	20
9	EH	-	-	-	0
10	TB	3	0	5	8
11	JD	1	0	8	9
12	EB	1	0	4	5
13	CS	-	-	-	0
Total		22	7	60	89
		25%	8%	67%	100%

Shops

No.	Code	Answers as most severe flood			Total
		1973	2000	2003	
2	JN	0	2	2	4
3	BS	0	0	8	8
8	MB	0	0	7	7
10	TB	0	0	2	2
11	JD	0	0	1	1
Total		0	2	20	22

Industries

No.	Code	Answers as most severe flood			Total
		1973	2000	2003	
2	JN	0	1	0	1
3	BS	0	0	2	2
8	MB	0	0	6	6
10	TB	0	0	1	1
Total		0	1	9	10

(c) Lessons learned and flood protection measures

More than 70 % of the respondents have expressed their negative views towards efforts of self-capacity based on experiences of the last destructive flood. In connection with this issue, most of the people revealed their worries over the threat of loss and damage due to possible future occurrence of the same magnitude of flood, and impact to their properties. It can be confirmed through their comments in the lessons learned.

The answers to the question related the existence of flood management structures (dike and canal, etc.) in the nearby location revealed that 70 to 90 % respondents have not noticed them at all. Furthermore, regarding the question related to the most important flood protection measures, 80% to 90% responded with "construction of structure measures" and "early warning system". Very few replied "proper instruction", "supporting staff" and "evacuation assistance" is ideal. It is evident that prominent replies vary according to municipalities, noted as follows:

Relationship between Required Flood Protection Measures and Municipalities

Most important flood protection measure (among five categories)	Municipalities who replied as the most important flood protection measure
Construction of structural measures	Nebeur, Bou Salem, Mejez El Bab, El Herri
Installation of early warning system	Jendouba, Sidi Ismail, Testour, Slouguia, Tebourba, Jedeida, El Battane

Source: the Study Team

5.2.2 Existing Flood Control Measures

The existing flood control measures in the Mejerda River basin are mainly dams and reservoirs, since the magnitude of floods in terms of peak discharge and runoff volume is quite high. In fact, the Mellegue and Sidi Salem Dams' essential function is to mitigate flood risks in their downstream areas. Therefore at present, a diking system with river improvement has been done only at minimal level and limited in some short stretches of the basin.

Aside from the large scale dams, a movable weir at Hir Tobias has a vital role of controlling discharge in the lower Mejerda and floodway to the sea. This floodway was completed in the 1950s, and the movable weir in the 1990s. After the construction of the movable weir, the original channel of the Mejerda River was disconnected from the presently recognized Mejerda River, and converted to an irrigation canal covered by concrete revetments, reducing its width.

5.3 Reservoir Operation

5.3.1 Present State of Dams and Reservoirs in the Mejerda River Basin

Currently eight dams are in operation in the Mejerda River basin, excluding the Laroussia Weir which is the only high weir intercepting the Mejerda River water for the Cap Bon canal and the Mejerda canal. In addition, there are presently six dams in the basin which are either under construction or still in the design/planning stages. Therefore, a total of 14 dams are taken into account in the flood control analysis, as summarized below.

Reservoirs in Mejerda River Basin

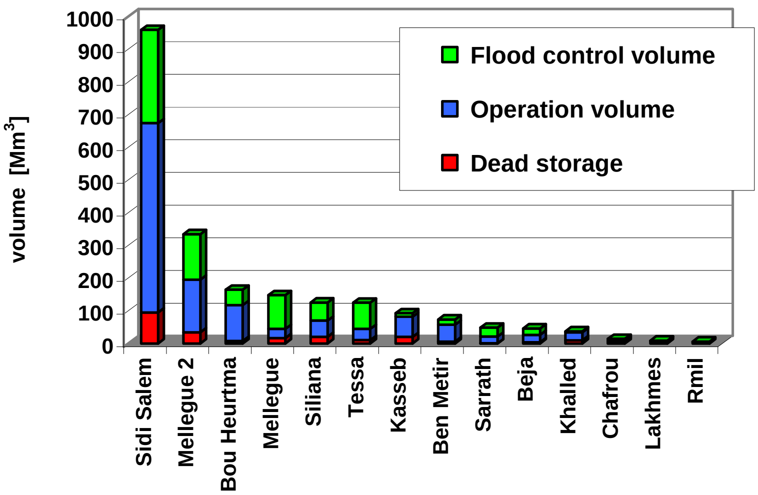
Name of dam	Catchment area (km^2)	Normal water level		Maximum high water level		
		Elevation (m)	Actual TOTAL capacity (Mm^3)	Elevation PHE (m)	TOTAL Volume at PHE (Mm^3)	Flood control volume (Mm^3)
Sidi Salem*	18,191	115.00	674.0	119.50	959.5	285.5
Mellegue 2	10,100	295.00	195.0	304.00	334.0	139.0
Bou Heurtma*	390	221.00	117.5	226.00	164.0	46.5
Mellegue*	10,309	260.00	44.4	269.00	147.5	103.1
Siliana*	1,040	388.50	70.0	395.50	125.1	55.1
Tessa	1,420	361.00	44.4	369.00	125.0	80.6
Kasseb*	101	292.00	81.9	294.40	92.6	10.7
Ben Metir*	103	435.10	57.2	440.00	73.4	16.2
Sarrath	1,850	546.00	21.0	552.00	48.5	27.6
Beja	72	230.00	26.4	234.00	46.0	19.6
Khalled	303	207.00	34.0	213.60	37.0	3.0
Chafrou	217	49.00	7.0	51.00	14.0	7.0
Lakhmes*	127	517.00	7.2	521.20	8.4	1.2
Rmil*	232	285.00	4.0	288.00	6.0	2.0

Notes: * existing, Source: MARH,

The above table compiles the designed reservoir normal water levels and corresponding total reservoir storage volumes, designed maximum water levels and flood control storage volumes. Most of the designed flood control storages (729 M m^3 equivalent to 91.4 %) is secured in the reservoirs upstream of the Sidi Salem Dam.

5.3.2 Ability of Reservoirs for Effective Flood Control

The volume of each reservoir, as well as the division of its volume into dead storage volume (not usable for any purpose), operation volume for water supply and flood control volume, is presented below.



Storage Volumes of Reservoirs in Mejerda River Basin

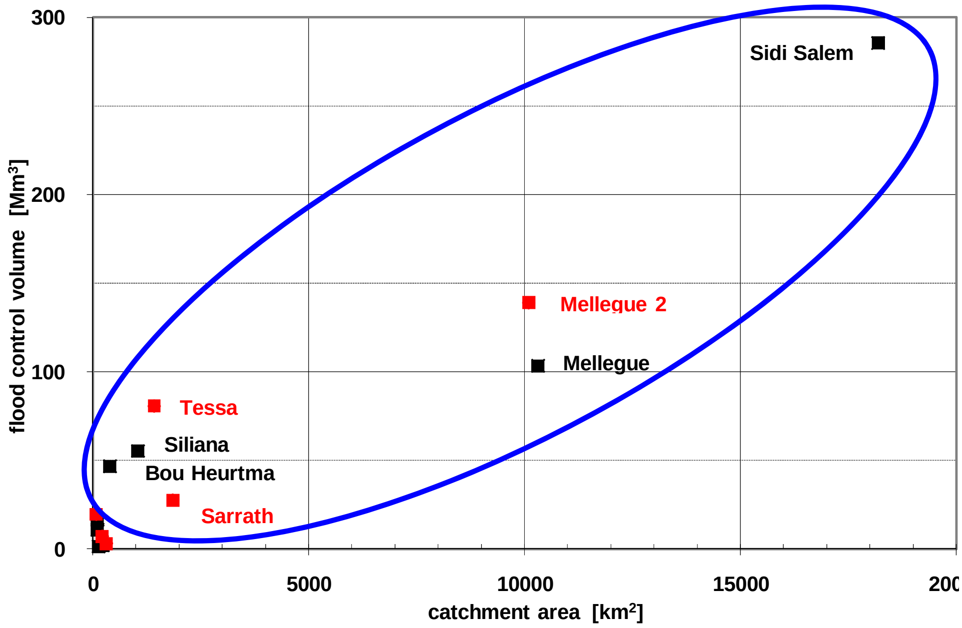
The biggest reservoir in the Mejerda River basin is the Sidi Salem Reservoir with a total volume of 960 M. m^3 at the maximum water level. Considering its designed flood control storage of 286 M. m^3, the reservoir is also deemed most important from the viewpoint of flood control.

(1) Selection of important reservoirs for effective flood control

As the sizes and purposes of the reservoirs in the Mejerda River basin differ significantly, the efficiency of their flood control function was assessed based on the following aspects related to flood control:

- Volume of reservoir storage for flood control,
- Catchment area upstream of reservoir, and
- Dam structures (a spillway equipped with gates, bottom outlets, etc.) for effective flood control

Considering these aspects, all reservoirs in the Mejerda River basin were plotted in a chart shown below. The most important reservoirs from the viewpoint of flood control are situated in the upper-right corner in the chart.



Flood control storages of reservoirs in Mejerda River catchment

According to the above diagram, seven reservoirs have been selected for further analysis and evaluation of their operation during floods. These include four existing reservoirs namely, Sidi Salem, Mellegue, Bou Heurtma and Siliana; and three reservoirs either under planning or construction namely, Mellegue 2, Tessa and Sarrath. The total flood control storages of these seven reservoirs represent roughly 91 to 95 % of the total flood control storage of all the reservoirs in Mejerda River basin, considering the reservoir development of up to the target year of 2030.

(2) Actual operation of reservoirs during floods

Upon reviewing the historical operation records of dams, it was noted that the past maximum water levels at most of the existing dams have never reached the designed highest water level. It means that the designed flood control storages have not been fully utilized even during the past serious floods (for example, the 2003 flood).

According to the operation records, only 13 % of the designed flood control storage of the Siliana Reservoir was used for flood control purpose in December 2003. Moreover, roughly 18 % of the designed flood control storage of the Bou Heurtma Reservoir was utilized in January 2003. Both dams are provided with an uncontrolled spillway for a flood control purposes only. At the Sidi Salem Dam, there are two spillways provided: the main spillway with three gates that controls floods while the second is the uncontrolled type (morning glory type). In January 2003 a relatively large amount (55%) of the flood control storage was used.

On the other hand, only a controlled spillway is provided for the Mellegue Dam and hence, outflows from the dam (spillway, bottom outlet, etc.) can be effectively controlled during floods. Almost all designed flood control storage (98.6 Mm3 = 96 % of designed flood control storage) was used for successfully reducing the peak discharge in December

2003.

Based on above discussions, it can be realized that roughly one half (at least) of the total designed flood storages in the Mejerda River basin is expected to be used for flood control operation, although it still depends on the magnitude of flood, spatial and temporal flood distributions and other factors.

5.4 River Channel Management

5.4.1 Morphological Processes and River Maintenance

The Mejerda River and its tributaries are typical alluvial rivers subjected to large amounts of sediment. Active morphological processes (bank erosion, river bank failure, large deposits of sediment, etc.) are typical especially in the upper and middle river reaches (see the following photo). The bulk of sediment material comes from the areas belonging to the Eastern Atlas mountain ridge, thus, is brought about into the Mejerda River from the right side tributaries, mainly from the Mellegue and the Tessa Rivers.

River bank failure and sedimentation near Testour

Construction of dams in the Mejerda River basin, especially the Sidi Salem Dam in the year 1981, has significantly influenced flood flow regime and maximum values of discharge during floods in the downstream reaches. As an example, the maximum discharge from the Sidi Salem Dam in 2003 was 750 m^3/s, while in 1973 when the dam has not existed, the discharge reached 3,500 m^3/s in the middle reaches of the Mejerda River. It is evident that the discharge capacity of the river channel has significantly reduced, and thus, the evolution of flooding risk changes with the aggradation of the riverbed.

Throughout the studied river stretches located between the Sidi Salem Dam and the Laroussia Weir, cross sections have considerably changed within seven years between 1996 and 2003. From the Sidi Salem Dam to the meander area in Matisse, it is noted that the increasing sediment loads in river channels resulted in serious aggradation of riverbed over seven years. This phenomenon may be attributed partly to the operation of the Sidi Salem Dam, resulting in the decrease of discharge and flood peaks in the downstream rivers, causing sediment deposition.

Under the decreased long-term average flow velocities due to dam construction, an intensive agriculture (bringing fertilizers and other nutrients into the rivers) has led to enormous growth of vegetation (in particular, "Tamarix") in the river channel and also directly in the river bed as shown in the following photo. The photo also shows that no appropriate maintenance works are carried out for the river channels.

Vegetation in river course – Bou Heurtma River (Bou Salem)

5.4.2 Decreased Discharge Capacity of River Channel

Deposition of sediment material, due to frequent discharges of small flows, results in substantial decrease of cross-sectional flow area and consequent reduction of discharge capacity of river channels, as mentioned earlier.

In addition, the total cross-sectional flow area at river crossing structures, such as a bridge, is usually smaller, compared to those in other reaches. In other words, such bridge is usually a flow obstacle, causing increase of water level up to several kilometers long upstream. As an example, it is mentioned that the bridge in El Battan and the Andalous bridge in Mejez El Bab (see the next photo) have affected the flow characteristics due mainly to the provision of considerable number of piers. Decreased cross sectional flow area generates more frequent catastrophic overflow during floods.

Historical Andalous bridge in Mejez El Bab

5.5 Basin Preservation

5.5.1 Problems with Basin Preservation

Surface soil erosion resulting from land destruction due to agricultural and grazing activities has caused not only long-term declination of crop productivity but also detrimental reservoir sedimentation, in parallel with progression of natural resources degradation in Tunisia. Therefore, it is pressing to prepare a new national strategy for the sectors related to natural resources management, such as “effective water resources use”, “forest and pasture lands” and “water and land conservation”, during the period of 2002 to 2011 as part of the Tenth and Eleventh National Development Plans.

Under such situation, the following are pointed out in the Mejerda River basin.

(1) In the northwestern region, where Jendouba and Beja Governorates are located, excessive deforestation resulting from land reclamation for the expansion of farming,

forest grazing and indiscriminate logging of trees through carbonization for domestic use and illegal business has aggravated surface soil erosion and destruction of vegetation.

(2) In the southern areas of Le Kef and Siliana Governorates, mechanized large-scale farmlands and small-scale lands cultivated by peasants coexist. Moreover, most of the peasants have cultivated cereals by leasing small lands on the steep slope of clayey soil. The cultivated slope lands become vulnerable to erosion during rains, eventually causing serious gully erosion.

5.5.2 Sediment Yield in the Basin

In order to quantitatively grasp the current progression of erosion in the Mejerda River basin, the sediment yields in several sub-basins are examined based on reservoir sediment data at seven dams reported in “Le Transport Solide des Oueds en Tunisie, Apr 2001”. These dams are the Sidi Salem, Mellegue, Bou Heurtma, Ben Metir, Kasseb, Lakhmes, and Siliana Dams, which have data on sediment volumes regularly surveyed in the reservoirs. Their locations are shown in **Figure 5.5.1**.

The computation results of sediment yield (as a denudation rate) in the sub-basins at the seven dams are compiled in **Table 5.5.1** and summarized below:

	Dam	Catchment area (km^2)	Denudation rate (mm/yr)
1	Sidi Salem	18,191	0.2
2	Mellegue	10,309	0.2
3	Bou Heurtma	390	0.2
5	Ben Metir	103	0.8
6	Kasseb	101	1.0
7	Lekhmes	127	0.2
8	Siliana	1,040	0.4

Source: the Study Team

5.5.3 Correlation between Sediment Yield and Basin Conditions

The correlation between the sediment yield and basin conditions is examined by selecting three conditions of the basin, such as distribution of land surface slope, land use and riverbank erosion, since such data are readily available in the Study.

It is noted however that the drainage basins of the Sidi Salem and Mellegue Dams are excluded from said correlation study since their catchment areas are relatively huge, which might be unsuitable for realization of the basin conditions.

(1) Sediment yield and land surface slope

The distribution of land surface slope in the sub-basins of five dams based on GIS data is as shown in the figures at the right. From the first and second figures the following are found.

(a) The features in distribution of land surface slope in the basins of three dams, namely the Bou Heurtma, Ben Metir

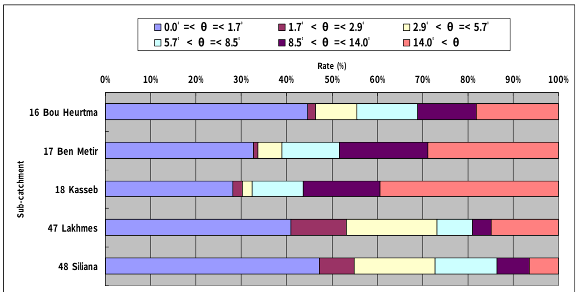


Figure-4-7 Rate of Ground Serface Slopes in 5 Sub-catchments

Source: the Study Team

and the Kasseb Dams located in the north of the Mejerda River, are different from those in the basins of two dams of Lakhmes and Silian Dams in the south of the Mejerda River. Thus, the basins in the north reveals a trend of higher percentage of steep slope land, while that for the southern basins exhibit more of moderate slope land.

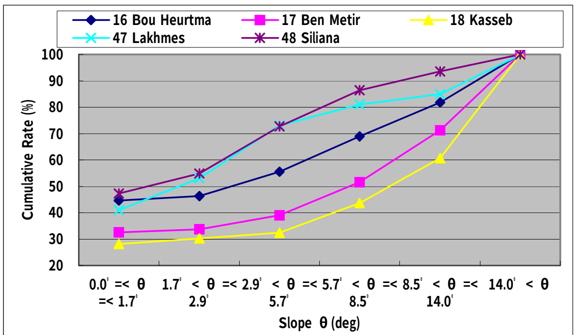


Figure -4-8 Cumulative Rate of Ground Serface Slopes

Source: the Study Team

(b) The next figure presents the relation of the denudation rates with percentages of lands having slopes of less than 1.7°and more than 14.0°. The figure reveals a trend that the higher the percentage of lands with slopes of less than 1.7°, the smaller the denudation rate. On the contrary the higher the percentage of lands with slopes of more than 14.0°, the higher the denudation rate, indicating that the denudation rate tends to be higher for basins having a higher percentage of steep slope lands.

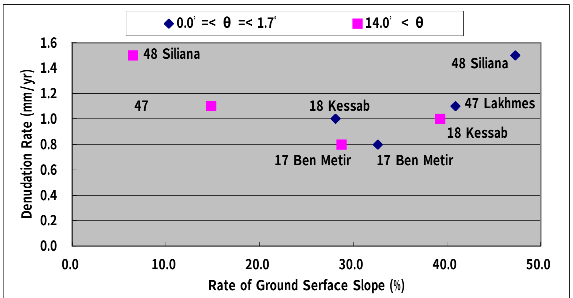


Figure -4-9 Relationship between Rate of Ground Serface Slopes and Denudation

Source: the Study Team

(2) Sediment yield and land use

The next figure shows the distribution ratios of land use which is classified into four categories namely, forest land, agricultural land, naked land and urbanized area. As illustrated in the figure, ninety five percent of the drainage basin is occupied at each dam by forest and agricultural lands. The areas of forest and agricultural land with surface slopes of less than 1.7° and more than 14.0° are shown in the next figure, which manifests the following:

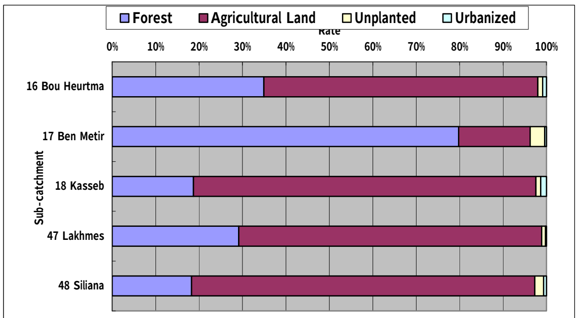


Figure-4-10 Rates of Land Use in 5 Sub-catchments

Source: the Study Team

(a) Comparing the basins of the Ben Metir and Kasseb Dams in the north of the Mejerda River, the latter basin has more agricultural lands in the "14.0° < θ" areas than those of the former. Moreover, the basin of Kasseb Dam has a denudation rate of 1.0 mm/y which is higher than that of Ben Metir Dam with 0.8 mm/y. Furthermore, in comparison of the denudation rates of 0.2 mm/y and 0.4 m/y

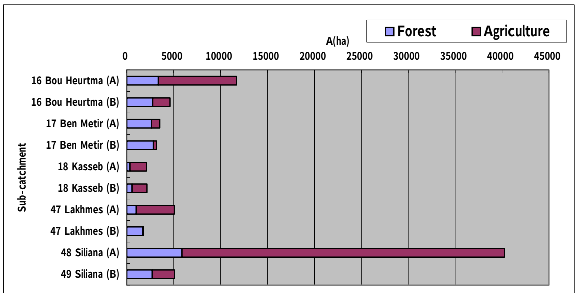


Figure-4-11 Areas of Forest and Agriculure Land in 5 Sub-catchments

Note A : Slope 0.0'=< θ =<1.7'
B : Slope 14.0'< θ

Source: the Study Team

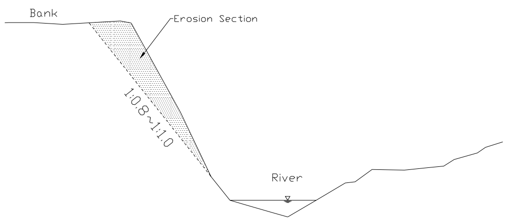
in the basins of the Lakhmes and Siliana Dams respectively, the basin with a higher percentage of agricultural lands in the "14.0° < θ" areas has a higher denudation rate. The findings suggest that some measures for erosion control should be considered in cases where steep slope lands are used as agricultural land.

(b) Although most of the Ben Metir Dam basin is occupied by forest lands, the basin has a higher denudation rate of 0.8 mm/y, as compared to 0.2 mm/y for the Bou Heurtma Dam basin whose wide areas are used as agricultural land. This suggests that some measures for erosion control should be considered even in the case of forest land, if the low layer vegetation expanding on and near the ground is poor.

(c) In case of the basins of the Lakhmes and Siliana Dams, both are mostly occupied by agricultural lands in the "θ < 1.7 °" areas. However, the Siliana Dam basin in which agricultural lands widely expand in the "θ < 1.7 °" areas has a higher denudation rate of 0.4 mm/y than 0.2 mm/y for the Lakhmes Dam basin. Hence, it is considered that some measures should be taken as well for erosion control in the case of the agricultural lands in moderate slope areas.

(3) Impact of riverbank failure/erosion on sediment yield

The riverbank failure and erosion particularly during floods also affects the sediment yield to some extent. In the field reconnaissance of the Majerda River basin, it was found through ocular inspection that in most stretches of the Majerda mainstream and its tributaries, the riverbank materials are clayey and silty soil. Hence, the estimation of sediment volume due to the riverbank failure/erosion is made by applying 1:08 to 1:1.0 as a stable slope of the riverbank. In other words, the amount of sediment produced in the river is computed on the assumption that the portions above the stable slope fail and/or are eroded, as illustrated in the right side figure.



On the above assumption, the total sediment volume produced in the river is computed at 0.314 Mm^3 (= 0.19 mil. m^3 from the main stream + 0.124 mil. m^3 from major seven tributaries). Said sediment volume is compared to the reservoir sediment at the Sidi Salem Dam, as tabulated below:

Time of reservoir sediment survey at Sidi Salem Dam	June 1987	Aug. 1989	Mar. 1991	Oct. 1998
Sediment volume in Sidi Salem reservoir (mil. m^3)	30.6	47.0	52.0	87.5
Period of sedimentation at Sidi Salem reservoir: A (yrs)	6.0	8.0	10.0	17.0
Annual sediment volume at Sidi Salem reservoir: B (Mm^3/yr)	5.1	5.9	5.2	5.1
Annual sediment volume from riverbank (Mm^3/yr) (C)*	0.052	0.039	0.031	0.018
Ratio (= C/B×100) (%)	1.0	0.7	0.6	0.4

Note: C = 0.314 (Mm^3)/A (years), Source: the Study Team

The ratio (=C/B) in the above table shows the percentage of sediment due to the riverbank failure/erosion to the sediment trapped in the Sidi Salem reservoir, on the assumption that the total sediment of 0.314 Mm^3 from the riverbank is produced in each period (A years).

As also shown in the table, the ratios are as small as less than 1 %, which means that the impact of the sediment due to the riverbank failure/erosion on sedimentation in the Sidi Salem Reservoir is rather small. Therefore, the measures are considered to be more important to minimize the sediment yield due to rain erosion in the basin.

5.5.4 Erosion Control for Basin Preservation

In due consideration of the following findings obtained through the above-mentioned sediment yield analysis in the drainage basins at several dams, some measures are to be taken for the lands classified as forest and agricultural land in order to control land surface erosion, aiming at basin preservation.

(1) The higher percentage of lands with steep slopes in the basin, the higher is its denudation rate.

(2) There is a need to properly take some measures for erosion control in the following land uses:

- Agricultural lands with steep and even moderate slopes,
- Forest lands wherein the low layer vegetation extending on and near the ground is poor.

5.6 Flood Forecasting and Warning

5.6.1 General

In terms of the flood forecasting and warning system (FFWS) in the Mejerda River basin, an installation of telemetry system has been developed through the technical and financial assistance of AFD (l'Agence Française de Développement)[1] in the program of PISEAU (Projet d'Investissement dans le Secteur de l'Eau)[2] since this basin seriously suffered from large floods in 2002/2003.

Installation of the new telemetry system was completed at 75 gauging stations in the whole Tunisia in August 2007. Said telemetry system has already commenced experimental operation. Out of the 75 stations, 56 exist in the Mejerda River basin.

The flow chart of coordination and reporting of FFWS is shown in **Figure 5.6.1**. The major agencies concerned to flood forecasting are DGRE, DGBGTH, IRESA and CRDAs, which are organized under the authority of MARH. Also, the major agencies concerned to the warning system are governorate offices, Civil Protection, National Security, National Guard, Police and their regional offices at the governorate level, which are under the authority of the Ministry of Interior.

[1] French Development Agency
[2] Water Sector Investment Project

5.6.2 Current State and Issues Identified

The present FFWS in the Mejerda River basin is largely divided into four sub-levels namely, observation, data transmission, analysis and warning dissemination systems. Their current issues for each are identified as follows:

(1) Observation system

DGRE is responsible for the observation and data management of rainfall and water level at the respective gauging stations in cooperation with CRDA offices.

There are 56 gauging stations in the Mejerda River basin, which consist of 18 rainfall gauging stations, 18 water level gauging stations and 20 rainfall and water level gauging stations. Out of these 56 stations, eight stations are located at dam sites.

The following issues were identified related to the observation system:

i) No operation manual for telemetry system has been prepared.
ii) The piezometer-type gauge, which is used at most water level gauging stations, is likely to be affected by scouring during floods. To obtain a reliable observation data, the radar type gauge is recommendable though its cost is higher than the piezometer-type.
iii) The observation area is currently limited to the Tunisian territory. In the future, it is preferable to obtain rainfall data for the upstream area in Algeria, through satellite measurement such as GEOSS (Global Earth Observation System of Systems).

(2) Data transmission system

The observed data at the respective gauging stations are automatically transmitted to the call center in DGRE, via the GSM network system as shown in **Figure 5.6.1**. Those data are stored in the database managed by IRESA, a research institution of MARH, which is responsible for data management and security management in the telemetry system under the instruction of DGRE.

In terms of data transmission system, the following issues were identified:

i) Sometimes, observed data are not properly transmitted to the call center due to malfunction of the GSM telecommunication system.
ii) The access speed in AGRINET is too slow to obtain data for performing analysis on time.

(3) Analysis system

Under flooding conditions, hydrograph forecasting is jointly conducted by DGRE and DGBGTH. They forecast hydrographs of inflows into each dam based on discharge at upper stream stations, using MS-Excel. Currently, there is no runoff analysis system developed based on rainfall data.

In the telemetry system, alert and overflow levels have been set up. Once a water level reaches the alert level, an alert message via Short Message Service (SMS) is automatically sent to mobile phones of pre-selected personnel in-charge, employed by either DGRE or DGBGTH, in order to commence necessary actions against flooding.

However, the alert and overflow levels are provided based on trial and error, and such levels do not correspond to the ground elevation system.

The inflow volume and hydrograph at each dam site under flooding condition are estimated by DGBGTH. Each dam office calculates released discharge separately depending on the information given by DGBGTH.

The following issues related to analysis system were identified:

i) No reliable runoff analysis system has been developed yet.
ii) Setting of the alert and overflow levels at the respective gauging stations are still at a try-and-error stage.
iii) No inundation analysis model has been developed.
iv) Coordinated operation of dams has not been initiated.

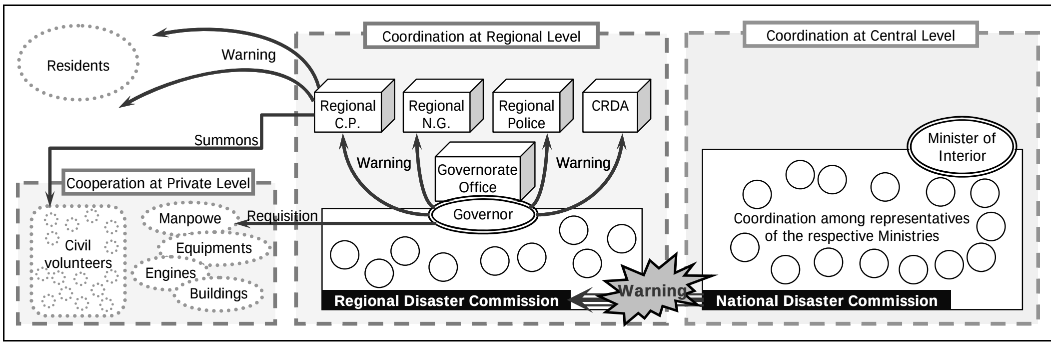
(4) Warning dissemination system

The following are three steps in disseminating flood warnings from the central government to terminal destinations, such as residents living near rivers:

In the first step, as shown in figure below, the National Disaster Commission chaired by the Minister of Interior issues a flood warning to the Governor, the chairman of the Regional Disaster Commission.

In the second step, the Governor transmits the warning to the concerned agencies at the regional level, namely the Civil Protection, National Guard, Police and CRDAs.

In the third step, the regional Civil Protection broadcasts the warning to residents either by patrolling around river areas or directly visiting residents' houses, advising them to evacuate.



Source: Interviews with MARH

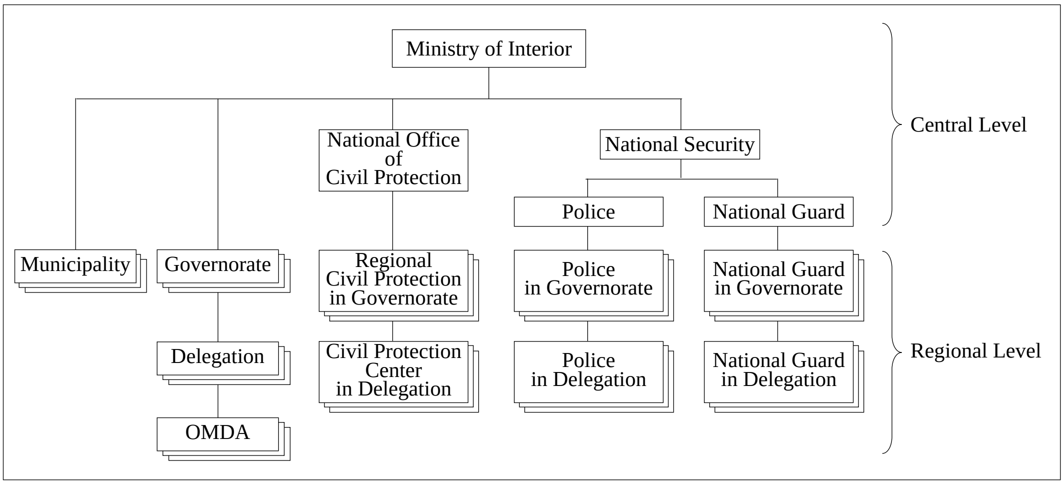
Warning Dissemination System

In terms of warning dissemination system, the following issues were identified:

i) Flood warnings do not reach some residents, or have been received late due to delayed forecasting period.
ii) Downstream residents are not warned when dam release is necessary.

5.7 Evacuation and Flood Fighting

The regional Civil Protection office is responsible for evacuation and flood fighting activities in cooperation with the National Guard, the police and the military at the regional level. These agencies except the military belong to the Ministry of Interior as shown in the figure below, and the military belongs to the Ministry of National Defense.



Source: Interviews with MARH

Agencies Concerned to Flood Fighting

According to interviews with residents living around inundation areas, some have evacuated at their own discretion, without instruction from the Civil Protection. This was because the instructions either did not reach the residents or have been issued late.

Even residents who received instruction from the Civil Protection had problems evacuating because they had no means of moving their properties.

Besides the Civil Protection, civil volunteers assisted flood fighting activities. According to the Decree No.2428-1999 on regulations of civil volunteers' involvement in disaster management activities (November 1, 1999), any citizen who passes a civil volunteer examination can register as a member of civil volunteers group. They are summoned by the regional Civil Protection in times of disaster.

In terms of evacuation and flood fighting activities, the following issues were identified:

i) It is not confirmed whether evacuation is completed or initiated even before occurrence of inundation.

ii) Some residents have no means of moving their properties and thus stay in their houses during disaster events.

iii) Evacuation areas are limited.

iv) Evacuation plan and map, which residents can clearly and easily understand, have not been prepared.

5.8 Organization and Institution

5.8.1 Present Organization and Institution for IWRM

(1) Organizational structure and competence of MARH

(a) Central directions of MARH

MARH is entrusted with the water management according to Article 2 of the updated Decree No. 2001-419, dated 13 February 2001 (JORT). The organizational structure of MARH is shown in **Figure 5.8.1**. Duties of MARH are managed by different directions and departments, under the legal framework defined in the updated Decree No. 2001-420 (13 February 2001, JORT).

Central directions, that have extensive competencies on water resources management field, are the General Direction of Dams and Large Hydraulic Works (DGBGTH), the General Direction of Water Resources (DGRE) and the General Direction of Rural Engineering and Water Exploitation (DGGREE). On the other hand, the General Direction of Planning, Management and Conservation of Agricultural Lands (DGACTA) is involved in the natural resources evaluation and preservation as well as in the hydrological and hydro-geological aspects linked to the water resources.

(b) Regional directions of MARH

MARH is involved in all the agricultural activities (i.e., natural resources, food production, vegetal and forestry domains, economic aspect, etc.), but it entrusts regional activities to each governorate (24 governorates) through regional services or district departments within the framework of the Tunisian decentralization policy. Its administrative and technical structure is called the Regional Commissaries of Agricultural Development or Regional District Department of MARH (CRDA). CRDAs are established by law that was successively updated in March 1989 (Law No. 89-44, JORT), October 1992 and October 1994.

Each CRDA supervises the agricultural activities and identification oh the technical, administrative, legislative, and financial issues. They are also in-charge of promoting new agricultural technologies, enhancing the related regional domain. CRDA has technical and administrative services (Arrondissement), provided by the representatives of the central directions, who realize their duties in the regional level.

(c) Institutions supervised by MARH

Water Exploitation and Distribution National Company (SONEDE), established by the law No. 68-33 (2 July 1968, JORT), is an autonomous institution under the umbrella of the MARH authorities. It ensures the efficient management of the domestic water and also the industrial and other (non agricultural) uses in all the country. Organized by several directions, SONEDE is responsible for the quantitative and qualitative fresh water management. It has to realize the water networks exploitation, maintenance, transportation (transfer and canalization), and all activities related to domestic water sector including water treatments for normalized qualities (physical, chemical, biological and bacteriological) and its equitable distribution.

The North Water Canal, Adductions and System Management Company (SECADENORD), established by the law No. 84-26 (14 May 1984, JORT), has its financial autonomy under the authority of MARH. It ensures the efficient management and maintenance of the part of North West water network transfer: i.e., the north water canal, and the adduction for the canalization of water from the Sidi Salem Dam, Ichkeul zone, and the extreme North West for the users in the North East, Centre and South of the country where fresh water shortage exists.

(2) Water resources legislation

(a) Water Code and Integrated Water Resources Management (IWRM)

Tunisia focused its policy on the water mobilization that is conceived with inter annual volume regulation approach and with inter-basins and within-basin water transfer system. IWRM has been implemented as policy instruments based on the Water Code (Law No. 75-16, 31 March 1975).

All the legislative texts concerning water resources management made during the French colonization period (1881 - 1956) were updated such as the Water Code in 1975 in order to identify the competencies of all operators and users in the water sector, to preserve the water resources and to ensure the equitable allocations. Since 1975 the water code was continually updated by modifying some legislation and supplementing with new ones related to socio-economic development, water demand evolution, and the environmental issues required to preserve the natural resources. The last update was made in November 2001.

(b) National Water Commission

The Water Code attributes to the National Water Commission (CNE) several competencies on water resources in the country. CNE examines and evaluates the general issues related to the water planning and management. The President of CNE is the Minister of MARH, and its members are composed of the representatives from the ministries linked to water resources management: i.e., Justice, Interior, Finance, Equipment, Development and International Cooperation, Public Health, Industry Energy, and Communication Technologies and Transport (Law No. 78-419 - 15 April 1978). The regional authority is associated when the subject discussed is related to its region.

5.8.2 Problems, Needs and Constraints in Organization and Institution

(1) Problems and needs in water use management

(a) Planning guidelines and standards for water supply master plan

All drought mitigation actions undertaken before 1999 in Tunisia are basically characterized by 'adaptive measures' that are linked with emergency intervention. However, those actions were rarely integrated.

In 1999, Tunisia published its first drought guideline on drought management, the 'Guide pratique de a gestion de la secheresse en Tunisie' (Louati et al., 1999). However, this guideline covers mainly emergency activities to save farmers and livestock, water saving and supply control and delivery of potable water by water tanks, and other salvation activities and coordination among stakeholders during consecutive severe draught. It neither includes planning guidelines nor standards for river basin and regional water supply plans.

(b) Target security level of water use

The drought management policy of MARH prefers a high security level of water use (water supply guarantee level). However, there is no written criterion for the target security level of water use at present. No specific planning target security level was set for Water 2000 (EAU 2000).

(2) Problems and needs in flood control management

(a) Characteristics of floods in the upper and lower reaches of the Mejerda River

In Tunisia, cities and urban areas are historically located on hills instead of lands with lower altitude such as flood plains. People who have suffered from significant flooding are found inside the hydraulic public domain near road bridges (Jendouba City, Bou Salem City) and the confluences of the mainstream of the Mejerda River and its tributaries (Bou Salem City) upstream the Sidi Salem Dam. These poor people constructed their houses illegally inside the domain about 10 years ago due to population increase in the urban areas. Flood plain is not prominent in the upstream areas of the Sidi Salem Dam, but a part of the agricultural lands have experienced flood inundation.

Significant parts of the alluvial plains downstream of the Sidi Salem Dam are flood prone areas. These inundation areas include partly agricultural lands with high production reclaimed in the delta of the Mejerda River during French occupation and partly salty wet lands called 'Sebkhas'.

The flow area of the river cannels and the drainage systems are seriously reduced and constrained not only by the existing old bridges but also by the expanding road systems in both rural and urban areas. In particular, a number of flood overflow at road bridges across the hydraulic public domain are reported. A number of disconnections of existing drainage systems due to new road systems in the wet lands and flood plains are also reported.

(b) Flood mitigation activities by MARH

Floods in the rural areas and agricultural lands are managed by MARH and the National Commission, while floods in the urban areas are managed by the Ministry of Equipment, Housing and Country Planning (MEHAT). Administrative territories of urban and rural areas are clearly defined. The flood mitigation and protection activities under MESTD are principally limited to the excess water management due to storm rainfalls inside city territories.

(c) Reinforcement of hydraulic public domain

Definition, conservation and water policy of the hydraulic public domain is stipulated in the Water Code. The articles in its Section II (Fight against Inundation) Chapter VII, are the basis for flood and management related to the hydraulic public domain. The hydraulic public domain defines legally the river area. The Water Code designates the minister of MARH as the administrator of the hydraulic public domain. However, the hydraulic public domain inside the urban areas is managed in practice by regional offices of the MESTD as well as flood control and drainage works in the urban areas. Management of the hydraulic public domain plays a very important role in various aspects in Tunisia. Its capacity improvement covering the following components would be effective:

- Flood control
- Control of sediment discharge
- Control of domestic waste water and solid waste from the public
- Control of road and bridges across the hydraulic public domain
- Forestation along the hydraulic public domain

(d) Reinforcement of planning and design standard and reservoir operation rules

Flood control requires prompt and timely operation and management of inflow and outflow. The related information includes the spatial distribution of rainfall upstream and downstream, flood discharges inside the river channels, reservoir high water levels upstream and downstream, flood water levels in the river channels, and flood inundation upstream and downstream.

Introduction of a target security level for flood control plan will be necessary in addition to the target security level for river basin water supply plan. Appropriate key management factors and planning and design parameters are also to be sought for the flood control management, e.g., the reservoir water level before the wet season and that during large floods, the design high water level (or design hydrograph) during large floods in the river channels.

(e) Flood forecasting, warning and evacuation activities

The Ministry of Interior takes charge of flood warning and evacuation activities provided with flood discharge data and forecasting information from MARH and support from relevant ministries, agencies and NGOs as part of the national security control. Community based flood fighting and evacuation activities seem to be uncommon.

(3) Problems and needs in watershed management

Sediment production, discharge and deposition in the river channels and the reservoirs would be one of the most significant issues in terms of both flood control and sustainability of the river and reservoir water supply system in the Mejerda River basin. Sediment control inside the river channel could be improved with the integration of the watershed management and the management of hydraulic public domain.

(4) Trans-boundary cooperation for river basin management

Since the 1980s, a joint technical committee meeting has been held annually to discuss water resources and environment of the shared (trans-boundary) river basins between Tunisia (MARH) and Algeria under the supervision of the Ministry of Foreign Affairs of both countries. The agenda for the committee meeting is opened for all issues related to water resources and environment. There were no agreement on the agenda discussed, nevertheless the minutes of meetings were signed.

At present the storm rainfall and flood discharge data observed hourly at the major stations inside the Algerian territory are not promptly made available to MARH of Tunisia for flood forecasting and warning. This is due to the technical and financial constraints in accessing international telephone calls and availability of telecommunication and computer systems at the meteorological and hydrological stations at site.

5.9 Environmental and Social Considerations

5.9.1 Field Reconnaissance Survey

A field reconnaissance survey was carried out by the Study Team in the Mejerda River basin from Jan. 30th to Feb. 1st and Feb. 6th to 9th, 2007, which covered the study area and immediate surrounding areas. During the survey, two national parks were visited along with some historical landmarks, and few major dams and reservoirs located in the areas. Other items of interest visited included the national sanitation utility, ONAS, located in the mid-stream stretch of the river which deals with waste water treatment for Beja City. Some of the lessons learned during the visits are as follows:

1) Sedimentation in the Mejerda River comes mainly from its right bank where there are fewer forests than the left bank;
2) Due to a geology characterized by pockets of gypsum deposits, the water from the right bank of the Mejerda River has higher salinity than that from the left bank. It has salt concentration often higher than 1.0 g/l, making it more suitable for irrigation than for drinking;
3) Dams in the right bank serve mainly for flood control and irrigation water supply;
4) Dams on the left bank serve mainly as flood control and drinking water storage, with salinity often less than 1g/l;
5) Bou Salem City is still under the threat of exceptional floods due to the three rivers namely, Bou Heurtma, Mellegue and Tessa, which drain into the Mejerda upstream. Flood risk could also be due to the back water from the Sidi Salem Dam;
6) Some residents at Bou Salem City still refuse to leave the hydraulic public domain (under 127 m altitude) despite the high risk of inundation in time of exceptional

floods. Some residents in Jendouba also still live in that public hydraulic domain (under 126 m altitude);

7) A high level of pollution is caused by these residents on the Mejerda River by dumping domestic garbage along the river banks;
8) Some hydrometric stations automatically measure water quality along the Mejerda River;
9) Sedimentation has greatly decreased the flow capacity of the Mejerda River;
10) Bridge structures crossing the river channel also reduce the water flow velocity and are contributing to sedimentation;
11) ONAS reduces the concern of lake or reservoir water eutrophication through thorough treatment of cities' waste water, but the activity of riparian populations contribute significantly in worsening the pollution by dumping domestic wastes along the river banks.

5.9.2 Legislative Aspects and International Cooperation

EIA Study was introduced for industrial, agricultural and commercial projects in 1991 following the creation of ANPE, as the police of the environment in Tunisia.

A dam construction project is listed in Appendix 1**(Table 5.9.1)** of the Decree regulating the EIA study as a Category B project (Item no.21 of list), which requires an EIA study.

A canal construction project is listed as Item no. 3 in Appendix 2**(Table 5.9.2)**.

Projects listed in Appendix 2 are considered not significantly disruptive to the environment and are simply subjected to the Terms and Conditions procedure. This procedure states the environmental measures that a project owner or petitioner must comply with. A "rough description" of the project is required in the procedure, allowing the ANPE to determine its potential harmful nature and, if necessary, require a full impact study or grant approval to the project.

The construction of embankment and excavation of riverbed, which are the proposed structural measures to be considered by the Study, are not listed in any of the Appendices of the decree.

With regard to the national legislation, there are numerous laws and decrees related to the protection and conservation of natural resources. Major laws concerning the environment include different codes and decrees that pertain to land tenure system, disaster prevention, forest conservation, hunting, air, waste and water, mining, fishery, etc.

At the international level, Tunisia has participated in several global, regional, bilateral and multilateral conventions, dealing with the protection of nature and species, maritime ecosystem and nuisances. These include Protection of World Cultural Heritage, Ramsar on wetlands, Biological diversity, Climatic change, and others.

Within the framework of international cooperation, much analysis has been performed on environmental issues for Tunisia. Most notably are issues on desertification and land degradation. Many agencies are involved in assisting the country address the broad agenda of environmental challenges, including UNSO, UNDP, the Governments of Germany and France, the World Bank and IUCN.

5.9.3 National Parks and Nature Reserves in the Study Area and its Surroundings

In the framework of the Study centered on flood control, Ichkeul National Park, a World Heritage of UNESCO, which is not in the immediate surrounding of the project area, seems not greatly affected. This has been guaranteed with an equal annual water quota as other two users of the Extreme North waters, namely cities' drinking water and irrigation.

The concerns for Ichkeul would rather come from riparians as their poor cultural practices may in the long run affect the water quality of the lake and cause sedimentation. Such concerns are already raised by MEDD, claiming that abusive use of agrochemicals and sediments are threatening the lake.

Feija National Park is the only park listed in the study area. The park seems to be secured from big floods of the Mejerda River considering its distance from that river and its high elevation. However, forest fire and land slide need to be closely monitored to avoid reduction of the forest tree resources in the area, which could cause land degradation and increased sedimentation in the Mejerda River due to runoff, considering the steep slopes observed. It is said that the communities living around the park are gaining their livelihood from the park, being involved in major conservation activities that would somehow support mitigation of some possible threats.

Furthermore, in neighboring Ain Draham and Tabarka, which have important forest areas and protected domains, land reclamation, grazing and illegal deforestation have caused decrease in forest resources, erosion and destruction of vegetation.

Special attention should be paid to this, as it is apparent that sedimentation has greatly decreased the flow capacity of the Mejerda River and is said to have contributed to the floods observed last few years.

5.9.4 Endangered Species of Flora and Fauna and Indigenous People

Though IUCN has presently identified about 80 species of mammals, 362 birds' species and more than 500 species of reptiles and fishes in the country, endangered species of flora and fauna are not confirmed in the flood plain and irrigable areas of the Mejerda River basin. However, the Study Team has confirmed that several fish species exist in the reservoirs of the many dams that were built over the years. It is therefore evident that several fish species are living in the Mejerda River and the Sidi Salem Reservoir. Among these, species include berbel (Barbus callensis), which is endemic in North Africa, the common Tilapia (Cyprinus carpis), several species of mullets and the catfish. Conserving these fish species against the fishing livelihood of the riparians is important as many depend on such livelihood activity. A minimum water flow is necessary in the Mejerda River, as well as a minimum water quality for the fish population.

Existence of indigenous people is not confirmed in the Mejerda River basin.

5.9.5 Historical Remains and Archeological Sites

Though there are no historical remains or archeological sites listed as a world heritage in the study area, several bridges of cultural assets exist along the Mejerda River, namely at Medjes el Bab, Jedeida and Bizerte Cities.

It is believed that the section of these bridges contributed to the floods in 2003.

In Jendouba Governorate, the vestiges of an old roman city famous for its marble quarry in the antiquities were found at Chemtou, which is located between Jendouba city and Oued Mliz River. Also an important archeological site of an important city with well conserved ruins was found at Bulla Regia, between Jendouba and Fernana. There are also some archeological ruins discovered in Utique in Bizerte Governorate. All of these sites are far from the Mejerda River basin.

5.9.6 Protective Measures for the Conservation of Environment

(1) Protection of the main forest areas

Several protected forests are observed in the study area and its neighboring areas. The role of these forests is very important for the preservation of the environment, the conservation of the water resources and for firewood needs. In the formulation of the master plan, the preservation of these protected forests should be taken into consideration in the selection of flood control measures and the promotion of sustainable development.

(2) Protection of the main species of fauna and flora

Though an exhaustive study of the fauna and flora was not carried out along the Mejerda River basin, it is confirmed by the Study Team that several fish species exist in the reservoirs of many dams that were built over the years. It is therefore evident that several fish species are living in the Mejerda River and the Sidi Salem Reservoir. Among these include berbel (*Barbus callensis*), which is endemic in North Africa, the common Tilapia (*Cyprinus carpis*), several species of mullets and the catfish. Conserving these fish species for the fishing livelihood of the riparians is important as many depend on such activity. A minimum water flow is necessary in the Mejerda River, as well as a minimum water quality for the fish population.

(3) Protection of soil against erosion

Cropping areas located in the flood plain along the Mejerda River are considered subjected to relatively fewer problems than those in the plateau, which are generally located on hillside. Soil protection ought to be an important issue to be considered on projects dealing with cultivable land development and implementation of good cultural practices. It is recommended to plant trees at locations where dams or structural measures are implemented in order to avoid soil sedimentation caused by erosion.

(4) Protection of soil against excessive use of agrochemicals

The introduction of modern cultural practices will replace the traditional system of slash and burn cultivation, which is proven to damage the environment. The contamination of soil through the over-use of agrochemicals could affect the quality of water in the river. Therefore, in order to protect the environment, it would be desirable to use fairly effective and recommendable products, which would require only minimum application.

(5) Steady flow of the Mejerda River

The river water is used for domestic purposes in the urban and rural areas, as well as for agriculture and industry. Maintaining a steady level of water in the river is also important for fish and animals. Thus, it would be ideal to maintain a minimum water level in the river.

CHAPTER 6 FRAMEWORK OF THE MASTER PLAN FOR INTEGRATED BASIN MANAGEMENT FOCUSED ON FLOOD CONTROL

6.1 Necessity of Integrated Flood Management

Flood management in the Mejerda River basin has been largely focusing on controlling floods and the susceptibility to related damages through the implementation of engineering interventions, such as large-scale reservoirs and embankment. However, flood control to avoid detrimental inundation has not been entirely realized during flood events, resulting in incomplete alleviation of damage in flood plain areas.

Considering this, the following are pointed out as issues relevant to flood control.

(1) Need for a basin approach

A river basin is a dynamic system in which a series of interactions between the land and water environment exist. These interactions involve not only water but also soil/sediment and pollutants/nutrients. The system is dynamic over time and space. The function of a river basin as a whole is governed by the nature and extent of these interactions.

Increase in economic activities, such as farming and urbanization, has caused deforestation, resulting in larger sediment yields from water catchments. Landslides/surface soil erosion induced by natural or human activities in hilly areas increase sediment concentration in the rivers. The increased sediment concentration disturbs natural river regimes. While some of the sediment flows into the sea, a large portion is deposited in river channels, thus reducing the discharge capacity of the rivers.

Large-scale urbanization accentuates flood peaks and reduces the time of flood runoff concentration. This is because the land use/surfaces in urbanized basins made up of roofed areas, paved streets and other impervious surfaces, increase surface water runoff volume and decrease groundwater recharge and evapotranspiration. In lowlands and coastal areas, road and railway embankments and similar infrastructure can obstruct flood flows and accentuate flood conditions in their upstream reaches.

The above-mentioned interactions progressing in the basin between the land and water environment call for an integrated basin-wide approach to flood management.

(2) Unachievable absolute safety from flooding

Absolute protection from flooding is neither technically feasible nor economically or environmentally viable. Devising a design standard for flood protection is unrealistic since it conflicts with the principle of managing all flood occurrences instead of a selected few. It is also impractical because estimates of the magnitude of extreme floods are very inaccurate and are likely to vary over time due to climate change.

An issue exists regarding whether it is ideal or not to design interventions as protection against large floods. By just aiming at reducing the losses from high frequency floods, there could be greater risk of disastrous consequences when more extreme events occur. It is also necessary to consider the likelihood of failure in the case of floods below the design standard. Some structural measures such as embankments and bypass channels, due to long-term disuse or lack of finances, may not be adequately maintained and can be susceptible to failure during flood events with magnitude lower than the design standard.

(3) Securing livelihoods

Economic activities enhanced in flood plains due to increased population pressure and the construction of infrastructure further increase the risk of flooding. Flood plains provide excellent, technically easy livelihood opportunities in many cases. In the countries with primarily agricultural economies, food security is a requisite to livelihood security. Flood plains contribute substantially to food production and provide nutrition to the people of these countries.

Regarding access to limited land resources, it should be ensured that the socially weaker class of population who largely occupy the flood plains do not suffer further due to the implementation of flood management measures which might reduce livelihood opportunities.

(4) Importance in ecosystem approach

Riverine ecosystems of aquatic habitats such as the rivers, wetlands and estuaries, provide many benefits to people including clean water, food, water purification, flood mitigation and recreational opportunities. Variability in flow quantity, quality, timing and duration is often critical for the maintenance of river ecosystems.

Different flood management measures have varying impacts on the ecosystem and at the same time changes in the ecosystem have consequential impacts on the flood situation, flood characteristics and river behavior. Some flood management interventions adversely impact on the riverine ecosystems by reducing the frequency of flooding of wetlands that develop around flood plains, which are subject to frequent flooding and owe the large variety of flora and fauna to this phenomenon. In these situations, it is desirable to avoid changes in high frequency floods since to do so would damage the ecosystems that have developed around the existing flood regime.

The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.

(5) Stakeholder involvement

In recent years the need for increased cooperation and collaboration across sectors and public participation has become more widely accepted. Greater participation of all stakeholders in flood management measures is considered vital since it enables communities affected by floods to choose the level of risks they are ready to take. The combined participation of government agencies, technical specialists and local residents in carrying out risk assessment is identified as a critical function that promotes public participation at local and national levels. A shared consensus has emerged in the past decade on the importance of participatory planning in disaster management. Individual and community ownership, commitment and concerted actions in disaster mitigation result in a wide range of appropriate, innovative and feasible mitigation solutions, which are both cost-effective and sustainable.

(6) Risk Management

An integrated risk management approach provides measures for preventing a flood hazard from turning into a flood disaster. It consists of systematic actions in a cycle of preparedness, response and recovery. These actions are taken, depending on the conditions of risk and social, economic and physical settings, with major considerations for reducing vulnerability and improving resilience.

As mentioned earlier, flood management has been largely focusing on defensive practices in the Mejerda River basin. Realizing worldwide approach from the point of view of flood management, however, it is generally recognized in recent years that a paradigm shift from defensive action to the proactive management of risks due to flooding is required. The paradigm shift encourages implementation of Integrated Flood Management (IMF) which is a process promoting an integrated, rather than fragmented, approach to flood management and seeks to integrate land and water resources development in a river basin and manage floods based on risk management principles in order to optimize the net benefits from the flood plains while minimizing the loss of life due to flooding. In order to thoroughly address the abovementioned issues on flood control, adoption of IFM is essential in the Mejerda River basin.

6.2 Target Planning Year

The target year for formulating "the master plan for integrated basin management focused on flood control (the MP)" is defined at the year 2030, which is that of the master plan of water supply for the Mejerda River basin and the extreme north region of Tunisia, entitled "EAU XXI", since the MP needs to strictly achieve the consistency with "EAU XXI" in terms of water resources management in the Mejerda River basin.

6.3 Water Use Security

MARH has indicated that the surface water system should be able to meet demands for a two consecutive year drought. However, the severity and probability of the drought event is not defined.

Reservoir yields provided by MARH are said to have an 80% probability, but the relationship between probability yield and reservoir operations is not clearly defined, i.e. water levels required to meet the said yield are not specified. Furthermore, there is no fixed plan for water supply operations and therefore storage boundaries at each reservoir are not distinct. The 80% yield quoted by MARH is consistent with those normally found for irrigation schemes in developing countries.

The absence of clearly defined probability yields and storage boundaries makes it impossible to assess existing operating practices or to identify required improvements for flood control.

To develop a framework for subsequent flood control analysis, the Study has carried out a water balance study to determine storage levels required to satisfy demands for the following three drought scenarios:

- One-year drought with a once-in-5 time (5 year) recurrence
- Two-year consecutive drought with a once-in-9 time (18 year) recurrence
- Three-year consecutive drought with a once-in-11 time (33 year) recurrence

These drought scenarios were discussed with the Steering Committee and with workshop participants, resulting in the following:

- Since the reservoir system is designed to regulate inter-annual inflows, storage volumes should be able to satisfy demands for more than one-year. Consequently water levels identified for the one-year drought scenario are too low and should not be considered for determining storage allocation boundaries.
- The two-year drought scenario is more realistic and provides an acceptable level of risk. The use of demand restrictions does not significantly increase available flood control storage, and therefore it should not be included when determining storage allocation boundaries. Demand restrictions can be applied in practice if actual droughts are more severe than the synthetic drought selected for analysis.
- The three-year drought scenario seems unrealistic since it reveals that severe demand restrictions must be implemented to prevent complete failure of the system even if all reservoirs are full at the beginning of a drought cycle. In this case additional flood control storage space should not be made available.

In conclusion, MARH has agreed to use the two-year drought scenario to define storage allocation in reservoirs. The flood control analysis will evaluate the impact of additional flood control storage and compare this to the case where all reservoirs are full at normal water levels i.e. no additional flood control storage.

6.4 Flood Protection Level

6.4.1 Laws/Guidelines in Tunisia

Based on the interviews conducted with DGBGTH and the personnel concerned in the Ministry of Equipment, it was clarified that the law and/or guideline, which defines the planning scale or magnitude of flood control (level of flood risk) in the nationwide basin or a particular river basin, dose not exist in Tunisia at present. When dam and reservoir construction is planned, an appropriate scale for design flood discharge is practically established in an independent manner. Therefore, the Study aiming at an integrated flood management would need to set the planning scale of flood control of the Mejerda River basin on the basis of specific concept and approach established in the Study.

6.4.2 Basin Concept and Approach for Preparation of Flood Protection Level

(1) Combination of improvement of reservoir operation and river improvement

In planning the structural measures for flood control, improvement of reservoir operation at the seven selected reservoirs is prioritized so as to maximum the flood control functions of the existing and future reservoirs. Then, when the improvement of reservoir operation can not satisfactorily achieve flood control, river improvement is additionally incorporated as part of the measures. Conceivable works of the river improvement are composed of riverbed excavation, river channel widening, embankment, and construction of a bypass channel and/or a retarding basin. The river improvement shall be planned so that it has no risk on detrimental artificial flood in downstream areas.

(2) Zoning of study area

The study area (the Mejerda River basin in the Tunisia territory) is as wide as 15,830 km^2 and regional importance and development level, as well as regional flood characteristics is uneven in the area. Therefore, the study area is divided into several zones while a flood protection level is to be established for each zone, taking into account such specific situations including hydrology, geography, economy and social condition.

(3) Optimum flood protection level

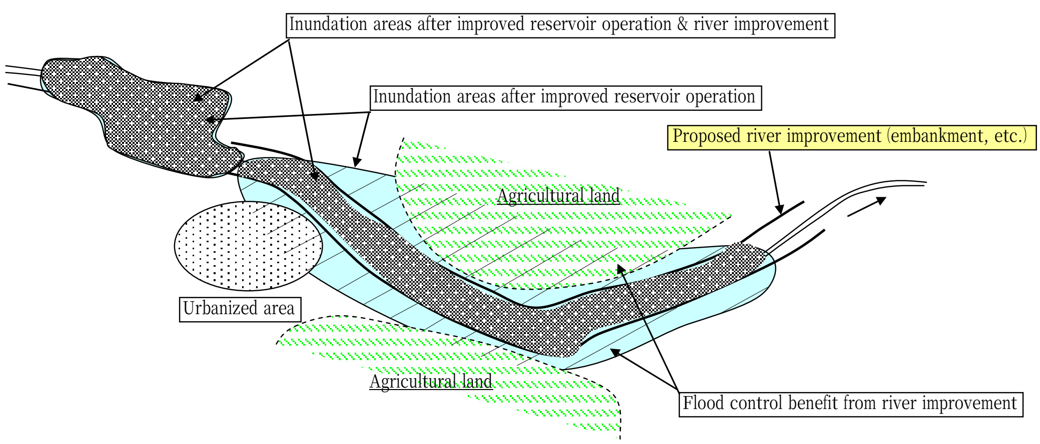
For each zone, the flood protection level with the highest benefit-cost ratio (B/C) is to be selected as an optimum flood protection level (benefit B: flood control benefit from river improvement in each zone; cost C: direct construction cost of river improvement works for each zone).

The flood control benefits from river improvement is estimated in the following manner

(i) FD1: amount of flood damage in flood inundation areas after improved/coordinated reservoir operation at four existing and three planned reservoirs,

(ii) FD2: amount of flood damage in flood inundation areas after improved/coordinated reservoir operation at four existing and three planned reservoirs and river improvement, and

(iii) Flood control benefit from river improvement = FD1 - FD2（see chart below）.



Flood Control Benefit from River Improvement

The flood damage to be estimated is composed of direct and indirect flood damage as stated below:

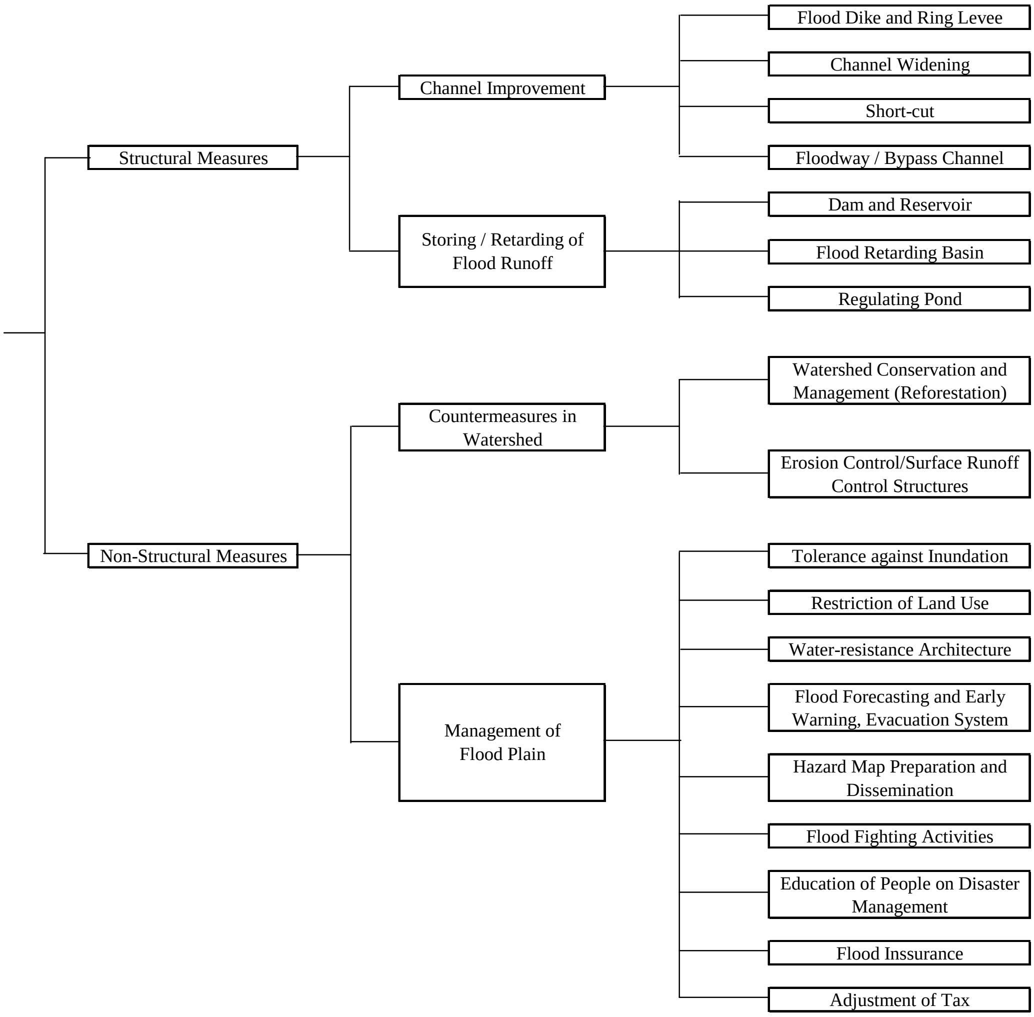
(a) Direct flood damage: agricultural products, housing and household effects, depreciable assets and inventory stocks of industrial sectors and infrastructure, and

(b) Indirect flood damage: Damage due to loss of business opportunities, interruption of public transportation, wage loss of employees, labor cost for cleaning houses, etc.

6.5 Flood Control Measures

6.5.1 General

Flood control measures shall be selected and applied in combination of their several types in accordance with the conditions of natural and social environments such as topography, hydrology, hydraulics, land use, affected population, infrastructure and properties to be protected, etc. In case of the Mejerda River basin, an integrated approach for better water resources utilization and allocation in the region shall be essentially applied. Commonly, the flood countermeasures are mainly divided into structural and non-structural measures, which are further classified as shown below:



Rearranged by the Study Team based on "Manual for Formulation of River Improvement Plan in Urban Area (Draft) Public Works Research Institute, MLIT, Government of Japan", 1998

Classification of Flood Control Measures

Based on the site conditions and benefit-cost performance etc., several alternatives were selected through evaluation from technical, environmental and institutional point of view.

6.5.2 Structural Measures

(1) Reservoir operation

Not every reservoir in the Mejerda River basin will significantly contribute to flood mitigation or flood protection. Among the reservoirs, seven dams are selected as those which are important for the analysis and evaluation of effective flood control, as discussed earlier. The master plan includes the schemes for effective operation of the dams, including coordinated operation, during flood events.

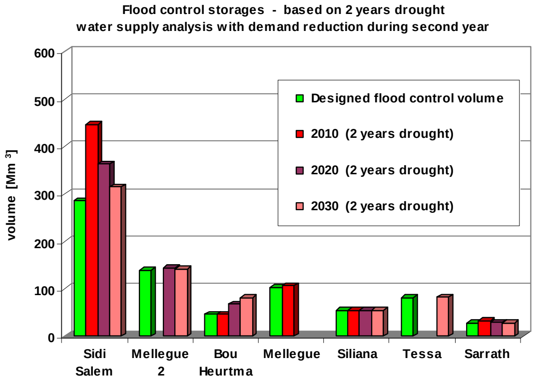
Reservoirs in Mejerda River Basin Selected for Evaluation of Effective Flood Control

Name of dam	Catchment area (km^2)	Spillway type	Maximum high water level				
			Elevation PHE (m)	TOTAL Volume at PHE (Mm^3)	Designed flood control volume (Mm^3)		
					year 2010	year 2020	year 2030
Sidi Salem*	18,191	cont. / uncont.	119.50	959.5	285.5	285.5	285.5
Mellegue*	10,309	controlled	269.00	147.5	103.1		
Siliana*	1,040	uncontrolled	395.50	125.1	55.1	55.1	55.1
Bou Heurtma*	390	uncontrolled	226.00	164.0	46.5	46.5	46.5
Mellegue 2	10,100	uncontrolled	304.00	334.0		139.0	139.0
Tessa	1,420	uncontrolled	369.00	125.0			80.6
Sarrath	1,850	uncontrolled	552.00	48.5	27.6	27.6	27.6
T O T A L					517.8	553.6	634.2
In all reservoirs in Mejerda River basin					547.9	583.7	693.9
In selected reservoirs					95%	95%	91%

Note: * existing

Seven reservoirs consisting of four existing reservoirs (Sidi Salem, Mellegue, Bou Heurtma and Siliana) and three reservoirs under planning or construction stage (Mellegue2, Tessa and Sarrath), have been selected as important ones for further analysis and evaluation of effective flood control. The total flood control storage volumes of the seven reservoirs is estimated at 518mil. m^3 in 2010, 554 mil. m^3 in 2020 and 634 mil. m^3 in 2030 as shown in the table above. This represents roughly 91 to 95 % of the flood control storage of all reservoirs in the Mejerda River basin, when reservoir development of up to the target year 2030 is considered.

At most of the existing reservoirs, the designed flood control storages have not been fully utilized so far. Many reservoirs have been operated with a designed normal water level equal to the uncontrolled spillway crest level, signifying that the designed flood control storages have not been utilized. Based on this, the key benefit for the improvement of flood control function is to find "additional flood control storage" of each reservoir, i.e. to lower the normal water level below the spillway crest for flood control.



Possible Increasing of Flood Control Storages in 7 Selected Reservoirs

The comprehensive water balance analysis made in the Study shows which reservoirs have some available additional flood control storages. The possible increase in flood control storage at the selected reservoirs until the target year 2030 is presented in the case of 2 year consecutive drought scenario in the chart above. In this figure, the flood control storage is increased, compared to the originally designed for each reservoir. It is evident that only Sidi Salem and Bou Heurtma Reservoirs have some additional flood control storages in the year 2030. The total flood control storage could be increased up to 687 M m^3 in 2010 (by 33 %) and up to 703 mil. m^3 in the target year 2030 (by 11 %).

Simulation of the reservoir operation, including coordinated operation, during floods need to be done to clarify potential flood control functions of the seven reservoirs.

In this connection, it is noted that optimum use of reservoirs for a flood control purpose needs to be examined in consideration of the combination of suitable measures along the rivers and in flood plains. This complex measures for flood control shall be worked out in the Study based on a suitable flood protection level. Furthermore, all operations and flood protection measures shall be designed so as not to threaten water supply operation.

(2) River improvement

Only reservoir operation using the total flood control storage of the seven selected reservoirs in the Mejerda River basin (even under optimum operation) would not satisfactorily eliminate flood damage in the basin in the light of relatively low discharge capacities of the current river channels. Therefore, the current river situation must be improved and the discharge capacities need to be substantially increased for the desirable flood control in the Mejerda River.

For this reason, detailed computation of current river discharge capacity was carried out. Based on the computed capacities, conceivable structural measures to be applied for river improvement have been identified, which are divided into the following three groups:

(i) For decreasing flood peak discharges
- retarding basins

(ii) For enhancing discharge capacity of river channels
- dredging/excavation and widening of river channels

- lateral channels (by-pass channels)
- shortcuts

(iii) For protecting particular areas

- dikes, including ring dikes

In the Mejerda River basin, gently undulating areas are lying in the upstream to middle stream reaches between the Ghardimaou area and the Sidi Salem Dam, where flood water has been naturally retarded and peak discharges were effectively attenuated in the past significant floods. These areas are practically candidate sites for natural retarding basins which temporarily store flood water to reduce acute peak discharges. Widely spread inundation areas of past major floods imply the effectiveness of retarding basin as one of successful flood control measures in the Mejerda River.

In order to select appropriate areas and to realize regulation rule/plan for the natural retarding basin, factors to be examined shall include topography, land use, river discharge frequency, natural environmental conditions, frequency of overtopping of flow, control of discharge (inflow/outflow), economical soundness and operation and maintenance, and environmental friendliness

6.5.3 Non-structural Measures

(1) Basin preservation

Some measures are essential to control erosion on the land surface in terms of basin preservation in the Mejerda River basin. The impacts of erosion recognized in the basin are characterized from the following points:

(a) The higher percentage of steep slope lands a basin has, the more sediment yield occur in the basin; and

(b) There is a need to take some measures for erosion control in the following lands:

- Agricultural lands with steep and even moderate slopes, and
- Forest lands wherein the low lying vegetation on and near the ground is poor.

In consideration of the above points, the measures need to be worked out placing great importance on the lands used as forest and agricultural land.

Identification and formulation of the schemes for basin preservation is to be carried out, paying special attention to the following, since the deforested lands in the forests and the agricultural lands used for cereal cultivation (olive tree cultivation, arboriculture and fallow) are extremely susceptible to erosion caused by rains:

- The measures have a superior durability against erosion.
- The measures are technically and economically suited also to vast lands.
- The works related to implementing the measures are easily realized.

(2) Flood forecasting and warning system (FFWS)

Based on the current state and identified issues concerning the existing FFWS, the alternative development or improvement plans are to be formulated as possible schemes to be incorporated into the MP in consideration of the following.

a) Observation system

Currently, the newly installed telemetry system is performing well. However, in order to properly obtain enhancement of the function of the system, the following requirements shall be realized:

- Preparation of operation manuals for the telemetry system,
- Application of a radar type water level gauge instead of the piezometer type, and
- Study on applicability of satellite measurement for rainfall data, particularly in the upper areas situated in Algeria.

b) Data transmission system

Similar to the observation system, in order to enhance the reliability of the data transmission system, the requirements of the existing transmission system shall be set up as follows:

- Settlement of the problems in telecommunication,
- Improvement of access speed in AGRINET, and
- Connection of dam offices to AGRINET so that the said offices can easily obtain real-time data.

c) Analysis system

In order to establish an accurate and timely forecasting and simulation system, it is essential to develop appropriate models and to carry our some studies as follows:

- Improvement of a low-and high-flow runoff analysis system,
- Development of a flood inundation analysis model,
- Study on classification of river water levels to define alert levels, and
- Establishment of rules for coordinated operation of dams

The developments of the above-mentioned runoff analysis system and the flood inundation analysis model could significantly contribute to appropriate and timely flood forecasting necessary for i) flood warning and evacuation activities and ii) coordinated operation of dams.

d) Warning dissemination system

The following requirements are identified in order to improve the current warning dissemination system:

- Preparation of flow chart for coordination and reporting of the warning system among all agencies concerned,
- Identifying existing residential houses in expected inundation areas so as to smoothly execute evacuation procedures, and
- Implementation of dam release warning to downstream residents.

(3) Flood fighting

Based on the issues identified concerning the current flood fighting system, the alternative development or improvement schemes are to be set up in consideration of the following.

a) Evacuation and flood fighting activities

The following requirements are recognized for the improvement of the current evacuation and flood fighting system:

- Formulation of governorate-specific evacuation plan,
- Preparation of evacuation map in expected inundation areas,
- Prior training of civil volunteers, and
- Establishment of system to confirm whether the evacuation of every resident is completed or not before occurrence of floods.

b) Institutional arrangement

Although the present institutional setup does not have serious bottlenecks to deliver desired services in relation to the FFWS and flood fighting activities, it is recommended that tasks and roles to be shared among the concerned agencies shall be clearly defined.

(4) Flood plain regulation/management

Commonly the structural measures need relatively large amount of finances and time frame for implementation, including environmental mitigation measures. On the other hand, non-structural measures require fewer budgets and less time until the realization of the measures.

Especially, the flood zoning through hazard map preparation, which delineates level of flood risk due to inundation, is often emphasized in many countries. As seen in the latest EC's Directive for flood management, it can be recognized as a current trend in Europe. Further, in the case of Japan, the flood hazard mapping has commenced since 1994 when the Ministry of Construction (currently the Ministry of Land, Infrastructure and Transport or MLIT) circulated an official notice to all the local municipalities in the preparation of the maps. The flood hazard maps are based on the premises that flooding would inevitably occur and aiming at minimizing loss of life by means of intensively encouraging evacuation of local residents.

In the Mejerda River basin, the flood hazard mapping in the area where habitual flooding occurred in past is indispensable to reduce regional vulnerability to floods. In particular, for the target area, detailed information to be incorporated and procedures of production, etc. need to be examined for the formulation of the MP. Further, since the hazard maps are a vital tool for flood fighting activities, practical and effective use should also be studied.

(5) Flood insurance

Flood insurance (or flood damage insurance) is one of the non-structural measures in cases where flood prone areas can not be totally protected by structural measures due to financial and technical constraints. It is very costly to protect all the flood prone areas with low risks of inundation. The amount of basic funding for flood insurance is generally smaller for a government than that required for structural measures with a high protection level. Flood insurance is basically a supplemental instrument to the structural measures, and thus it is generally arranged together with land use control, flood zoning, FFWS, and flood fighting programs.

6.6 Organization and Institution

(1) General framework

Based on the analysis of problems, needs and constraints identified in Section 5.8, necessary organizational and institutional arrangements are sought out to reach the goal of the comprehensive flood control master plan. The following measures are to be addressed in the framework for organization and institution as one of the alternative solutions:

a) Establishment of permanent division or service for flood control activities and management in the central and regional directions,
b) Development of documented technical planning and design guidelines/standards: flood control plan, river basin water supply plan, and reservoir operation rule,
c) Strengthening coordination between MARH and MEHAT for the hydraulic public domain (HPD) and flood plain management: for example, involuntary resettlement, to avoid river flow disturbance by bridges, to avoid drainage system damages by highways, etc.,
d) Strengthening coordination or support by MARH to the Ministry of Interior to strengthen flood fighting activities by civil defense: warning, fighting & evacuation,
e) Improvement of maintenance activities of sediments inside river channels and reservoirs, and control of sediment discharges from the watershed, and
f) Obtaining effective cooperation on river basin management with Algeria concerning rainfall, discharge, reservoir operation, and dam construction plans.

(2) Permanent organization for flood control management

Prompt, timely and effective are the key words for successful flood control activities and management. If a relevant organization only is formed as an ad hoc arrangement after a significant flood event, flood control activities will be limited to passive measures required for mitigating the disaster that just occurred. A comprehensive and rational flood control planning and management system may not be established in just a short period. Setting up a permanent division or a service section within the relevant organizations in both the central and regional directives will enable implementation of positive actions and continued improvement of flood control planning and activities, based on a cycle management (feedback of plan, do, check, action). Generally, short-term and long-term roadmaps to the national goal can be only established by permanent organizations.

(3) Technical planning and design guidelines and standards

(a) Unified and documented guidelines and standards

Use of unified planning and design guidelines, standards and practices and reservoir operation rules is effective to achieve efficiently and effectively activities of planning, design, construction, operation and maintenance of the river and water use facilities.

Documentation of unified planning and design guidelines and standards, and reservoir operation rules is also effective in establishing integrated flood control management and activities among multiple ministries and agencies concerned.

(b) Key planning and design criteria

Water supply security level

It is generally very costly to establish a low risk water supply security level in arid areas where dry season water demand is much higher than the water supply capacity. Appropriate combination of water supply security level, emergency intervention/salvation programs and crop insurance is generally sought to determine the target water supply security level, taking into considerations local conditions including cost, benefit, natural and social environments.

Design flood

There are two types of planning criteria for design flood in terms of flood protection level. One is the design flood for the safety of the dam body, in other words, the design flood discharge for spillway and /or outlet facilities. The other is the design high water level (or design flood hydrograph) for river basin flood control master plan to protect people and assets in flood prone areas.

River maintenance flow

Japan and most European countries have a planning criterion to allocate the minimum amount of river maintenance flow in a water supply master plan. It is called as the essential flow, environmental flow or ecological flow, depending on nation’s water environment management policy. The amount of flow varies depending on the local conditions. In Tunisia, such concept does not exist at present.

Adoptive Flood Control Plan

Flood control plan shall be created so that various facilities and measures which are constructed to meet the design flood hydrograph (or the design high water level) will be mutually harmonious technically and economically throughout the river system. Moreover, it can satisfactorily accomplish the objective functions of the plan. Overall examination shall also be made in forming the flood control plan on such river functions as flood control, water utilization and environment.

In addition, the following three matters are to be clarified in the flood control plan:

i) Forecast models of occurrence of excess flood and the related damages caused,
ii) Clarification to the related regional society regarding the maximum limit of the flood that can be accommodated by the flood control plan and the method of how to cope with the flood, consequently obtaining prior adequate measures

against the occurrence of excess floods, and

iii) Provision of a plan which can disperse as far as possible the damages due to the excess flood within the scope of technical and economical feasibility.

It is technically and financially not feasible to consider protecting all the people and their assets from flood damages through implementing structural measures only. This is deemed related to financial constraints of the government. Appropriate institutional and organizational framework is to be sought to establish adoptive flood control plan covering:

- Appropriate combination of structural measures, land use control, FFWS, emergency salvation, insurance, operation& maintenance,
- Adaptive target flood control level based on a cost benefit concept.

6.7 Environmental and Social Considerations

EIA in the planning stage is not legally required in Tunisia. The Study, however, include execution of an Initial Environmental Examination (IEE) in the planning stage, in accordance with JICA Strategic Environmental Assessment and the Environmental and Social Consideration Guidelines. IEE is the first review of the reasonably foreseeable effects of the proposed actions of flood control on the natural and social environment. There is a possibility that structural and non-structural measures proposed through the Study may pose risks in inducing adverse effects to local people and environment to some extent. IEE is undertaken in the Phase-II field work in Tunisia and identifies key issues that require full investigation. Issues that are not likely to be significant based on the measures proposed will be disregarded. The Study follows the basic concept and procedure of the environmental laws and decrees relating to EIA in Tunisia.

In line with strategic decision making and according to JICA environmental and social considerations guidelines, the two participatory approaches, namely an interview survey to affected people and stakeholders' meetings, were undertaken in the upstream, mid-stream and downstream reaches of the Mejerda River basin to survey social opinions and acceptance of flood control measures. These measures are to be well provided in harmony with public expectations of the residents in the flood prone areas against flood risk and damages. The achievements through the participatory approaches can serve as guides on what can be considered relevant from the problems and issues identified.

Part 3

PHASE-II STUDY:

FORMULATION OF THE MASTER PLAN

CHAPTER 7 HYDROLOGIC AND HYDRAULIC STUDIES FOR FORMULATING THE MASTER PLAN

7.1 General

The purposes of the hydrologic and hydraulic studies at the stage of formulating the master plan are:

- To estimate hydrographs of different probable floods from each sub-catchment to be utilized for reservoir operation and inundation analyses (flood runoff analysis),
- To estimate inundation areas, depths and durations caused by different probable floods (flood inundation analysis), and
- To reveal the present sediment conditions in the river channel as background information for formulating the river improvement plan (sediment analysis).

7.2 Flood Runoff Analysis

7.2.1 Basic Concept and Conditions of Flood Analysis

(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 reservoir operation study.

A six-day rainfall was applied to this analysis, because this duration is sufficient to cover major one-peak rainstorms which produced one peak hydrographs in the past serious flood events.

The flood magnitudes along the Mejerda mainstream are described based on excess probabilities of six-day basin rainfall in the hydrological zones (HY-M, HY-U1, HY-U2, HY-D1 and HY-D2) shown in **Figure 7.2.1**. These hydrological zones were defined following the zoning of the study area for flood control planning. This concept of basin average rainfall came from the investigation results of isohyetal maps of the past major floods, which explains that the rainfalls covered the almost entire basin during the extensive flood events. Isohyetal maps of major floods are in **Data A4 in Data Book**.

Applying basin average six-day rainfall for the discussion of the scale of flood, simultaneousness of rainfall in one flood event can be obtained.

(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. 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 Algerian border were derived from the probability analysis of the observed peak discharges at the Ghardimaou and K13 stream gauging stations (see **Section 4.1.3**). Probable discharges at K13 were converted to the one at BP-AM, the confluence of the Mellegue and the Sarrath Rivers (see **Figure 7.2.1**) based on the differences of the catchment area. 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

7.2.2 Flood Runoff Analysis

(1) Rainfall analysis

The daily rainfall records at gauging stations furnished by DGRE were utilized for the analysis. Those point rainfalls were first converted to daily basin rainfalls by the Thiessen method. Then, frequency of annual maximum six-day basin rainfall was analyzed, and probable six-day basin rainfalls were assigned to each hydrological zone (HY-M, HY-U1, HY-U2, HY-D1 and HY-D2).

The derived probable rainfalls are summarized in the following table, while **Table 7.2.1** lists the six-day basin rainfalls and their probabilities related to the past major floods. For the sake of simplicity, the six-day basin rainfall for HY-U2 was determined to be applied also to HY-D1 and HY-D2, since their values are similar.

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

Design hyetographs were developed from the temporal distribution pattern of a peak of typical rainfalls in available hourly rainfall data observed, during the experienced major floods (1973, 2000, 2003, and 2004).

(2) Unit hydrograph

Figure 7.2.2 illustrates sub-catchments for runoff analysis, and **Figure 7.2.3** schematically shows the runoff analysis model.

The dimensionless unit hydrograph method was employed in this analysis for computing runoff from subcatchments, in consideration of the basin characteristics, data availability, and the required accuracy for a master plan study. A dimensionless unit hydrograph for the study area can be derived from observed hydrographs in the basin, and it allows expressing runoff characteristics in the study area. Among recorded hydrographs of the past major floods at the major gauging stations, the observed hydrographs at Ghardimaou and K13 gauging stations 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 7.2.4** shows the applied dimensionless unit hydrograph.

The dimensionless unit hydrograph was converted to a unit hydrograph for each sub-catchment applying required parameters, such as the catchment area and a lag time. **Figure 7.2.5** presents examples of obtained unit hydrographs against a unit excess rainfall of 10mm in 1 hour.

(3) Probable floods

The rainfall inputs (design hyetographs) were transformed to runoff from each sub-catchment. The 2, 5, 10, 20, 50, 100 and 200-year probable runoffs were computed. The computed runoff hydrographs for sample sub-catchments are compiled in **Data A5 of Data Book**, and peak discharges of runoff from each sub-catchment are listed in **Table 7.2.2**.

The resulting discharges at the base points along the Mejerda River have to be computed from the runoffs from each sub-catchment. In the Mejerda River network, runoff hydrographs from sub-catchments are transformed and mitigated by reservoir operation as well as flood routine along the river channels. Therefore, in this analysis, hydrographs at the base points were computed by the commercial software called MIKE BASIN which can simulate reservoir operation together with river channel flood routine. **Figure 7.2.6** presents simulated peak discharges of natural (without dam), current (“Standard dam operation”) and improved reservoir operation (“Optimised Operation 2030”) cases at some base points. Inflow hydrographs from the Algerian part of the Mejerda basin was derived from hydrograph records as mentioned in **Section 7.2.1**. 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**.

In order to verify the derived probable floods at the base points, specific discharges of the acquired probable floods were examined in comparison with the ones from other sources, such as:

- Probability analysis results of observed discharges at gauging stations in the Study and existing studies (e.g. “Monographies Hydrologiques”, 1981), and

- Probable discharges at existing and planned dam sites in existing studies/designs.

Figure 7.2.7 plots specific discharges at various base points in the study area. This proves that the specific discharges for the probable floods obtained in this analysis are plotted along curves formed by the specific discharges in the existing studies.

Recorded and simulated hydrographs were also compared.

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

7.3 Flood Inundation Analysis

7.3.1 General

The purposes of the inundation analysis for the 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 with different probabilities, 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 was simulated. The simulation results have been utilized to estimate and evaluate flood damages (benefits from reservoir operation and river improvement) for establishing flood control planning.

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

Cases	Reservoir Operation Types	River Channel Conditions
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 types and the river channel conditions in the above table are briefly described below. Details are discussed in **Supporting Reports C and 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 Conditions	
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

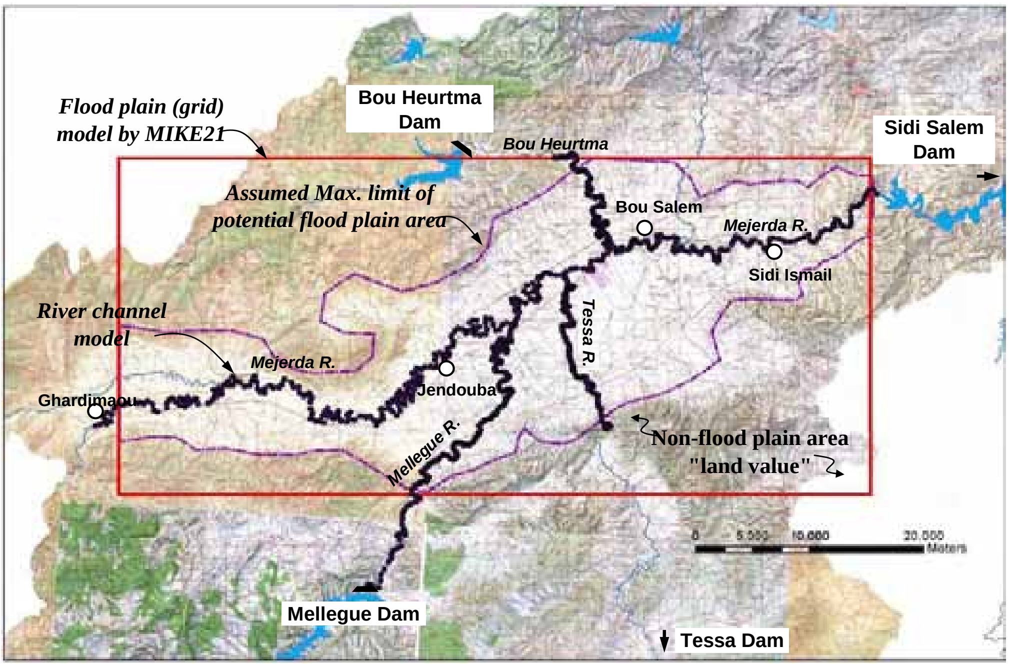
7.3.2 Methodology

(1) Overall model description

The unsteady two dimensional model was employed to the inundation analysis for the Study. The unsteady analysis was chosen because it allows investigating temporal changes of flood behaviours including the inundated area, water levels and discharges. Further, the two-dimensional model was applied to simulate the widespread inundation area observed during the experienced floods, especially in the downstream area. The commercial software MIKE FLOOD authored by DHI was used for this study. It enables combination of one dimensional (1-D) and two dimensional (2-D) hydraulic models.

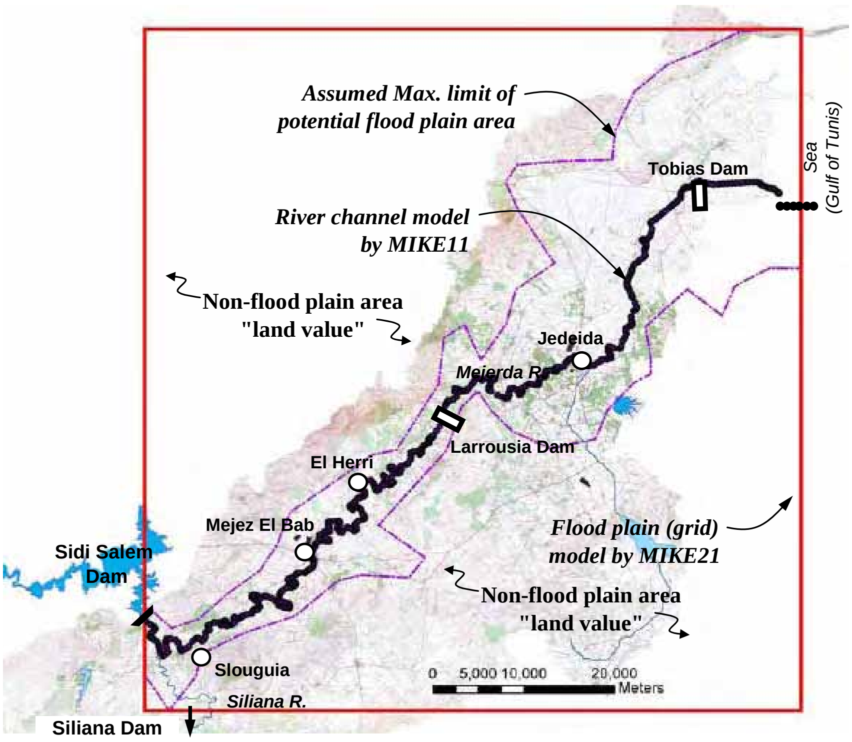
This section briefly discusses the simulation model, and its details are contained in **Data A6 in Data Book** (Training Text: Explanation Note on Inundation Analysis Model (MIKE FLOOD) for the Mejerda River Basin).

The inundation analysis model for this master plan study has been designed to cover potential flood plains in the entire Mejerda River basin. The model was divided into two models representing the upstream and downstream zones of the Sidi Salem Dam. since the dam separates the hydraulic conditions of flood inundation of the two zones. The following maps indicate the extent covered by the models.



Source: the Study Team

The Area Covered by Mejerda Upstream Model



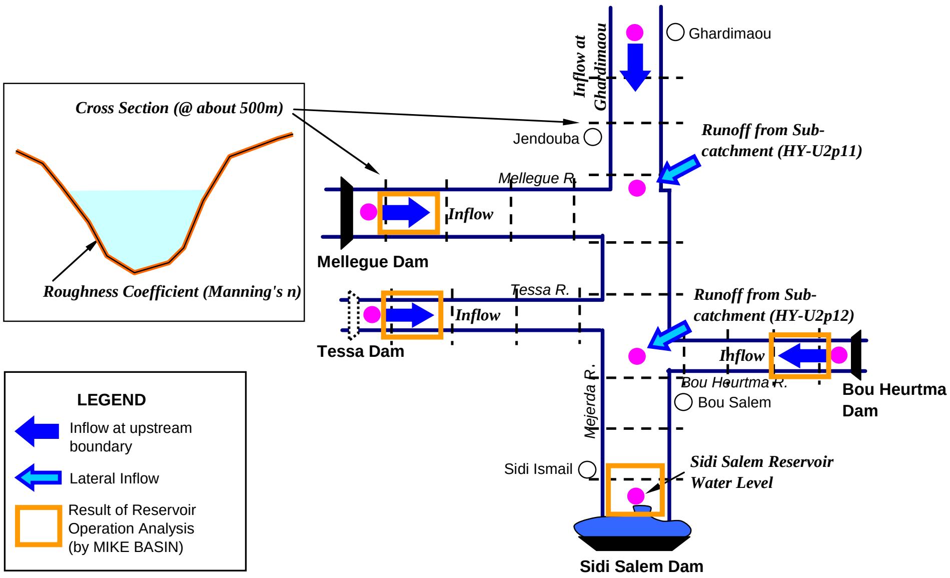
Source: the Study Team

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. The 2-D part of the model was constructed along the 1-D model river 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 500 m). An independent model with a smaller grid size (76m x 76m) was prepared only for Bou Salem City area so as to reproduce actual inundation conditions attributing to locally low banks of the Bou Hertma River.

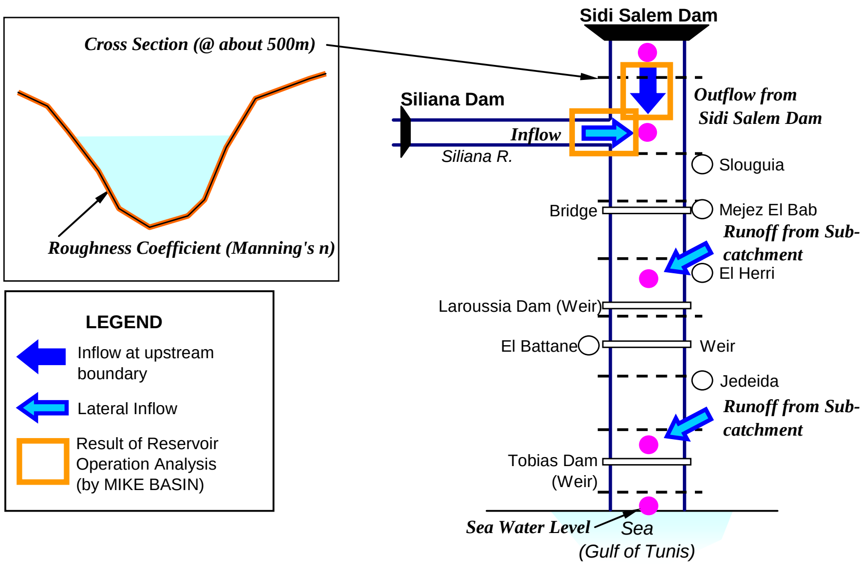
(2) Data applied and boundary conditions

Major required inputs for building the model are illustrated below. As shown, the inundation analysis model necessitates dam outflow discharges as its inputs, resulting from the reservoir operation simulation using the MIKE BASIN software in **Figure 7.2.6**.



Source: the Study Team

1-D (MIKE11) Mejerda Model for Upstream of Sidi Salem Dam



Source: the Study Team

1-D (MIKE11) Mejerda Model for Downstream of Sidi Salem Dam

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

Upstream of Sidi Salem Dam	• The 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 the periods of major floods, following the present operation.

7.3.3 Calibration of Models

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

Based on the comparison among observed hydrographs during the past major floods, the MIKE FLOOD simulation results and the MIKE BASIN simulation results, the simulation result based on the MIKE FLOOD model has been confirmed to tally with the observed records and the MIKE BASIN results.

7.3.4 Inundation Analysis Simulation Results

Examples of inundation maps prepared by the inundation simulation results are shown in **Figure 7.3.1**. Other inundation maps for various cases are presented in **Data A7 of Data Book**. Findings of the inundation analysis are briefly described below.

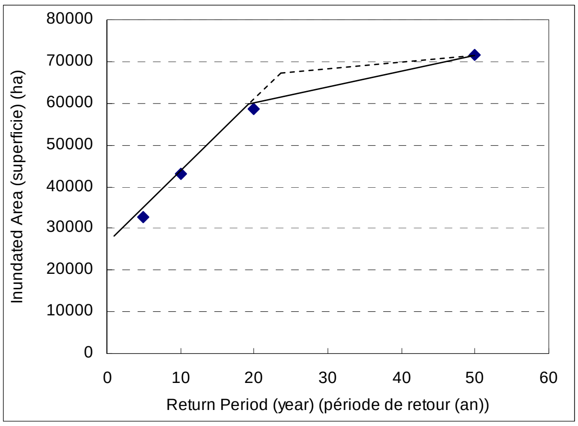
(1) Inundation under Present Conditions (Before Project Case)

The simulated total inundated area according to the return period (5 to 50 years) is summarised in the following table. In terms of the area of inundation, the region covering Jedeida to El Mabtouh low lying area (in D2) appears to be 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.

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
Upstream 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
Downstream 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)



Inundated area (simulation) and Return Period

As shown in the figure at the right, the inundated area expands with an increase of the flood scale of up to around 20-year period, but for larger floods with higher return periods an increase rate of the area drops. This trend would be brought by the topographical limit of flood plains.

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

(i) 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 City
  - Around the confluence of the 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 ten 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.

(ii) Downstream of Sidi Salem Dam

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

- The following areas are susceptible to inundation, even in the cases of five-year and ten-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 for a week or more.

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

- When the magnitude of flood reaches the 20-year probability, the inundation can be observed also in the following areas

- 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 overflow is (i) upstream of Larrousia Dam, (ii) downstream of Jedeida City, and then (iii) El Battan-Tebourba area.

(2) Inundation under After Project 1 condition (Improved reservoir operation)

The first step of the "After Project Condition" considers improved reservoir operation with present river channels. The table below compares the inundated area of the before project condition and the first step of the "After Project" Condition.

Inundated Area before and after Project 1 (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 1 -Reservoir Operation	1,800	4,200	8,900	14,800
Downstream				
Before Project	29,900	37,400	48,900	56,500
After Project 1 -Reservoir Operation	20,600	35,900	44,900	55,900
Upstream + Downstream				
Before Project	32,600	43,100	58,500	71,500
After Project 1 -Reservoir Operation	22,400	40,100	53,800	70,700

Source: the Study team (Simulation result)

The major inundation characteristics of the After Project 1 case are summarized below.

• With the improved reservoir operation followed by reduced outflow, the inundated area becomes smaller than the present condition. However, this effect becomes less remarkable as return period increases. This is directly related to the regulated peak outflow discharges from the dams.
• Inundation could still occur even after the improvement of reservoir operation.
• The overall characteristics of inundation behaviour, such as overflowing fragile reaches and flow directions, basically corresponds to the Before Project case, except for 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 at the downstream of the Sidi Salem Dam.

(3) Inundation under After Project 2 (Improved reservoir operation and River improvement)

The second step of the "After Project Condition" is the combination of improved reservoir operation and river improvement. Inundation of various river improvement alternatives has been simulated for each probable flood 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 were determined to be the most appropriate scales for the river improvement plan. (See **Chapter 8**.) **Figure 7.3.1** compares the inundation maps of the selected cases of before and after project conditions.

As shown in the Figure, some inundation still remains even after implementation of river improvement works. These inundation 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 **Chapter 8** and **Supporting Report D**.

7.3.5 Comments on Conceivable Inundation Analysis at the Future Stage

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

- For the Study, the model was generated applying 500 m intervals of cross sections, and topography grid data with a size of 228m x 228m. The intervals and grid size led to obtaining accurate results adequate for the master planning study of inundation analysis. However, for more detailed analyses of the future stages, higher resolution of grid topography data (smaller grid size) and shorter interval cross sections need to be applied in order to simulate more sporadic hydraulic phenomena.
- For the more detailed analysis with a 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 only, instead of using the models for the Study that covers the entire upstream or downstream areas.
- A new set of cross-section survey might be required when the model is updated in the future. This is required because intervals will be smaller than those in the current model, and because cross section shapes might change due to future sedimentation or erosions. The roughness coefficients might also be updated in consideration of vegetation conditions.
- More structures may have to be included in the future model with higher resolution, if necessary.

7.4 Sediment Analysis

7.4.1 General

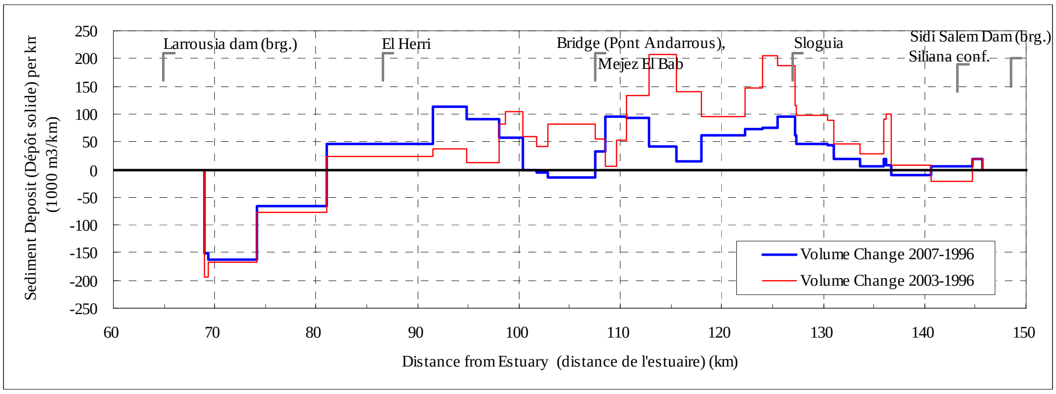
In order to sustain an expected river channel capacity conveying flood water, periodic maintenance dredging/excavation of river channel is indispensable if sedimentation prevails against scouring in the river channel of the Mejerda River. A general tendency of sediment deposits in the river channel was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

In this analysis, a general tendency of sedimentation in the river channel over time was evaluated based on cross section geometry data. 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.

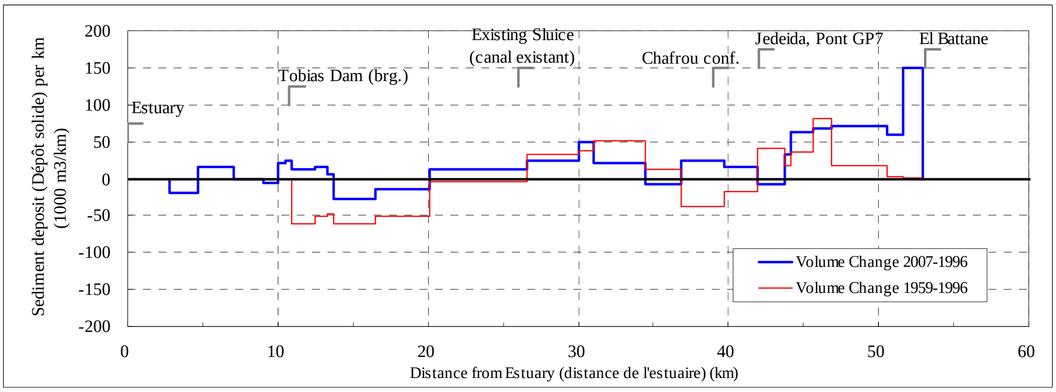
7.4.2 Preliminary Estimate of Sedimentation Amount in the Mejerda River

The cross sectional survey results conducted in 1996, 2003 and 2007 by MARH in the downstream of the Sidi Salem Dam have been compared to examine the amount of changes. The 2003 cross section data exist only for the stretch between the Sidi Salem and Larrousia Dams, whereas the other two sets of data cover the Sidi Salem Dam to the estuary. Although a number of cross sections in 1959 were also available, those were not used in this analysis due to limited availability and lack of reliability.

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 shown 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) El Battane – Estuary

Source: the Study Team

Sediment Deposit (or Scouring) Volumes against River Channel of 1996

The following are findings observed:

- Comparison of existing data indicates that the flow capacities of river channel are not in a constantly decreasing trend. Changes vary with locations along the river. Besides, even at the same location, the river channel has been scoured for certain periods and has accumulated sediment deposits for other periods.

- In general, existing records suggest that sedimentation prevails against scouring, and the flow areas tend to decrease accordingly.
- In the Mejerda River, deposits are often observed on riverbanks rather than at riverbed. Then, to restore flow capacities, scouring could occur at the riverbed. Hence, in the Mejerda River, deposition which causes reduction of flow capacity does not always mean riverbed aggregation.
- Deposits from 1996 to 2003 generally show higher volume than those of from 1996 to 2007. This would result from frequent floods from 2003 to 2005, after a relatively drought period between 1996 and 2002.

The average sediment amounting between 1996 and 2007 was determined to be utilized for discussing long-term averages of sedimentation in the river channel downstream of the Sidi Salem Dam in the analysis. This period is preferable for the analysis purposes, since cross sectional data for these years were adequately available and reliable, and because this period also includes both flooding and drought years impartially.

The following table compiles 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	
	Testour	-	Slouguia		11.0	30	2.727	0.030	0.036	0.018	
	Slouguia	-	Mejez El Bab		19.5	75	6.818	0.133	0.160	0.080	
	Mejez El Bab	-	MD145, 100 km from estuary (100 km de l'estuaire)		7.9	0	0	0.000	0.000	0.000	
	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	
	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	
	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 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	
	El Battane	-	Jedeida		11.4	70	6.364	0.073	0.087	0.044	
	Jedeida	-	Chafrou		2.7	10	0.909	0.002	0.003	0.002	
	Chafrou	-	Existing Slouice (Existants canal)		12.9	20	1.818	0.023	0.028	0.014	
	Existing Slouice (Existants canal)	-	Tobias		15.3	10	0.909	0.014	0.017	0.009	
	Tobias	-	Estuary (Estuaire)		10.8	0	0	0.000	0.000	0.000	
	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

In summary, the long-term average sedimentation in the Mejerda River basin can be as shown below, based on the preliminary estimate obtained from the analysis.

Zone	**C.A*** km^2	**River Length** km	**Sediment 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 upstream of the Sidi Salem Dam where past cross sectional survey results along the channel were not available, the sedimentation rate for Zone D1 was applied, because the D1 catchment shows similar geographical and land use features to those of the upstream basins.

It should be noted that reduction of flow capacity in the Mejerda River depends not only on sediment deposits, but also on growing bush trees in the river channel, according to investigations of several sources, including the above analysis results and actual site conditions. For instance, the channel width and flow capacity of the Mejerda is often said to halve or reduce even more in these two or three decades, and is often said that was due to heavy sediment loads. However, such stories do not consider separation of impacts of sedimentation and vegetation. This is considering that the increased channel roughness due to thick bushes and shrubs has alos 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 order to secure conveyance of water and maintain design flow capacity in the Mejerda River basin, cutting / removing bushes in the river channels, as well as removal of sediment deposits, is necessary.

CHAPTER 8 STUDY ON ALTERNATIVE PLANS OF THE MASTER PLAN

8.1 Basic Strategy for Master Plan Formulation

The primary purpose of the Study is to formulate a master plan for sustainable control and management of floods in the Mejerda River. The ultimate goal of the Study is to eventually accomplish implementation of the flood control measures in accordance with the master plan in order to achieve safety against flood events and security of social welfare as well as to benefit the State in terms of regional and national economic development. The proposed master plan will provide an action plan and indicates the direction towards which comprehensive flood control and management for the Mejerda River should go. Hence, the measures to be proposed under the Study shall be realistic and practical.

In view of the above, the master plan has been formulated based on the following strategies.

(1) Comprehensive approach for flood control on the basis of the concept of Integrated Flood Management (IFM)

Flood management has focused on defensive practices, although it is recognized that over the recent years, a paradigm shift from defensive action to proactive management of risks due to flooding is required. The paradigm shift encourages implementation of IMF, which is a process promoting an integrated, rather than fragmented, approach to flood management and seeks to integrate land and water resources development in a river basin, within the context of Integrated Water Resources Management (IWRM). This consequently leads to management of floods based on risk management principles in order to optimize the net benefits from flood plains, while minimizing the loss to life due to flooding.

When implementing policies to maximize the efficient use of the resources of the river basin, efforts should be made to maintain or augment the productivity of flood plains. On the other hand, economic and human life losses due to flooding cannot be ignored. Treating flood as an isolated problem is a localized approach and not preferable. Hence, IFM calls for a paradigm shift from the traditional fragmented approach of flood management.

The defining characteristic of IFM is integration, expressed simultaneously in different forms: an appropriate mix of strategies, points of interventions, and types of interventions (namely, structural/non-structural measures and short-term/long-term measures). It is also intended as a participatory and transparent approach to decision making, particularly in terms of institutional integration and how decisions are made and implemented within the given institutional structure.

Therefore, an IFM plan should address the following five key elements that would seem to logically implement managing of floods in the context of an IWRM approach:

- Manage the water cycle as a whole,
- Integrate land and water management,
- Adopt a best mix of strategies,
- Ensure a participatory approach, and,
- Adopt integrated hazard management approaches.

Therefore, in order to thoroughly address the issues of flood control in the Mejerda River basin, it is essential to adopt the comprehensive approach based on the concept of IFM in formulating the master plan.

(2) Priority to water supply security

There is limited precious resources of water in Tunisia, located in arid and semiarid zones. It needs to be ensured that no drop of water is wasted. Hence, the government has developed a national water management plan placing precedence to water use. Consequently, the water demand and supply balance and water resources administration has been managed as a whole system in Tunisia, and securing the amount of water required, by exploiting relatively abundant surface water in the northern area including the Mejerda River basin, is a crucial key issue in Tunisia.

In consideration of the above, the flood control plan in the Majerda River basin should seek harmony with the water use plan in the basin, assigning priority to realization of water supply with required security, because there would be a tradeoff between the water supply risk and the flood control risk.

(3) Share of roles between structural and non-structural measures

Absolute protection from flooding is neither technically feasible nor economically or environmentally viable. Therefore, it is essential that flood control measures should aim at minimizing flood damage, and combining structural and non-structural measures appropriately.

The structural measures are intended to prevent inundation up to a design flood of the measures and are given a design flood which is both technically and economically feasible, as well as environmentally sound. The non-structural measures meanwhile focus on mitigating related damage due to excess floods which exceed the design flood. In addition, the non-structural measures shall also be expected to sustain flood preventing capacities of the structural measures.

Flood event is a natural phenomenon and thus the events of extraordinary floods which may cause devastating damage within its affected areas are anticipated. Such events, however, should be categorized into a national crisis event which could paralyze the state’s function and should be regarded as an overwhelming calamity beyond the extent of responsibility to be shouldered by flood control under river administration. With this perception, the Study has proposed that the non-structural measures in the master plan deal with flood events of up to a 100 year return period, within the task of river administration.

(4) Attention to public acceptance to flood control measures

Flood control measures need to be well provided in harmony with public expectations of the residents in the flood prone areas against flood risk and damage. Therefore, an interview survey to the residents on public acceptance of flood risk and two public consultation meetings with stakeholders, including central/local governmental agencies and local residents, were conducted in the upstream, middle and downstream reaches of the Mejerda River basin in order to sound social needs, views, opinions and acceptance to flood control measures and utilize them as relevant information for decision making process for the plan formulation.

The achievements of the interview survey and public consultation meetings are compiled in **Table 8.1.1** and are to be reflected in the master plan.

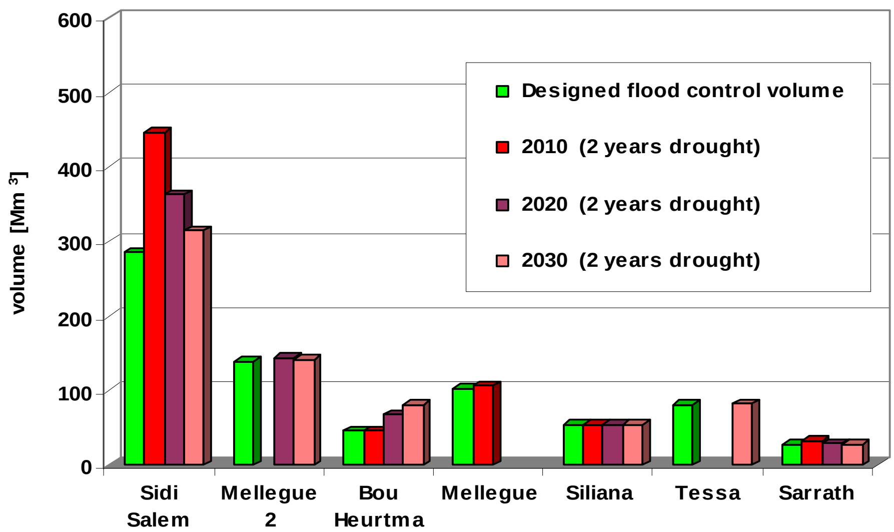
The existing Andalous Bridge in Mejez El Bab City and an old weir in El Batten City on the Mejerda River are the remains of high historical value, constructed in the 17th century, which need to be carefully taken into account in terms of environmental and social considerations. The interview survey has clarified, as referred to in **Table 8.1.1,** that the residents hope to maintain the existing historical structures as they are. In addition, the national policy of Tunisia requires preservation of historical remains, without any removal/change. The master plan shall pay careful attention to the desires of the residents and the national policy for historical remains.

8.2 Reservoir Operation Plan for Flood Control

8.2.1 Necessity of Optimized Reservoir Operation

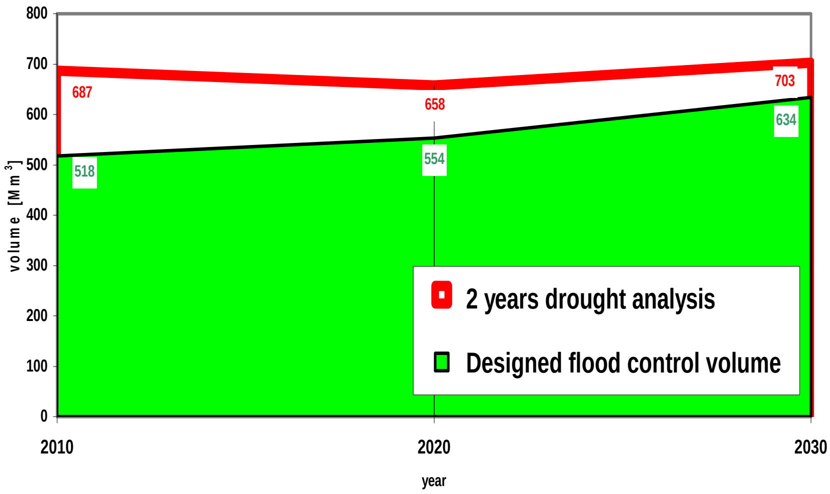
The originally designed reservoir storage capacity for flood control in the Mejerda River basin cannot be fully utilized at most of the existing reservoirs for mitigating flood flow. In addition, many reservoirs are equipped only with an uncontrolled spillway (non-gated spillway) and hence, the designed flood control storage is activated without any flexible regulation achieved through gate operation.

Based on the above, the key to improving flood control function of the dams is to determine some permanent or temporary additional flood control storage for each reservoir. The additional flood control storage which could be secured bellow the spillway crest can be effectively used by operating the bottom outlet(s).



Flood Control Storages for 2010, 2020 and 2030 in 7 Selected Reservoirs

Comprehensive water demand and supply balance analysis was done for the years 2010, 2020 and 2030 (the target year of the Study) in the Study (see Supporting Report B). Its results showed that some additional flood control storages can be found at some reservoirs. The possible increase of flood control storages of seven reservoirs (four existing reservoirs: Sidi Salem, Mellegue, Bou Heurtma and Siliana Reservoirs; and three reservoirs under construction or in a design/plan stage: Sarrath, Mellegue 2 and Tessa Reservoirs), which are important for flood control in the Mejerda River, is seen in the figure above for the years 2010, 2020 and 2030. As shown, originally designed flood control storage (the green bar) and increased ones (other colored bars), which are derived from the water demand and supply balance analysis under the typical two consecutive dry years with designed water supply security of a once-in-9 time (18 year) recurrence, are compared for each reservoir. It is evident that only at the Sidi Salem and the Bou Heurtma Reservoirs, some significantly additional flood control storage can be found. The total increase of flood control storages in all seven selected reservoirs is as plotted in diagram below. The total flood control storage could be increased up to 687 mil. m^3 in year 2010 (by 33 %) and up to 703 mil. m^3 in the target year 2030 (by 11 %).



Possible Increase of Flood Control Storage in 7 Selected Reservoirs

The key for optimized operation of dams is to facilitate well timed release of water from the reservoir (at the beginning or even before occurrence of floods) considering "flow capacity" of its downstream river course as its limiting factor.

Prior to deciding on reservoir release, it is necessary to optimize releasing based on information on the inflow from the upstream, several rainfall/water level gauging stations in the downstream and knowledge of flood propagation times to the downstream. Furthermore, it is necessary to determine the release so as to prevent flood peaks of two or more sub-basins from joining at one site. This is another key consideration which could be implemented through well coordinated dam operation.

The effective use of available flood control storage including additional storage, and the coordination of dam operation is essential for the flood control requirements in the Mejerda River basin, in view of the hydrological characteristics in the basin regarding the flood runoff mechanism and flood propagation.

Currently, detailed rules of reservoir operation during floods have not been formally documented as part of the operation standards or manuals in Tunisia. Guidelines entitled "Flood Management of Main Rivers in Tunisia and Operation of Hydraulic Facilities" were prepared by DG/BGTH in year 1988. However, these are not applied at present to actual operations of flood related facilities. Besides, though a general framework of reservoir operation is commonly determined among stakeholder organizations concerned in due consideration of storage conditions of other dams, regional rainfalls, overall conditions of the river system concerned, etc., actual reservoir operation depends on experiences and ad hoc decisions of the operation staff at site.

In view of the above, it is essential to introduce an optimized operation system of dams based on firm and reasonable operation rules, supported with computerized mathematical models of flood forecast and reservoir simulation so as to effectively and efficiently minimize flood discharges in the Mejerda River basin.

8.2.2 Fundamental Rules for Optimized Reservoir Operation

The 14 reservoirs (eight existing and six under construction or in a design/planning stage) in the Mejerda River basin have established in fact a water management structure. All these reservoirs must be operated as one structure, i.e. in a coordinated phase. Thus, it is necessary to provide fundamental rules to be followed at any time in order to realize an optimum dam operation including coordination, for the most effective flood control and for successful water supply as well.

The main goal of optimum reservoir operation is to use the available flood control storage above the normal water level (NWL) as effectively as possible, and to minimize flood peaks downstream of dams. Therefore, the following should be carefully considered as the fundamental rules for reservoir operation:

(a) During non-flood periods:

- Maintain the water level in reservoirs properly at NWL (actually valid and approved), which is designed for suitable water supply regulation.

(b) During floods:

- The highest priority has to be given to safety of dam in all operations.
- Pre-release of reservoir water

  The water level in reservoirs shall be lowered as soon as the information about flood attack is issued. The water to be released shall be equal to the anticipated flood discharge reaching the reservoir during the flood event and up to the flow capacity of the downstream river channels (hereinafter referred to as "the channel capacity"). These pre-release specifications can be determined from the information on observed discharges in upstream reaches of the reservoir or from the results of discharge forecast based on rainfall data.
- Release of reservoir water equal to the channel capacity

  The release of water from the reservoir shall be operated in such a way that the downstream river does not overflow as long as possible due to releasing reservoir water.
- Avoidance of flood peaks joining at one site

  Control outflow from the dams based on information regarding flood propagation times downstream of the dams, with the aim of avoiding flood peaks from two or more sub-basins joining at one site, so as to minimize the flow downstream.
- Operating a cascade of reservoirs (e.g. Mellegue and Mellegue 2)

  Fill the upper reservoir with flood water at first and empty the lower reservoir at first,
- Release of flood control storage for next flood

  After water level culmination in the reservoir, the flood control storage must be released in preparation for the next flood. At first, the flood control storage is released through outflow, slightly exceeding inflow into the reservoir. The outflow is then continuously reduced. As soon as outflow drops to the channel capacity downstream of the dam, the reservoir water is released with "the channel capacity" discharge (or close – according to situation on tributaries) until the flood control storage is empty.

All reservoirs in the Mejerda River basin are recommended to be operational during flood events, based on the discretion of one control center, which will be constantly provided with all necessary "on-line" information (discharges in gauging stations, status and operations at all dams, discharge forecast, rainfall forecast, etc.).

8.2.3 Analysis of Flood Control Ability of Reservoirs

(1) General

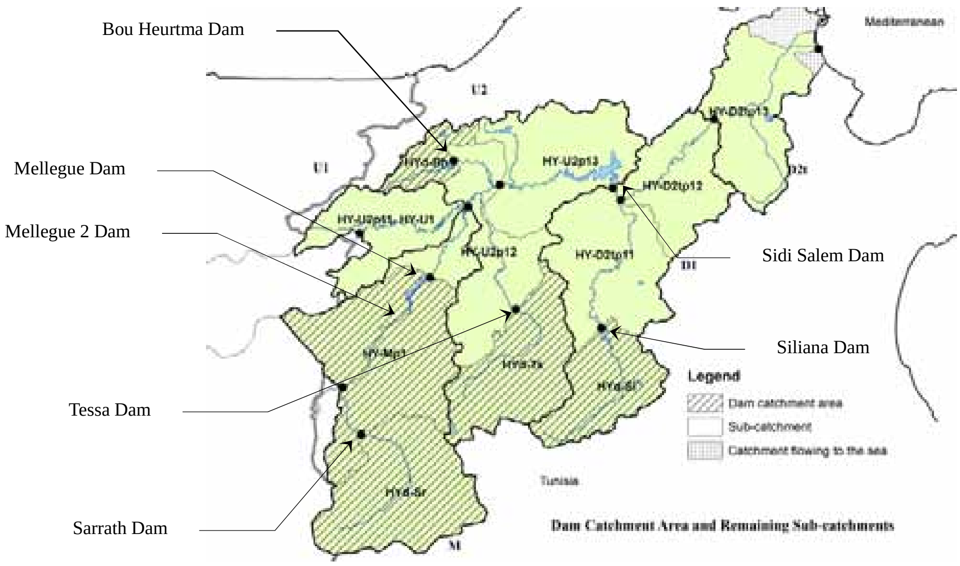
The analysis was carried out at the following four stages of flood control storages in the seven selected reservoirs:

Stages	Flood control storages
Current stage	originally designed flood control storage (OFCS) above original NWL
Year 2010 stage	OFCS + additionally available storage straight below OFCS (below original NWL) for flood control under designed water supply security* against 2010 water demand
Year 2020 stage	OFCS + additionally available storage straight below OFCS (below original NWL) for flood control under designed water supply security* against 2020 water demand
Target year 2030 stage	OFCS +additionally available storage straight below OFCS (below original NWL) for flood control under designed water supply security* against 2030 water demand

Note: * The designed water supply security is equivalent to 2-year consecutive drought with a once in 9 time (18 year) recurrence

In this analysis, the coordinated reservoir operation for flood control has been examined on condition that the designed water supply security has to be assured by priority. **Table 8.2.1** compiles the fundamental rules for coordinated operation of the seven selected reservoirs for flood control, which have been formulated in this analysis according to the "fundamental rules for optimized reservoir operation" mentioned in Subsection 8.2.2. **Figure 8.2.1** schematically presents the locations of (i) dams to be coordinated and (ii) discharge reference points required for the coordinated operation.

Analysis was performed based on floods of 2, 5, 10, 20, 50, 100 and 200-year return periods. The subdivision in the Tunisian territory of the Mejerda River basin is as shown in the figure below.



Subdivision in Tunisian Territory of Mejerda River Basin for Analysis

The Tunisian territory of the Mejerda River basin consists of:

- Five subcatchments upstream of existing and/or designed/planned dams,
- Seven subcatchments of the Mejerda River and its tributary subcatchments downstream of the dams, and
- Two inflows from the Algerian territory.

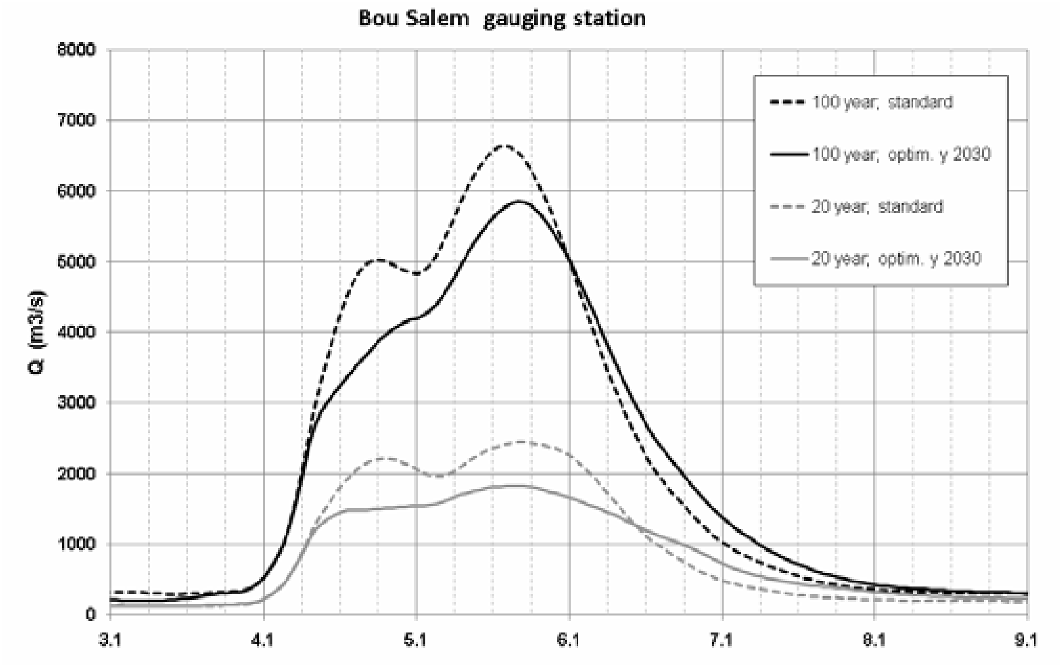
(2) Flood control ability in the target year 2030 under optimized reservoir operation

Analysis of reservoir operation in the future years up to the target year 2030 has been carried out with the aim of evaluating the contribution of reservoirs including the three newly constructed/planned Mellegue 2, the Sarrath and the Tessa Reservoirs, to the flood control in the Mejerda River. In addition, the evaluation also aims to find optimum reservoir operation at the seven selected reservoirs, in due consideration of the additionally available flood control storages under 2010, 2020 and 2030 water demands.

The fundamental rules of optimum reservoir operation mentioned in Subsection 8.2.2 were applied to this analysis (see Table 8.2.1 and Figure 8.2.1).

The analysis results are described in detail in Supporting Report C. The following exemplifies those of flood control ability in the target year 2030 under optimized reservoir operation.

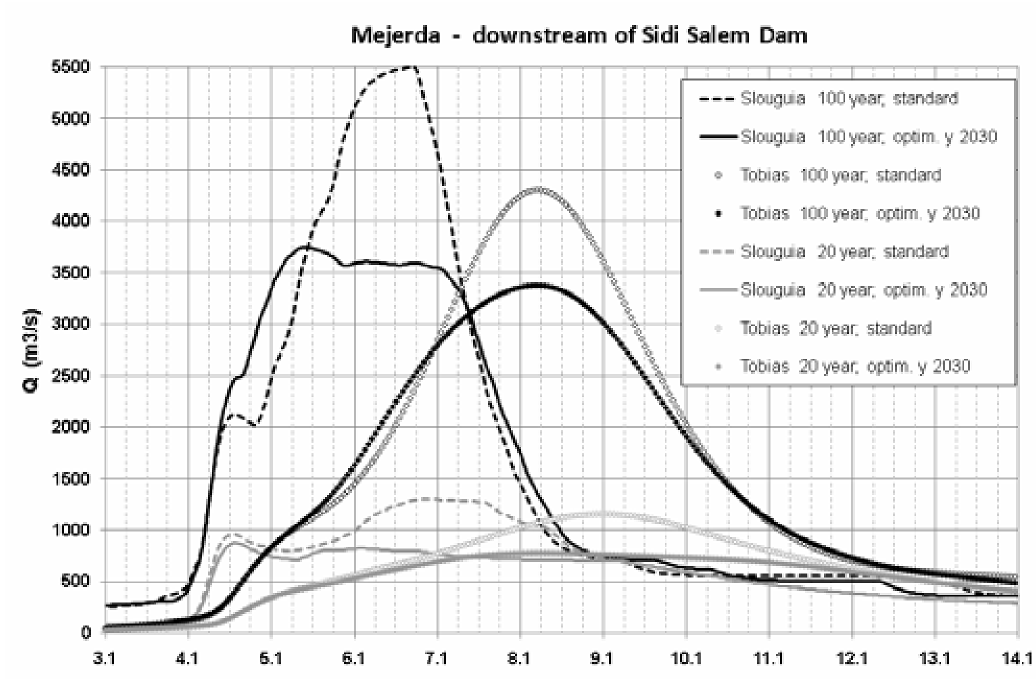
At the Bou Salem gauging station, located downstream of the Mejerda - Tessa confluence, the flood discharge at an initial stage is mitigated by the Bou Heurtma Reservoir (see the figure below). This reservoir operates under lowered normal water level of 216.77 m, which represents an additional flood control storage of 35 mil. m^3 below the uncontrolled spillway crest.



Flood Mitigation Effect at Bou Salem Gauging Station in 2030

The Sidi Salem Reservoir in the target year 2030 is able to reduce discharges even during the 100-year flood event, due to increased flood control storage of 29 mil. m^3 straight below the current normal water level and also effective operation of all reservoirs upstream of the Sidi Salem Dam.

The following hydrographs show the effects of flood control function under improved reservoir operation downstream of the Sidi Salem Dam in 2030.



Flood Mitigation Effects in Mejerda River Downstream of Sidi Salem Dam in 2030

It is found that the Sidi Salem Dam is able to significantly reduce the downstream flood discharges even during a 100-year flood. The peak discharge is reduced by 1,770 m^3/s at Slouguia and by 930 m^3/s at Tobias, which are equivalent to 22 % and 32 % reduction rates of peak discharge at respective sites. These are compared to the peak discharges under the current standard reservoir operation.

As for the 20-year flood, the peak discharges are reduced by 420 m^3/s at Slouguia and by 385 m^3/s at Tobias, indicating 32 % and 33 % reduction rates of peak discharges at the sites, respectively.

In addition, the flood control effect of coordinated reservoir operation is discussed in terms of inundation area in Subsection 7.3.4 and is summarized below, presenting the whole Mejerda River basin in the Tunisian territory.

Inundation Area before and after Coordinated Reservoir Operation (unit : ha)

Return period of flood	5-year	10-year	20-year	50-year
(1) Before	32,600	43,100	58,500	71,500
(2) After	22,400	40,100	53,800	70,700
Reduction rate = (2)/(1)	69%	93%	92%	99%

Source: the Study Team (Simulation result)

As shown above, the inundation areas due to 5-year flood and 10 to 20-year floods are found to reduce by 30 % and 7 to 8 %, respectively, through coordinated reservoir operation. The distribution of inundation areas before and after the coordinated reservoir operation is as exemplified in **Figure 7.3.1**.

Based on the above, it is anticipated that adoption of improved reservoir operation at the Sidi Salem Dam could improve flood control to such an extent that related damage in the areas along the Mejerda River is significantly alleviated.

8.3 River Improvement Plan

8.3.1 Methodology of Plan Formulation of River Improvement Works

As the first priority of structural measures in the Mejerda River basin, a study was conducted on the optimization of reservoir operation rules (flood peak discharge and volume) based on projected storage volume of the seven selected reservoirs in the target year 2030. Considering the result of the said study as the given conditions, preliminary planning of river improvement works were worked out in order to determine the flood protection level.

In this purpose, following rules for river improvement were applied to decide the scale of each construction work (river reaches for improvement, channel bottom width, height of embankment, etc.), in conformity with the peak discharges under optimized operation of the reservoirs:

(1) Empirical practices/theories for planning of river channel improvement shall be applied to designed longitudinal profile and designed cross section, in order to cope with probable flood peak discharges (e.g. to approximate existing channel riverbed gradient, minimizing excavation of river banks for setting excavation line, etc.)

(2) Considering the existing inundation condition versus channel flow capacity, overtopping of the river banks is allowed to decrease water levels as much as possible (allow overtopping of river banks taking account of the current land use conditions).

(3) In connection with item (2) above, due care shall be taken not to increase flood risk at downstream areas due to widening/deepening of river channel at upstream reaches.

(4) Existing channel flow capacity should be utilized to a maximum extent to reduce the volume of channel excavation and embankment of levee, assuming design channel geometry.

(5) As for planning of a new bypass channel to augment flow capacity, practical widening of existing river channel shall be considered to a maximum extent as the first priority (accommodating excess discharge over the flow capacity of original river course by new bypass canal).

(6) Minimizing size of bypass channel shall be considered from the aspect of operation and maintenance (O&M), and appropriate proportion of peak discharges between existing channel and new bypass channel.

In particular, the opinions revealed through a series of stakeholders' meetings were substantially reflected in the plan formulation of river improvement works. In fact, as the most urgent structural measures in the Mejerda River basin, river widening and river course clearing to remove sediment and vegetation was suggested. The participants of the meetings have unanimously supported to preserve the historical inheritance such as the ancient bridge in Mejez El Bab City. The construction of a new bypass channel to control big discharge during floods has been highly suggested in the meetings as well.

Although short-cutting of meandering portion is one of the common improvement methods for stabilizing a river channel and/or lowering water level at upstream reaches, it was not applied in this study. On the other hand, some participants mentioned requirement of short-cut channel to rectify the river course in order to avoid meandering which invades their cultivated lands.

However, in order to avoid unexpected slope protection works and strengthening of levee embankment against future erosion, it was judged not advantageous in general. Further, it is envisaged that incremental land acquisition cost for shortcut channel will make the proposed improvement works less viable. It is noted that in the next study stage, short-cut of existing channel would remain under consideration for the subsequent detailed assessment of the hydraulic analysis, boundary of PHD and social impact by proposed channel improvement etc.

8.3.2 Priority Areas for River Improvement

In accordance with the basic idea mentioned above, following eight priority areas were selected through review of the past flood events, field reconnaissance and stakeholders' meetings:

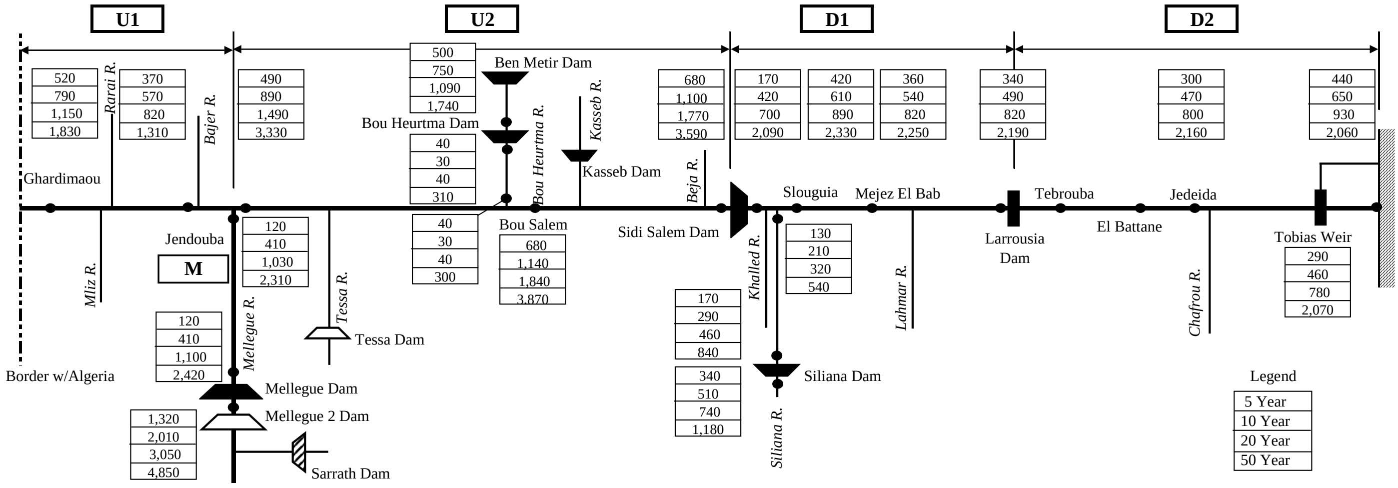
Priority Areas for River Improvement

Zone	Selected Priority Areas
U1	Ghardimaou, Jendouba
U2	Bou Salem, Sidi Ismail, U/S of Sidi Salem Dam
M	Lower reaches of Mellegue River near the confluence
D1	Slouguia, Mejez El Bab
D2	Tebrouba- El Battane, Jedeida, El Mabtouh- Tobias Movable Weir, Tobias Movable Weir – Oued El Hmadha canal (floodway)

Note: The subject area of "Zone" is described in Sub-Section 8.3.4.
Source: the Study Team

8.3.3 Configuration of River Improvement Works

Based on the reservoir operation study by integrated manner (optimum operation rules) and hydraulic/inundation analyses, probable discharges at each element of river stretches in the Mejerda River basin were computed. The distribution of the probable discharges, which was utilized for the study on flood protection level (see Subsection 8.3.4) is shown below:



Source: the Study Team

Distribution of Probable Flood Discharge

In order to determine the major dimensions of river improvement works for preliminary cost estimate in the study of flood protection level, the following basic concept was applied to meet the respective magnitude of probable discharges:

(1) Longitudinal profile of riverbed

Riverbed excavation with river channel widening was firstly considered to accommodate the discharge. As designed for setting the channel bed elevation, the longitudinal gradient of the lowest riverbed was assumed taking account of the existing channel bed profile. In particular, existing river crossing structures, such as Sidi Salem Dam, El Herri Weir, Larrousia Weir and Tobias Movable Weir, were duly considered as fixed vertical control points.

(2) Width of riverbed (Channel geometry)

The extent of river channel widening was decided in the light of existing channel width at bridge sites and dominant widths in urban areas, aiming to minimize the impact to the existing properties. Excavation lines of channel (with bank slope gradient of 1:2.0 on both sides) were fit on the cross sections based on the longitudinal gradient.

(3) Treatment of tributaries

In principle, the level back levee with the same elevation as the levee along the main stream of the Mejerda River was designed to protect the riparian areas along the tributaries.

(4) Alignment and height of levee embankment

In case that incremental capacity of discharge by channel excavation is not sufficient, levee embankment was considered at such river stretches. The alignment of the embankment was decided based on the shoulder of riverbank with proposed excavation lines. The height of levee embankment was determined based on estimated water levels and required free board.

(5) Alignment of bypass channel

In order to deal with the magnitude of probable discharges of up to a 50-year flood, four sites of bypass channel route were selected for estimating the cost of river improvement works as part of examination of optimum flood protection level. To assess the optimum flood protection level, four bypass channels at Jendouba, Bou Salem, Mejez El Bab and El Battane Cities were considered at an initial stage. After determination of flood protection level in each zone through examination of cost-benefit performance, only two bypass channels at Bou Salem and Mejez El Bab were selected. The locations of the two bypass channels selected are shown in the general plans of **Figures 9.1.1 and 9.1.2**.

As for the selected ones, some technical information is described below:

(a) Bou Salem bypass channel

Bou Salem City is one of the most heavily damaged areas related to the flood in January- February 2003. Most of the urban zone were submerged under water for about three weeks in accrdance with the “Flood Damage and Inundation Survey, March 2007”. The hydraulic model for inundation analysis was substantially calibrated through verification of flood mechanism in the current study. Due to its geographic location in the basin, situated adjacently downstream of the confluences of the Mellegue and the Bou Heurtma Rivers with the Mejerda River, it should be noted that this area is highly susceptible to floods.

In order to mitigate the flood risk, a large scale of bypass channel is required. The candidate route starts at 5.5 km upstream from the confluence with the Bou Heurtma River (No.MU124) and empties to the Mejerda at 6.9 km downstream from the Bou Salem road bridge at right bank side. The bypass with a total length of 8.0 km crosses a flat irrigated land, which is owned by the National Government. At the left downstream side of the outlet with the Mejerda River, the Kasseb River joins at MU75 in a meandering section. It is expected to utilize the river area of the meandering section for flood retarding before flowing to downstream area.

(b) Mejez El Bab bypass channel

As in the case of Bou Salem City, Mejez El Bab city is also one of the most significantly affetced areas related to the 2003 flood in the basin. In accordance with the agreement with the Tunisian side, the old Andarous Bridge (constructed early in the 17th century) crossing the Mejerda River should be preserved as it is. This means that another waterway is absolutely necessary to prevent the city and heritage bridge from inundation. In particular, the ground elevation of the city center is quite low and it makes effective flood protection in this area rather difficult.

Flood water in the subject current river stretches near Mejez El Bab City is anticipated to overflow during a 10-year probable flood event. The proposed bypass route of a total lengh of 4.7 km is located on the left side to detour at the starting point 3.4 km upstream of the historical bridge and to connect with the Mejerda River 1.9 km downstream of the same bridge. The current land use along the planned route is mainly for agriculture. Since the bypass channel is planned to cross the existing roads at four locations, the same number of new bridges should be constructed.

(6) Alignment of retarding basin at El Mabtouh

The area of El Mabtouh is located on the left side of the Mejerda River, between Jedeida and Tobias Movable Weir, which belongs to Bizerte Governorate in the north and to Manouba Governorate in the south. This plain having a total area of approximately 20,000 ha has been developed mainly into agriculture as a bread-basket to meet the increasing demand in the metropolitan Tunis.

On the other hand, a part of this area has been utilized as a natural storage area for flood water which overtopped from the Mejerda River, while some control structures remain. However, these were heavily damaged and mostly abandoned, and no restoration works have been conducted at present.

A location map of El Mabtouh Plain is shown in **Figure 8.3.1**, which contains a plan showing existing drainage system. Figures 8.3.2 and 8.3.4 show the sluiceways along the El Mabtouh Canal.

Through integration of available information, a development plan of the El Mabtouh retarding basin was studied. The basic concept of flood discharge retarding is prepared as follows:

(i) To allow flood overtopping from the left bank of the Mejerda River at Henchir El Henna located approximately 7.5 km from the confluence of the Chafrou River with the Mejerda River.

(ii) To lead the flood water toward the lowest areas as temporarily storage (Presently abandoned and partly utilized as grazing land. Cultivation is not suitable due to wet and salined soil characteristics)

(iii) To clearly delineate zones for the purpose of development by surrounding diking and a drainage canal system (existing drainage networks should be effectively connected and rearranged)

(iv) To rehabilitate the deteriorated facilities (control gates and canals, etc.) which were heavily damaged due to past floods

(v) To safely drain the stored flood water into the Mejerda River through El Mabtouh drainage canal considering the downstream flow capacity (ex. Tobias Movable Weir) as well as back water effect to the upstream

(7) Areas for allowing overflow

Considering the hydraulic conditions and land use along the upstream and downstream reaches of the subject sites, allowing overflow, particularly for retarding effect, is incorporated in the river improvement from the flood control aspect. The areas for allowing such inundation were carefully selected.

8.3.4 Basic Principle for Selection of Flood Protection Level

(1) General

Based on the framework of master plan, optimum protection level of flood control in the whole Mejerda River basin was examined. This is one of the crucial premises for the master plan formulation as an ultimate goal of the Study. In this respect, cost-benefit performance associated with combination of river improvement works such as riverbed excavation, river channel widening, embankment, and construction of bypass channel and retarding basin etc. were studied. In other words, in order to evaluate the flood protection level to further proceed with the study of structural measure(s), the preliminary cost – benefit relationship was worked out

(2) Basic approach for formulation of structural flood control measures

Aiming at maximizing the flood control effect, the following two-step measures were applied:

(i) Prioritize improvement of reservoir operation for flood control.

(ii) When the improvement of reservoir operation can not satisfactorily achieve flood control, consider river improvement to supplement the measures.

(3) Fundamental rule of river improvement

Following fundamental rules for river improvement works were applied:

(i) The river improvement is vital to alleviate urbanized areas that have suffered from serious flood damage so far, and the flood damage in the areas shall be equitably alleviated by the river improvement. Further, flood damage in the agricultural land along the Mejerda River is also equitably alleviated by the river improvement.

(ii) River improvement which has no risk of detrimental artificial flood in the downstream areas shall be employed.

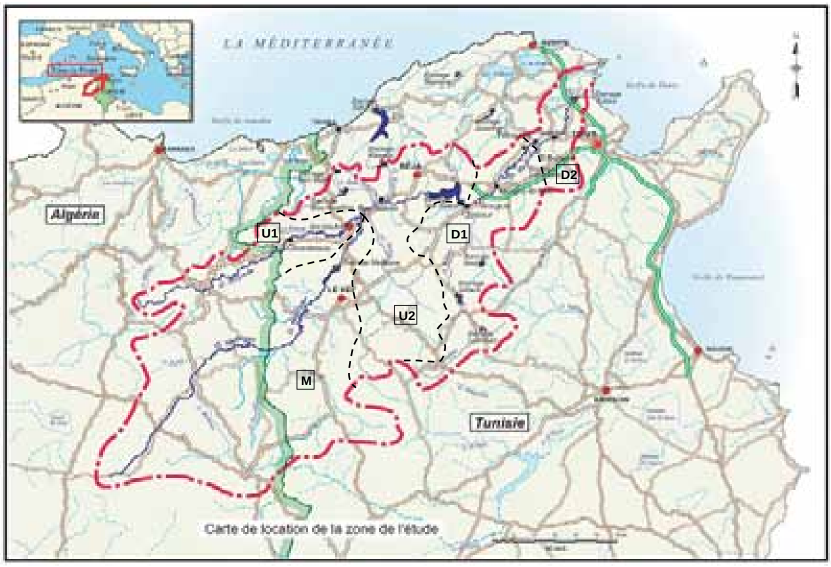
(4) Zoning (Division) of Mejerda River Basin

The study area (the Mejerda River basin in the Tunisia territory) is as wide as 15,830 km^2. Its regional importance and development level as well as regional flood characteristics is uneven in the area. Therefore, the study area is divided into five sub-basins (zones). A flood protection level is to be examined and prepared for each zone.

Since the Sidi Salem Dam accommodates a huge flood control volume, the flood control at the dam divides the continuity of flooding phenomenon along the Mejerda River.

Therefore, the study area is largely divided into two sub-basins, namely the upstream and downstream sub-basins of the dam site.

Moreover, the upstream sub-basin is divided into M, U1 and U2, while the downstream into D1 and D2, resulting in a total of five sub-basins (zones). The location map and some key information of each zone are presented as follows:



Source: the Study Team

Zoning of Study on Flood Protection Level

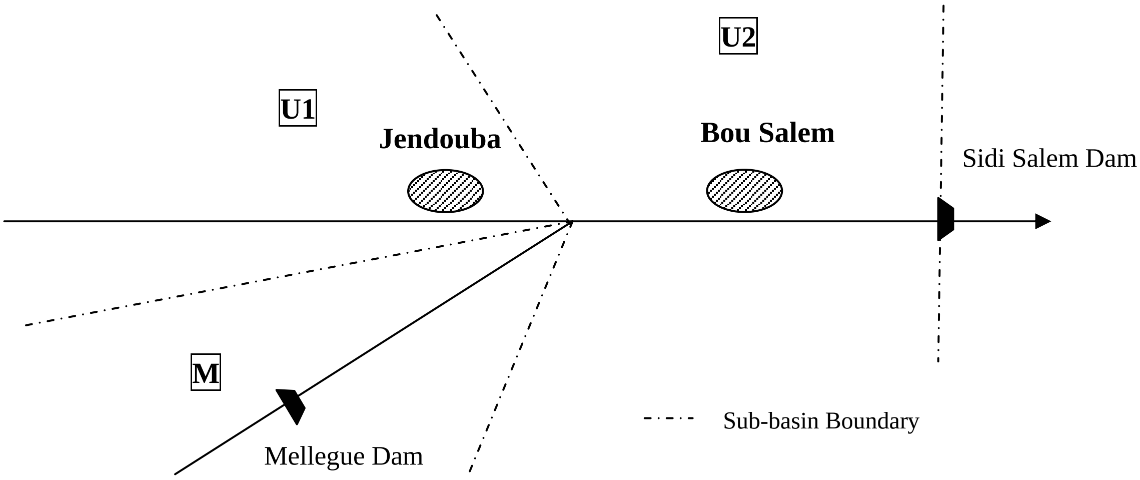
Key Information of Each Zone

Code No.	Nominal Stretch	River Stretches	Distance (km)	Cross Section No.
U1	Upper most reach	National boundary with Algeria at outskirts of Ghardimaou – Confluence with Mellegue River	94.4	MU193-MU360
U2	Upper middle reach	Confluence with Mellegue River – Sidi Salem Reservoir upstream end	63.9	MU1-MU192
M	Mellegue River	Mellegue River basin (from national boundary to confluence with the Mejerda River)	45.0 (D/S of Mellegue Dam)	MG1-MG114
D1	Lower middle reach	Downstream of Sidi Salem Dam – Laroussia Dam	83.5	MD1-MD252
D2	Lower most reach	Laroussia Dam – River mouth of Mejerda	65.0	MD253-MD447

Source : the Study Team

8.3.5 Definition of Optimum Flood Protection Level

(1) Upstream Sub-basin of Sidi Salem Dam



Source: the Study Team

Schematic Feature of Upstream Basin of Mejerda River

(a) Optimum flood protection level for U1 and M

(i) For each of U1 and M, the protection level with the highest B/C ratio is to be evaluated to determine an optimum flood protection level (B: Flood control benefit from river improvement in each zone, C: Direct construction cost of river improvement works for each region).

(ii) Areal rainfall covering each zone is to be used for estimating B in the zone.

(b) Optimum flood protection level for U2

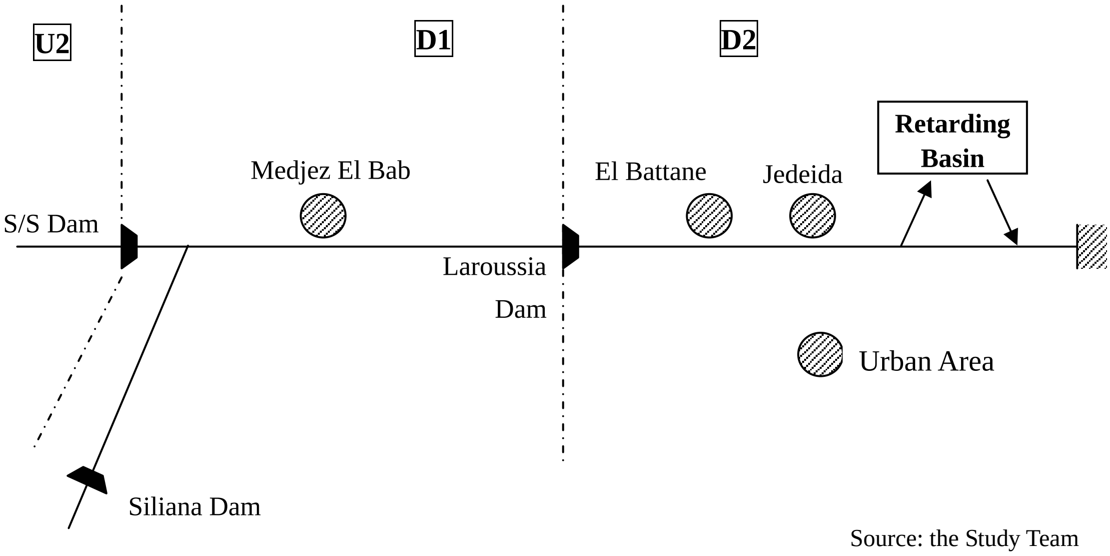
(i) Under the condition that river improvement works corresponding to the optimum flood protection levels obtained in (a) above are employed in U1 and M, the optimum flood protection level for U2 is to be assessed as the protection level with the highest B/C ratio.

(ii) Areal rainfall covering U2 and its upstream areas is to be used so as to ensure simultaneousness of rainfall occurrence for estimating B in U2.

(c) If the above river improvement works in U1 and M have risks of causing detrimental artificial flood in U2, the optimum flood protection levels in (a) and (b) are to be reviewed to avoid the artificial flood.

(d) In the review above, the protection levels with the highest ΣB/ΣC ratio for U1, M and U2 are to be evaluated to determine the optimum flood protection levels respectively for U1, M, U2 under the condition that the river improvement works in U1 and M have no risk of causing detrimental artificial flood in U2.

(2) Downstream Sub-basin of Sidi Salem Dam



Source: the Study Team

Schematic Feature of Downstream Basin of Mejerda River

(a) Optimum flood protection level in D1

(i) For D1, the protection level with the highest B/C ratio is to be evaluated to determine an optimum flood protection level.

(ii) Areal rainfall covering D1 and its upstream areas is to be used so as to secure simultaneousness of rainfall occurrence for estimate of B in D1.

(iii) Flood water retained by Sidi Salem Dam shall flow into the upper end of the Mejerda River in D1.

(b) Optimum flood protection level for D2

(i) Under the condition that river improvement works corresponding to the optimum flood protection level obtained in (a) above are employed for D1, the optimum flood protection level for D2 is to be assessed as the protection level with the highest B/C ratio.

(ii) Areal rainfall covering D2 and its upstream areas is to be used so as to secure simultaneousness of rainfall occurrence for estimate of B in D2.

(c) If the above river improvement works in D1 have risks of causing detrimental artificial flood in D2, the optimum flood protection levels in (a) and (b) are to be reviewed to avoid the artificial flood.

(d) In the review above, the protection levels with the highest ΣB/ΣC ratio for D1 and D2 are to be evaluated to determine the optimum flood protection levels respectively for D1 and D2 under the condition that the river improvement works in D1 have no risk of causing detrimental artificial flood in D2.

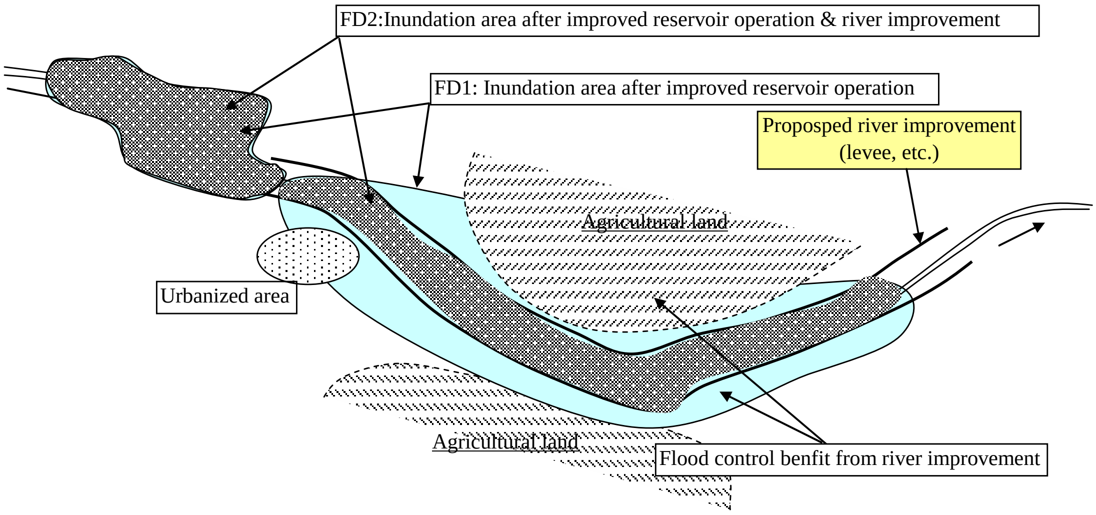
8.3.6 Flood Control Benefits from River Improvement

(1) Basic concept of flood control benefit from river improvement

• FD1: amount of flood damage in flood inundation areas after improved/coordinated reservoir operation at four existing and three future reservoirs

- FD2: amount of flood damage in flood inundation areas after improved/coordinated reservoir operation at four existing and three future reservoirs and river improvement

- Flood control benefit from river improvement = FD1 - FD2（see Figure below）



Source: the Study Team

Flood Control Benefits from River Improvement

(2) Composition of flood damage to be estimated in inundation areas

The flood damage is composed of direct and indirect flood damage as stated below:

(i) Direct flood damage
- Agricultural products
- Housing and household effects
- Depreciable assets and inventory stocks of industrial sectors
- Infrastructure

(ii) Indirect flood damage
- Damage due to loss of business opportunities, interruption of public transportation, wage loss of employees, labor cost for cleaning houses, etc.

In this preliminary study, the amount of indirect flood damage is assumed to be 30% of the total amount of direct flood damage, taking account of similar economic analysis undertaken in the Asian countries. Applied unit values and breakdown of each item are presented in the Supporting Report D.

(3) Review of flood damage due to past major floods

In order to estimate the flood damage based on the different scale of flood occurrence, following manual and related data/information were utilized:

(i) "Manual on Economic Survey for Flood Control (Draft) ", Ministry of

Infrastructure, Land and Transport (MILT), Japan, April 2005 (latest version of the Manual)
(hereinafter referred to as "the Japanese Manual")

(ii) National Census in Tunisia, 2004

(iii) Flood damage records and related documents obtained from CRDAs

(iv) Results and collected information by "Flood Inundation and Damage Survey" conducted in the Study by ECO Resources International in March 2007

It is noted that the Japanese Manual above is widely applied not only in Japan but also in the other countries, since the concept of methodology and attached information include universality in planning and design of flood control projects.

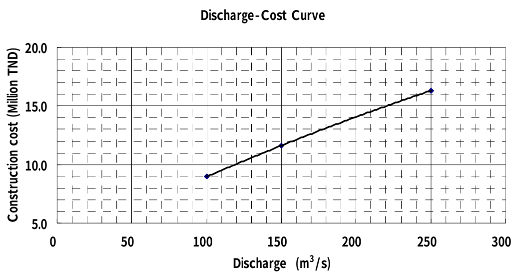
8.3.7 Preliminary Cost Estimate of River Improvement Works

(1) Unit cost and bill of quantity

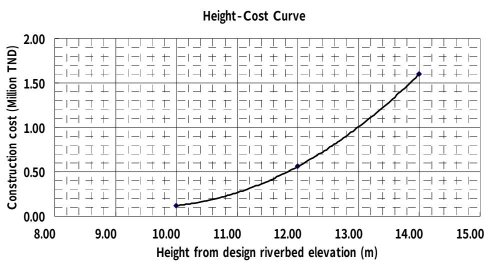
The unit costs of major work items are investigated in the recently implemented or on going projects by MARH and MEHAT. After the review and comparison of these collected data, the unit price was adjusted to current values for purposes of the Study. The bill of quantities of earth works and structures is preliminarily estimated based on the drawings of river profile, cross sections, plans, etc.

(2) Summary of cost estimate

In accordance with the different sizes of the works into 50 categories, the cost curves were prepared for convenience in estimating the related costs depending on the magnitude of probable flood discharges and volume. By means of the cost curves, the direct construction cost was estimated as tabulated in **Table 8.3.1**. As examples, the following two figures show the cost curves for the El Mabtouh retarding basin and levee embankment.



El Mabtouh Retarding Basin



Levee Embankment (MD281-MD251)

8.3.8 Selected Flood Protection Level

With the proposed structures; measures, the inundation analysis was worked out using the same method as that for the "without improvement condition" (present river condition). The results of reduction of flood damage i.e.. "Without-" condition minus "With-" condition are summarized as follows:

Summary of Reduction of Flood Damage

Unit: TND 1,000

Zone	5-Year	10-Year	20-Year	30-Year	40-Year	50-Year
U1	0	3,246	3,690	4,107	4,524	4,941
U2	4,920	11,916	21,619	23,489	25,359	27,229
M	0	1,531	3,026	3,627	4,228	4,829
D1	4,006	6,559	8,102	8,263	8,425	8,586
D2	9,169	23,029	27,604	29,099	30,595	32,090

Source: the Study Team

Following conditions were applied to estimate B/C ratio for each zone:

(1) Duration for computation of B/C ratio

In order to assess the B/C ratio, the duration of computation to estimate present values is set at 50 years taking into account the objective of the study and common practice for a similar kind of economic analysis for flood control projects.

(2) Discount rate

A discount rate of 12 % for the loss of opportunity cost in the flood control sector of the country was applied to convert direct costs and benefits to present values in the cost-benefit stream.

(3) Standard conversion factor (SCF)

In order to estimate the economic cost and benefits, a SCF of 88 % was applied. Since the unit prices of the cost estimate include value added taxes, the values after reduction of 18% (tax rate for most commodities in Tunisia) and the SCF was applied.

(4) Economic benefit and cost of flood control

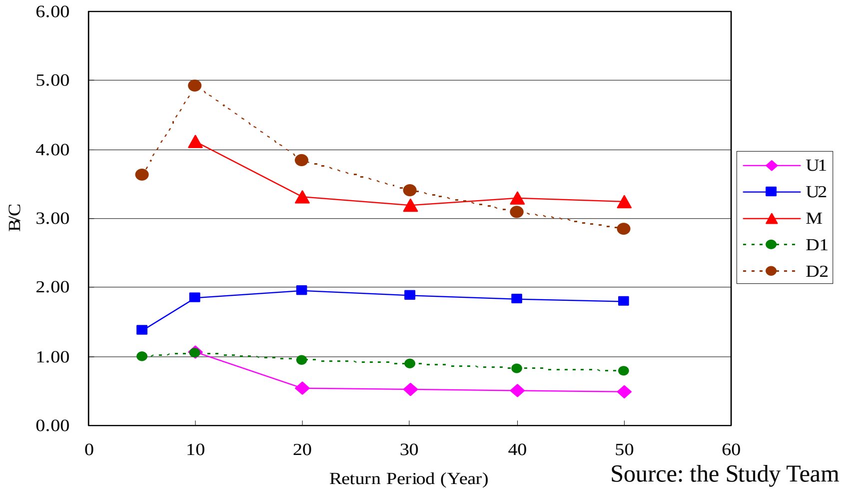
Based on the above mentioned premises, the economic benefit and cost of flood control were estimated in each zone.

The following figure shows the results of B/C ratios for the five zones. Based on the results, a ten-year return period was selected as the optimum flood protection level of river improvement for each of U1, M, D1 and D2, because the selected return period has the highest B/C ratio for each zone. In the case of U2, a 20 year return period was selected. Detailed cost-benefit stream for each zone is attached in Data Book DD1.

Through numerous trials with different combinations of river improvement works, which involve variation of channel width of the Mejerda mainstream, length of levee embankment, size of new bypass channels, etc., the cost and benefits were duly estimated to realize the most viable combination of river improvement works in each zone.

<u>Design Flood Discharge</u>

Zone U1, M, D1, D2 → 10-year probability
Zone U2 → 20-Year probability

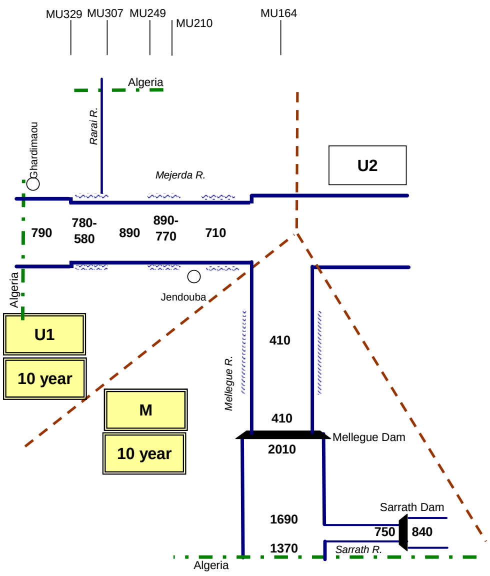


Source: the Study Team

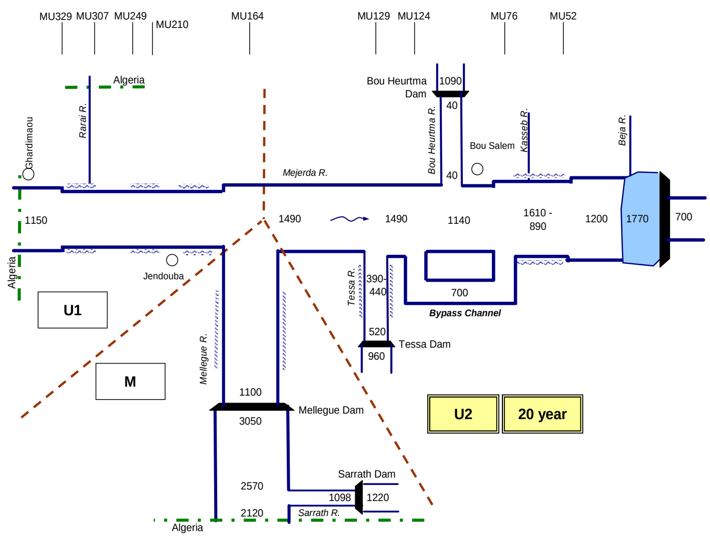
Benefit/Cost and Flood Probability Relationship by Zone
(River Improvement Works)

8.3.9 Distribution of Design Flood Discharges

Based on the selected flood protection levels, further detailed hydraulic analysis to determine the design flood water levels was carried out. In order to prepare preliminary design of river improvement works, the distribution of design flood dischagre in the entire study area was established through the hydraulic study as shown below.

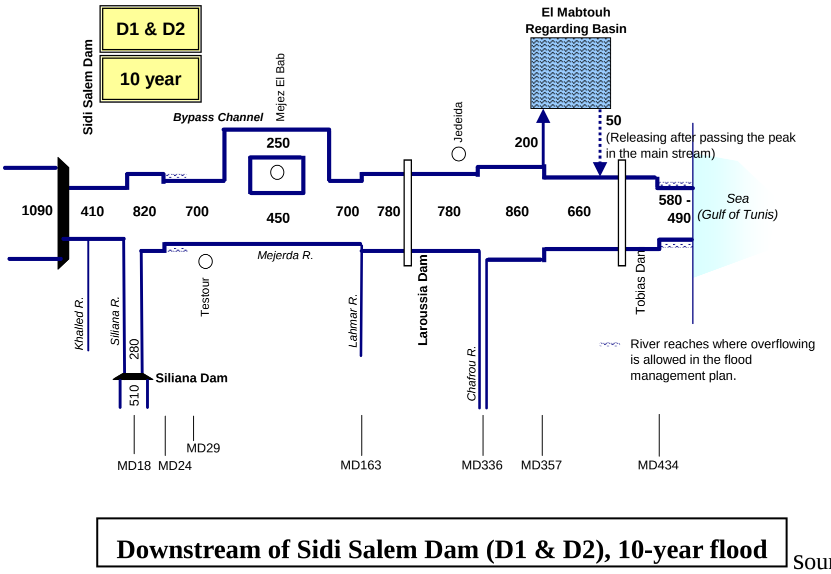


U1 & M, 10-Year Flood



Design Discharge Distribution (U2, 20-year Flood)

U2, 20-Year Flood



Source: the Study Team

Distribution of Design Flood Dischage

8.4 Basin Preservation Plan

8.4.1 Necessity of Basin Preservation

In Tunisia, a problem of surface soil erosion exists in parallel with progression of natural resources degradation. The problem is due mainly to land destruction resulting from agricultural and grazing activities, and has caused detrimental river and reservoir sedimentation as well as long-term declination of crop productivity. Under such conditions, the following are pointed out related to basin preservation in the Mejerda River basin.

(a) In the northwestern region, where Jendouba and Beja Governorates are located, over deforestation after land reclamation for farming expansion, forest grazing and disorderly logging through carbonization for domestic use and illegal businesses have worsened surface soil erosion and destruction of vegetation.

(b) In the south areas of Le Kef and Siliana Governorates, mechanized large-scale farming and small-scale cultivation by peasants coexist. Most of the peasants cultivate cereals by leasing small lands on the steep slope of clayey soil. The cultivated slope lands are deemed vulnerable to erosion that may be caused by intensive rains, eventually subjecting the areas to serious gully erosion.

Such surface soil erosion has brought about sedimentation in rivers and reservoirs, causing significant decrease in flow capacity of rivers and water supply capacity of reservoirs, as discussed below:

(1) Decrease of flow capacity in rivers

At the national road bridge in the Bou Salem City, crossing the Mejerda mainstream upstream of the Sidi Salem Dam, the cross-sectional flow area (699 m^2) in the year 2000 was found to have decreased by 16% from the area (837 m^2) in the year 1969, owing to considerable sedimentation. In the Mejez El Bab City, downstream of the Sidi Salem Dam, the present flow capacity of the Mejerda River has been drastically reduced to about 200 m^3/s, though the capacity was estimated at more than 1,000 m^3/s before the construction of the dam in 1981. Furthermore, it is reported that the flow capacity at the Bizerte Bridge in the Mejerda lower reaches has decreased to as much as 45%, compared to that in the 1980s.

(2) Reservoir sedimentation

High rates of sedimentation as shown below have progressed at the existing reservoirs in the Mejerda River basin:

Name of reservoir	Catchment area (km^2)	Initial storage volume at NWL: A (mil. m^3)	Sedimentation rate: B (mil. m^3/year)	A/B (years)
Sidi Salem	18,191	762	4.5	169
Mellegue	10,309	182	2.8	65
Siliana	1,040	70	1.1	64

In the case of the Sidi Salem Dam, the initial storage volume is feared to be filled with 60 % sediment in 100 years. It is also anticipated that the other two dams will be completely filled with sedimentation in 60 to 65 years after being constructed.

In view of the above problems related to sedimentation, some measures of erosion control are indispensable for basin preservation so as to realize sustainable use of rivers and reservoirs by properly preserving their capacities in the Mejerda River basin.

8.4.2 Measures of Erosion Control for Basin Preservation

The impacts of surface soil erosion recognized in the Mejerda River basin are characterized by the following points:

(a) The higher percentage of steep slope lands a basin has, the more sediment yield has occurred at the basin.

(b) There is a need to take measures of erosion control in the following lands:

- Forest lands wherein the low lying vegetation on and near the ground is poor, and
- Farmlands with steep and even moderate slopes.

In consideration of (a) and (b) above, the following land use classifications are selected as the objective areas of erosion control, particularly in the light of susceptibility to rain erosion,

Land category	Land use classification
(a) Forest	1) Deforested/waste land 2) Grazing land
(b) Farmland	1) Cereal field 2) Fallow 3) Olive groves 4) Arboricultural land

Furthermore, the measures applicable to the selected land use classifications for erosion control are examined, on the premise that the measures are to be taken under the implementation of a proper management plan/system of forest and farmland resources.

This is intended to prevent problems related to sedimentation, such as disorderly reclamation of land and illegal logging.

The measures are identified as compiled below, placing great importance on:

1) The measures with superior durability against erosive action;
2) The measures which are technically and economically suited to extensive lands; and
3) The works related to the measures can be easily executed.

Land category	Land use classification	Applicable Measures
Forest	Deforested/waste land	- Reforestation
	Grazing land	- Materialization of proper management program on grazing in forest under closed coordination among governmental organizations concerned, the people and other stakeholders including NGOs
Farmland	Cereal field and fallow	- Adoption of crop rotation method under horizontal land zoning system and construction of dry stone wall/sill along contour lines aiming to moderate the steep slope surfaces
	Olive groves and arboricultural land	- Introduction of ground cover to improve poor low lying vegetation

The table below shows the areas of the said classifications distributed in the Mejerda River basin (only in Tunisia territory), which are tentatively estimated based on the GIS data obtained in the Study.

Forest	Farmland		Total
Deforested/waste land	Cereal field/fallow	Olive groves/arboricultural land	
500 (ha)	774,695 (ha)	117,811 (ha)	893,006 (ha)

A large area of cereal fields and fallow is found in the Mejerda River basin. Hence, it is essential to formulate an erosion control scheme with careful attention to cereal fields and fallow.

8.5 Flood Forecasting and Warning System Plan

8.5.1 General

In the Mejerda River basin, it is basically expected that floods are controlled by all possible structural measures, such as reservoir operation and river improvement. However, a flood is a natural phenomenon, and hence extraordinary floods exceeding a planning/design level may occur. A flood forecasting and warning system (FFWS), categorized into non-structural measures, is effective to mitigate the loss of life and property in areas vulnerable to flooding, in particular the extraordinary floods.

In the Study, development and improvement plan for strengthening the existing FFWS is recommended from the following viewpoints with due consideration for the important elements for formulating the master plan:

1) As immediate measures to minimize the risk of and mitigate flood damage before the completion of structural measures;
2) As measures to minimize the risk of and mitigate damage due to extraordinary floods

exceeding a planning/design level of structural measures; and

3) As measures to contribute to coordinated operation of dams by providing hydrological information timely and accurately.

The basic conditions of the FFWS in the Mejerda River basin, of which the overview is schematically depicted in **Figure 5.6.1**, are as compiled below.

System composition	- Observation, data transmission, analysis and warning dissemination systems
Objectives	- To provide hydrological information in order to conduct integrated management of river structures including coordinated operation of dams, which would contribute to damage mitigation in inundation areas, and - To provide hydrological information in order to make decisions of required actions for evacuation / flood fighting system.
Covering area	- Cities and towns as Jendouba, Bou Salem, Sidi Smail, Slouguia, Medjez El Bab, El Herri, Tebourba, El Battan, Jedeida, El Henna, and El Mabtou, having been seriously damaged by past significant floods
Responsible institutions	- Flood forecasting: DGRE, DGBGTH, IRESA and CRDAs under the authority of MARH - Flood warning: the Minister of Interior and civil protection offices

8.5.2 Recommended Plan for Strengthening Existing FFWS

(1) Observation System

(a) Additional installation of telemetric rainfall gauges

The number of rainfall gauges in the present telemetry system, which was installed in 2007 and is currently in test operation and control of DGRE, seems to be insufficient, particularly in the southern part of the Mejerda River basin, in the light of its large extent of catchment area. In the Study, the suitable number of rainfall stations was statistically analyzed, as detailed in Supporting Report G, for the Mejerda River basin, focusing on past major floods which had caused large damage.

The result of the analysis indicates that 37 gauging stations in total are required in the whole basin in the Tunisian Territory, which include existing 23 stations and proposed 14 stations as shown in the following table. The exact locations are presented in **Figure 8.5.1**.

In view of forecasting large scale floods, the above 37 specific rainfall gauges have almost the same level of function as in the case where all the 144 existing manual gauges are used. Some existing telemetric gauges were not included in the 37 stations. However, the un-selected existing telemetric gauges are recommended to be continuously utilized since these might still be necessary to forecast small to middle scale floods and determine decision on water use control.

The required number of rainfall gauges should be examined for forecasting small to middle scale floods also at the next project stage.

Required Number and ID No. of Telemetric Rainfall Gauging Stations

Sub-basin (Group)	Required Stations									
	Number	Station ID No. *[1] (Existing)					Station ID No. *[1] (Proposed)			
G1: Lower Reach	5	50692	51552	52905	56670	57122	-----	-----	-----	-----
G2: Sidi Salem	5	51403	51672	52864	57018	57643	-----	-----	-----	-----
G3: Bou Heurtma	1	51403	-----	-----	-----	-----	-----	-----	-----	-----
G4: DS of Siliana	6	55080	56757	57558	57646	-----	50568	50591	-----	-----
G5: US of Siliana	6	54102	56757	-----	-----	-----	53446	54671	56764	56906
G6: Tessa	4	53778	58272	-----	-----	-----	50421	55888	-----	-----
G7: Mellegue	6	53525	53605	55483	55502	-----	56595	57328	-----	-----
G8: Sarrath	6	55991	57678	-----	-----	-----	50522	53046	53311	53508
Total	37 *[2]	23 stations *[2]					14 stations*[3]			

Source: the Study Team

Note *[1]: The stations ID Numbers denote only 4th digit (basin name) and 5th to 8th digit (ID number for stations)

*[2]: Station ID No. 51403 and 56757 are incorporated into two groups, but they are counted as one station in calculating the total numbers.

*[3]: Station ID No. 53311 represents the Sarrath proposed dam site, and it will also be identified in the following clause (b) as a station to be equipped with both rainfall and water level gauges.

(b) Additional installation of telemetric water level gauges

In view of reservoir operations, water level gauges, particularly upstream of the Sidi Salem Dam, play important roles. Moreover, water level gauges in and just upstream of objective areas where water level forecast is required by FFWS, need to indicate criterial water levels to decide commencement of evacuation and flood fighting activities.

Judging from the above two aspects, additional installation of telemetric water level gauges are recommended as shown below. The exact locations are shown in **Figure 8.5.1**.

Proposed Additional Installation of Telemetric Water Level Gauging Stations

No.	Location	Reason for additional installation
1	Near the border on the Mellegue River	For reservoir operation
2	Sidi Smail	For judging of flood risk at Sidi Smail Town
3	Sarrath Dam *	For reservoir operation
4	Tessa Dam *	For reservoir operation

Source: the Study Team

Note: *Stations at the dam sites shall be equipped with both rainfall and water level gauges in view of its manageability and availability for normal dam operation as well.

(c) Incorporation of reservoir outflow data to existing telemetry system

In view of coordinated operation of dams, information about reservoir outflow is essential for operation of the dam located on the downstream side. All reservoir outflow data of the seven selected dams (Sidi Salem, Mellegue, Bou Heurtma, Siliana, Mellegue 2, Sarrath and Tessa Dams) that could be utilized for optimized reservoir operations should be incorporated into the telemetry system.

(2) Data Transmission System

(a) Settlement of GSM telecommunication trouble

The system has sometimes failed to transmit observed data to the call center in DGRE because of GSM telecommunication deficiencies. In the current test operation, the GSM provider, Tunisiana, is trying to solve the problem by installing new antennas or moving existing antennas. Such situation appears to be gradually improving.

However, inextricable telecommunication troubles should be covered by some conventional manual transmission devices such as telephone, facsimile, radio transmission, etc.

(b) Improvement of AGRINET network

Currently, the present telemetry system has not fulfilled its tasks due to the limited capacity of AGRINET (limited number of dam offices that could access the network and system access speed). The telemetry system should be effectively utilized through the improvements of capacity expansion of the network and upgrading of access speed (at least 2.0 Gbps).

(3) Analysis System

Even if the system to gather information of hydrological data is improved, the FFWS cannot effectively function without an appropriate analysis system to make hydrology-related decisions timely and accurately, based on flood forecasting. Thus, it is recommended to establish the following system.

(a) Flood forecasting model/system

i) Upstream of Sidi Salem Dam

Short term development

Flood forecasting shall be made at the first stage by using "river water stage correlation method" based on water level at upstream gauging stations. This is necessary because the development of flood runoff analysis models for flood forecast requires substantial time in carrying out through a trial and error process which is essential for the model development.

The "river water stage correlation method" forecasts the water level, discharge, arrival time, etc. related to the flood peak at a selected site by using the correlation of flood phenomenon presented by water level, discharge, propagation time, etc. between the selected site and its several upstream sites. This correlation could be developed based on the data of past major floods which actually occurred in the river stretches concerned.

The Study has compiled the propagation time, which is a litmus test for finding out the possibility of applying the "river water stage correlation method" for the Mejerda River and its tributaries, as referred to in **Figure 8.5.2**, and those between some major stations are exemplified below.

Propagation Time between the Major Stations

Stations		Distance (km)	Minimum Time (hr)	Maximum Time (hr)
From Ghardimaou	To Bou Salem	112	17	22
From Bou Salem	To Sidi Salem Dam	55	14	16
From Sidi Salem Dam	To Jedeida	108	26	33

Source: DGRE

Middle term development (the development by the target year 2030)

By the target year 2030, flood runoff analysis models based on telemetric rainfall data in the Tunisian territory shall be developed.

In the Study, a flood runoff analysis model has been developed for the Tunisian territory of the Mejerda River basin. Although the model is rather simplified in due consideration of its requirements, it might be effectively used for the purpose of flood forecasting through improving basin division and other enhancements.

Long term development (after the target year 2030)

As for long term development, a flood runoff analysis model based on rainfall data to be obtained through satellite measurement, including those for the Mejerda River basin in the Algerian territory, shall be developed. In case further longer lead time is required, an examination on applicability of rainfall forecasting would be necessary.

Currently, Global Earth Observation System of Systems (GEOSS) is being developed under the collaboration and coordination of concerned research institutes in the world. Furthermore, effectiveness of a radar rainfall observation system is recently reported. These systems are expected to contribute in the future to the acquisition of rainfall data in any area with no rainfall gauge.

ii) Downstream of Sidi Salem Dam

Flood forecasting for the downstream areas shall be in the initial stage made by “river water stage correlation method” based on reservoir outflows from the Sidi Salem and the Siliana Dams, and river water levels in consideration of flood runoff in the downstream sub-catchment areas. This method could provide the necessary lead times for residents’ evacuation activities.

Considering middle and long term needs, it will be necessary to develop a flood runoff analysis model also, as in the upstream case.

(b) Setting of alert levels in FFWS

The purpose of alert level setting at the major water level gauging stations is to indicate criterial water levels for commencement of phased steps related to required responses, such as reservoir operations, evacuation and flood fighting activities.

In the current system of the Mejerda River basin, alert and overflow water levels have been determined at 13 gauging stations on the Mejerda River and at 17 stations on its tributaries, which are based only on experiences, as detailed in Subsection G2.1.4 of Supporting Report G. However, it is pointed out that these water levels do not follow the national geodetic elevation system in Tunisia. Therefore, it is essential to set step-wise water levels below the overflow level at these gauging stations that comply with the Tunisian geodetic elevation system to serve the above-mentioned purpose.

Classification of step-wise alert water levels and their setting criteria with their indications are provided below:

Alert Water Levels and Setting Basis

Step	Water Level	Setting Criteria
1st	Advisory water level	• Water level based on which flood fighting units start preparation for mobilization
2nd	Warning water level	• Possible water level that causes flooding • Water level based on which evacuation announcement is issued and flood fighting units mobilize
3rd	Bankful water level	• Possible water level above which flood overtopping occur • Water level determined based on design high water level with consideration of field conditions

Source: Ministry of Land, Infrastructure and Transport, Japan

(c) System of coordinated operation of selected dams

The following telemetric hydrological data shall be shared among the seven selected dam control offices and proposed control center under DGBGTH in order to mutually grasp overall coordination of the dams.

- Discharge/water level at selected reference points (see Figure 8.2.1)
- Operation status of the dams to be coordinated (including inflow and outflow data, see Figure 8.2.1)

In this relation to this, it is recommended, as discussed above, that the seven dams' control offices should firmly access AGRINET.

It would be necessary to acquire the above hydrological data in advance for optimization analysis on reservoir operation in the proposed control center.

(4) Recommended Plan for Warning Dissemination System

Flood warning is issued by the Minister of Interior. Once the Regional Commission has been established, communication at the regional level shall be made using all available means such as telephone, facsimile, mobile phone, radio transmission, etc. in line with the organization structure fixed by the regional disaster management plan.

The dissemination to the residents is discussed in Section 8.6, considering evacuation as its primary purpose.

(5) Lead times related to FFWS

There are three kinds of lead times defined in the Study, as stated below, in relation to FFWS.

(a) Required lead time

A required lead time is defined as the time necessary to complete several activities once risk of flood attack is recognized. Based on interview survey with the institutions in charge of the respective response activities, necessary times for execution of respective activities were preliminarily estimated in the Study as follows:

Necessary Time by Response Activity

Response Activity	Responsible Institution	Necessary Time for Completion of Activity	
Flood forecast analysis* and decision making for issuance of flood warning	DGRE/DGBGTH/ National Commission	1.5 hours	3.0 hours
Warning dissemination to residents	Civil Protection	0.5 hours	
Evacuation with minimum necessary belongings	Civil Protection	1.0 hour	
Evacuation of livestock	Civil Protection	1.5 hours	1.5 hours

Source: Interview with DGRE, DGBGTH and Civil Protection Manouba
Note: * excluding analysis on coordinated reservoir operation

(b) Target lead time

The target lead time is defined as the time allotted for protecting the subjects (human lives) covered in the Study. Referring to the above required lead time, the target lead time to be allotted by the FFWS is estimated to be at least 3.0 hours. To meet this target lead time, it is necessary for the FFWS to acquire the hydro-meteorological information in the upstream basin as early as possible.

(c) Possible lead time

This lead time is defined as the time available for activities between recognition of flood phenomenon in the upstream basin and occurrence of flood in an objective area. The possible lead time differs throughout the river basin according to the local hydrological and topographical conditions. The following table shows the minimum and maximum possible lead times, which are based on the propagation times of the past floods. The gauging stations in the table have been selected to recognize a flood phenomenon by water level or a reservoir outflow for each objective area. The possible lead times in the table hinted that it would be more possible to apply “the water stage correlation method” to the Mejerda River.

Possible Lead Time by Object Area (Example)

Objective Area	Gauging Station To Recognize Flood Phenomenon	Possible Lead Time under the Current Condition	
		Minimum	Maximum
Jendouba	Ghardimaou	10 hours	13 hours
Bou Salem	Bou Heurtma Dam	7 hours	9 hours
Sidi Smail	Ghardimaou	at least 17 hours	at least 22 hours
Slouguia	Sidi Salem Dam	4 hours	6 hours
Medjez El Bab	Sidi Salem Dam	8 hours	11 hours
El Herri	Sidi Salem Dam	14 hours	18 hours
Tebourba	Sidi Salem Dam	at least 14 hours	at least 18 hours
El Battan	Sidi Salem Dam	23 hours	29 hours
Jedeida	Sidi Salem Dam	26 hours	33 hours
El Henna	Sidi Salem Dam	at least 26 hours	at least 33 hours
El Mabtou	Sidi Salem Dam	at least 26 hours	at least 33 hours

Source: Propagation time provided by DGRE
Note: “At least” denotes that the possible lead times were set with reference to the upper stream gauging stations because those propagation times have not been exactly provided.

8.6 Evacuation and Flood Fighting System Plan

The current evacuation/flood fighting system for the Mejerda River basin needs to be reconsidered to strengthen its function from the following two viewpoints:

(a) In order to decide well-timed commencement of evacuation/flood fighting activities, it is important to clarify precise commencement criteria.

(b) Raising peoples' awareness on disaster mitigation is essential, since understanding and cooperation of the public and their communities are indispensable for evacuation activities.

Based on the above, the development and improvement plan for strengthening evacuation and flood fighting system is recommended below:

(1) Formulation of information sharing system

Sharing of information between the concerned public and government agencies and recognizing their respective responsibilities is essential for effective evacuation system.

In order to raise people's awareness of disaster mitigation, they should be at least informed about the following information in advance and in the case of a flood event:

- Warning/announcement dissemination method and route,
- The nearest or available evacuation spaces in their area, and
- Key contact addresses of those who can provide assistance to the evacuees when required.

The above information can be shown on an evacuation map, which shall be distributed to residents in expected inundation areas or displayed in prominent places such as administrative offices and public meeting places.

The Study has worked out an evacuation map for Jedeida Delegation as a model area in close cooperation with Civil Protection Manouba, as shown in **Figure 8.6.1**. The evacuation map of this sort is recommended to be properly prepared by each Governorate, paying special attention to the following technical approaches:

(a) Delineation of maximum extent of flood inundation, referring to the past maximum flood, taking into account utilization of the map during a flood event prior to completion of the structural measures.

(b) Selection of public sites and access routes of evacuation areas situated far from the flood inundation locations, with due consideration to capacity, available facilities and accessibility of the sites, and

(c) Supplementary information required on the map, such as dissemination routes of announcement for evacuation, emergency medical facilities, and local government offices in charge of evacuation/flood fighting activities.

(2) Clarification of commencement criteria for activities required

For the purpose of smooth and effective commencement of activities required for evacuation and/or flood fighting, the Governor shall timely issue evacuation announcements and flood fighting warnings in a stepwise manner as classified below:

(a) Classification of evacuation announcements into three steps, namely 1st) evacuation preparation, 2nd) evacuation advisory, and 3rd) evacuation order, in accordance with water levels at key gauging stations and condition of flood control structures, and

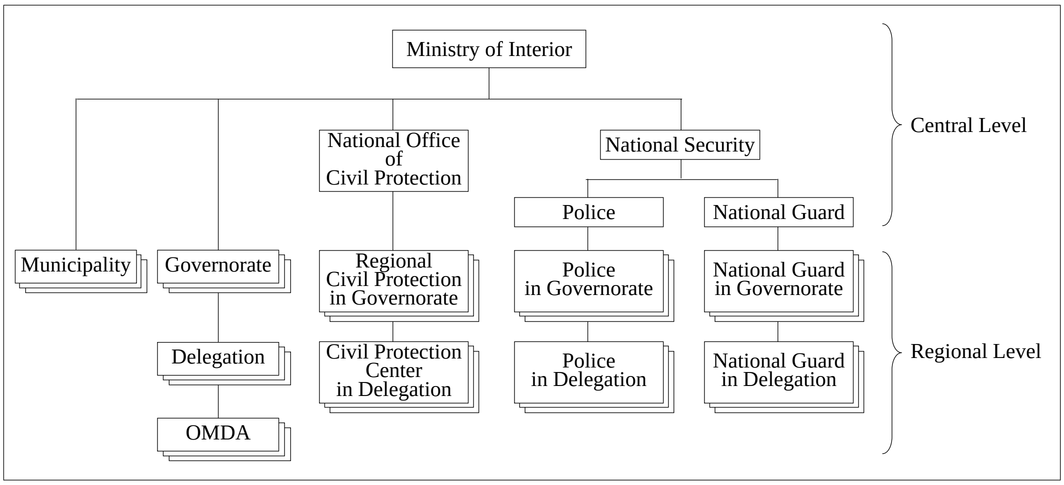
(b) Classification of flood fighting warnings into four steps, namely 1st) standby, 2nd) preparation, 3rd) mobilization, and 4th) continuous caution, in accordance with water levels, including overflow levels, at key gauging stations.

(3) Development of evacuation procedures

It is necessary to develop easily understandable evacuation procedures for both the rescue team composed of the Civil Protection, the police and the National Guard offices, and the public considering the following three aspects:

<u>Assured dissemination method:</u>

- Through mass media under agreement with media organizations, such as national TV stations (TV-7 and TV-2) and national radio stations (Radio Young and Mosaic Radio),
- Through other available means such as utilizing vehicles equipped with a loudspeaker, etc. with the efforts of the Civil Protection and in cooperation with such institutions as the National Guard, the police and the military (see following figure),
- Through communication networks of Imada, that is designated as minimum unit of local community under delegation.



Source: Interviews with MARH

Agencies Concerned to Flood Fighting

<u>Understandable contents of announcements:</u>

- Issuing agency of evacuation advisory/order
- Reason of the evacuation advisory/order
- Target area of the evacuation advisory/order
- Evacuation space and suitable route leading to the evacuation space

Systematic evacuation confirmation system:

- Utilizing the leadership of Omda, a head of Imada, who is most familiar with the residents living in his/her Imada
- Checking names of evacuees with the aid of lists at checkpoints provided inside or along the routes leading the evacuation spaces

These activities depend on residents' self-initiative and communities' cooperation. Detailed evacuation plan for each Governorate shall be formulated in consideration of involvement of the public and possible community-based activities.

8.7 Flood Plain Regulation/Management Plan

8.7.1 Rationale of Flood Plain Regulation/Management

As for the structural measures proposed in the Mejerda River basin, the target scale of planning level, as "flood protection level" has been set at a 10-year excess probability for Zones D2, D1, U1 and M, and a 20-year excess probability for Zone U2. However, even if the proposed river improvement works are completed, it should be realized that excess floods beyond the design scale could still occur and cause a certain extent of damage to properties in the basin.

In order to cope with such excess floods and mitigate damage due to inundation, non-structural measures should be positively introduced in the Mejerda River basin, which are vital in supplementing the structural measures. However, the target scale for the planning of flood plain regulation/management is not clearly defined in Tunisia and in other developed countries.

In the Mejerda River basin, the magnitude of a 100-year probable flood is set as the target scale for flood plain regulation/management plan, which should be handled by the responsible institution of river administration, MARH, discussed in Section 8.1. Clear presentation of the target range is recognized as quite essential, to reasonably demarcate the responsibility of the government agencies concerned. This concept is highly recommended to be incorporated in flood control policy of the Mejerda River basin. Furthermore, although the excessive scale of flood would be beyond the control of responsible agency in river administration, a disaster/risk management entity at a national level should assume the responsibility, since related calamities are subject to national alert or declaration of state of emergency, which requires saving human lives. This will be part of the duties of the Ministry of Interior or Civil Defense, in the case of Tunisia.

The above concept is proposed as the "Mejerda Flood Directive", which is recommended as a core concept of the future flood control policy of the Mejerda River basin.

On the other hand, the Public Hydraulic Domain (PHD) in Tunisia, has been defined in the "Water Code" (1975), and actual delimitation of the boundaries is presently undertaken by MARH. Since these activities can be recognized as a sort of flood zoning, its review was firstly done to set the appropriate direction and concept of flood plain regulation/management plan in the Mejerda River basin.

8.7.2 Delimitation Works of Public Hydraulic Domains (PHD)

(1) Legislative Definition of PHD

PHD is defined to include the following water bodies in the “Water Code” of Tunisia[1]:

(i) All kinds of water courses and land included in their vicinities
(ii) Ponds constituted on water courses
(iii) All kinds of springs
(iv) All kinds of underground waters
(v) Lakes and Sebkhas (salted lakes)
(vi) Aqueducts, wells, and water in places for public use as well as their dependents
(vii) Navigation, irrigation or draining channels managed directly by the State or through delegation of authority (to a third party) for a public use as well as land uses which are located on their vicinities and their dependents.

Further, the Water Code stipulates that the limits of water course be fixed according to the water level flowing at the bank full before overflowing. The clause on “Easement” stipulates that those residing near water courses, lakes and sebkhas (salted lakes) identified by the decree are compelled to easement called ”the free board (vicinity)”. This vicinity is within the limits of a 3 m width, starting from the shore, aiming at allowing a free access for the administrator’s personnel and equipment. The easement does not allow rights to indemnity. Moreover, proposed construction works at the easement, such as heightening of the fixed boundary and plantation, shall be subject to prior authorization from the MARH. In order to materialize the concept of the “Water Code”, in particular for the delimitation of PHD, the following Official Gazettes have been published by MARH:

(i) Decree No.87-1202 of September 04, 1987, fixing the procedure of delimitation of water course, lakes and sebkhas coming under the PHD,
(ii) Decree No.89-1059 on July 27, 1989, modifying the Decree No.87-1202 of September 04, 1978,
(iii) Circular for the attention of the Governors and Mayors of October 20, 2005, concerning clarifications of procedures relating to the delimitation of water courses, lakes and sebkhas falling under the PHD, and
(iv) Attached documents: “Guideline on Procedures for Delimitation of PHD”

Aside from the regulations above mentioned, special rules are enacted by “Town and Country Planning Code and Related Enforcement Laws” (modified/added to the law No.2003-78 issued on December 29, 2003). In accordance with the rules, it is forbidden to build facilities in the zones, which are not covered by an approved urban development plan, within 100 m from the boundaries of PHD. On the other hand, in zones covered by an approved development plan in the rural areas, it is prohibited to construct structures within 25 m starting from the boundaries of PHD.

[1] Issued in Law No.16 of the year 1975 dated on March 31, 1975, and modified and completed by the texts particularly the order No.2606 for the year 2001 issued on November 09, 2001.

8.7.3 Delimitation Operation by DGRE, MARH

In the framework of delimitation of the PHD, whose objective is to achieve more precise delimitation and thus allowing for more refined definition of the PHD, the DGRE of MARH is mandated to conduct topographic and bathymetric surveys along with property surveys (parcellery surveys) of water courses and sebkhas throughout the different regions of the country.

The delimitation of PHD (drawing boundaries along the Mejerda River) is actually undertaken by Topographic and Cartography National Agency – Office de la Topographic et de la Cartographie (OTC), based on the agreement No.06M23 between DGRE and OTC. In fact, DGRE is supervising the works in compliance with the latest Circular of the MARH.

According to the information provided by DGRE, delimitation works of PHD along the Mejerda River has been completed for 292 km stretches in total as of year-end 2007, and is scheduled to be conducted for further 138 km in the year 2008.

8.7.4 Basic Concept for Flood Plain Regulation/Management in Mejerda River Basin

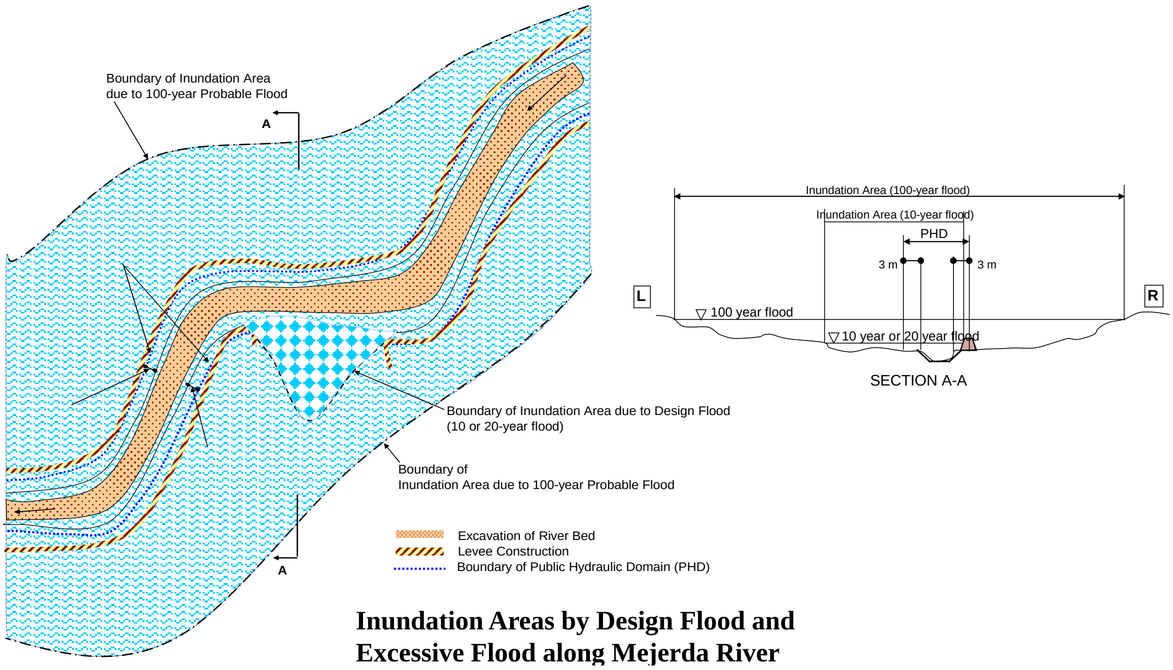
As of now, no flood hazard or risk map has been prepared for the river basins in Tunisia. Flood hazard maps are related to flood forecasting and warning system, and evacuation and flood fighting activities. In the case of the Mejerda River basin, delineating risk level of inundation in the region will become one of vital tools to mitigate vulnerability in the flood prone areas. In particular, taking into account that the land is generally developed for agricultural cultivation, certain regulations on land utilization as well as restrictions of constructing new houses/buildings in riparian urban areas will be prerequisite for supplementing the structural measures. Therefore, the basic concept of flood plain regulation/management is set for the enhancement of land use control in the aspect of flood disaster management in the flood prone areas, through preparation and dissemination of flood risk maps.

8.7.5 Target Risk Level for Plan Formulation

In order to delineate the boundary of areas affected by excessive flood, the inundation areas with a 100-year probable flood were applied taking into account the valuable resources defined as the breadbasket of the country. When such a large scale (100-year) flood occurs, the proposed levee system will fail to accommodate the flood water in the channel and prevent overtopping along the whole stretches of the mainstream. The proposed levee will be breached and destroyed due to such catastrophe.

Moreover, it is commonly reported that large scale floods with torrential local rainfalls, which cannot be presumed based on the historical trend of meteorological events, occur due mainly to global warming. In this aspect, strategic control for future land use in the Mejerda River basin would become more crucial for sustainable development.

The relationship of the target areas as mentioned above is illustrated as follows:



Inundation Areas by Design Flood and Excessive Flood along Mejerda River

8.7.6 Preliminary Analysis on Current Land Use in Flood Prone Areas

(1) Flood prone areas due to design flood discharge

(a) Characteristics of inundation areas

In the study on river improvement through inundation analysis of the design flood, the areas where overtopping of river banks and inundation are allowed to some extent, were carefully selected aiming at retaining flood peak discharges at downstream reaches. The hydraulic features of these areas are summarized below:

Hydraulic Conditions of Inundation Areas based on Design Flood Discharge

Zone	River Stretches where allows overflowing	Location	Length of River Stretches (km)	Designed Flood Protection Level	Design Flood Discharge (m^3/s)	Present Flow Capacity (m^3/s)
U1	MU228~ MU215	U/S of Jendouba	6.4	10 year	570	250
U2	MU53~ MU80	D/S of confluence of Kasseb River	10.8	20 year	1,840	250
M	ME19~ ME106	Lower Mellegue	20.8	10 year	410	200
D1	MD29~ MD24	U/S of Testour	1.7	10 year	410	350
D2	MD434~ MD447	Lower reach of floodway (Oued El Hmadha)	5.2	10 year	580	180

Source: the Study Team

As a result of the inundation analysis, the flood prone areas under the design flood discharge in five zones can be summarized by land use as tabulated below:

Estimated Flood Prone Area by Design Flood Discharge

Zone	River Stretches where allows Overflowing	Agricultural Area (non-irrigated)	Agricultural Area (irrigated)	Other Area	Total Area
U1	MU228~ MU215	348	93	31	472
U2	MU53~ MU80	411	614	15	1,040
M	ME19~ ME106	322	317	26	665
D2	MD29~ MD24	3,224	390	2,881	6,495
D1	MD434~ MD447	109	68	10	187

Source: the Study Team

In order to establish appropriate countermeasures to cope with the excess flood, size of affected people, inundation depth/duration, flow velocity and influence to irrigation facilities in the flood prone areas are to be further examined.

(b) Expected function of inundation area

Considering the hydraulic conditions and land use along the upstream and downstream of the subject stretches allowing overflowing as indicated in the previous Clause, particular vital function of retarding effect is given from flood control aspect. In order to keep the flood protection level set for each zone, such distinct function should be individually noted as follows:

Expected Function in Inundation Areas for Flood Damage Mitigation (below design flood discharges)

Zone	River Stretches where allows Overflowing	Expected Function for Flood Damage Mitigation
U1	MU228~MU215	To mitigate flood damage in the urban area of Jendouba by reducing flood peak discharge at upstream area.
U2	MU53~MU80	To reduce flood peak discharge, which propagates to the downstream, by allowing local inundation after joining of flood water at outlet of Bou Salem Bypass Channel
M	ME19~ME106	To reduce flood peak discharge before joining with the Mejerda River by allowing overflow along the Mellegue River. Due consideration to protect the urban area of Jendouba will be required.
D2	MD29~MD24	To regulate the flood water level at El Battane weir (about 86 km downstream) below the existing elevation of road pavement on the weir (29.1m NGT), local inundation will be allowed upstream of Testour.
D1	MD434~MD447	To allow overflowing of flood water downstream of existing road bridge crossing over the floodway to the river mouth. Recommendation is made for reconstruction of the bridge and heightening of the approach road at both banks.

Source: the Study Team

(2) Flood prone areas due to excessive flood (100-year probable flood)

The flood prone area due to a 100-year probable flood is preliminarily assessed based on the result of inundation analysis. **Figures 8.7.1** and **8.7.2** show separately the flood prone areas in the upstream and downstream of Sidi Salem Dam, respectively. The following table presents current land use classified into four categories for each zone:

Estimated Flood Prone Areas by Excess Flood (100-year)

Zone	Urban Area affected	Current Land Use in Flood Prone Area (ha)				
		Agricultural Area (non-irrigated)	Agricultural Area (irrigated)	Urban Area	Other Area	Total Area
U1	Jendouba	2,725	1,976	156	130	4,987
U2	Bou Salem	4,046	7,810	468	26	12,350
M	Jendouba	4,160	5,684	660	83	10,587
D1	Mejez El Bab	1,602	4,950	182	42	6,776
D2	Tebourba, El Battane, Jedeida, Sidi Thabet	22,771	22,136	390	9,776	55,073

Source: the Study Team

In addition to the analysis of land use as shown above, affected population was estimated based on the proportion of areas subject to inundation and population density by each delegation. As a result, it was clarified that approximately 143,000 people reside in the flood prone areas of the Mejerda River basin, which are subjected to the 100-year flood as shown below:

Estimated Affected Population by Excess Flood

Zone	Urban Area	Rural Area	Total
U1, U2 & M	49,474 (34.7%)	32,987 (23.1%)	82,461 (57.8%)
D1 & D2	25,443 (17.8%)	34,870 (24.4%)	60,313 (42.2%)
Total	74,917 (52.5%)	67,857 (47.5%)	142,774 (100.0%)

Source: the Study Team

8.7.7 Flood Plain Regulation/Management Plan

The strengthening of flood plain regulation/management aims to contribute to reducing flood damage risk through the betterment of the present land use, which should be initiated considering potential occurrence of flood risk, and sustainable urban and agricultural development in the flood prone areas. As explained in the previous section, flood inundation areas subject to a 100-year probable flood (excessive flood) delineated in the Study are set as the target area of the plan.

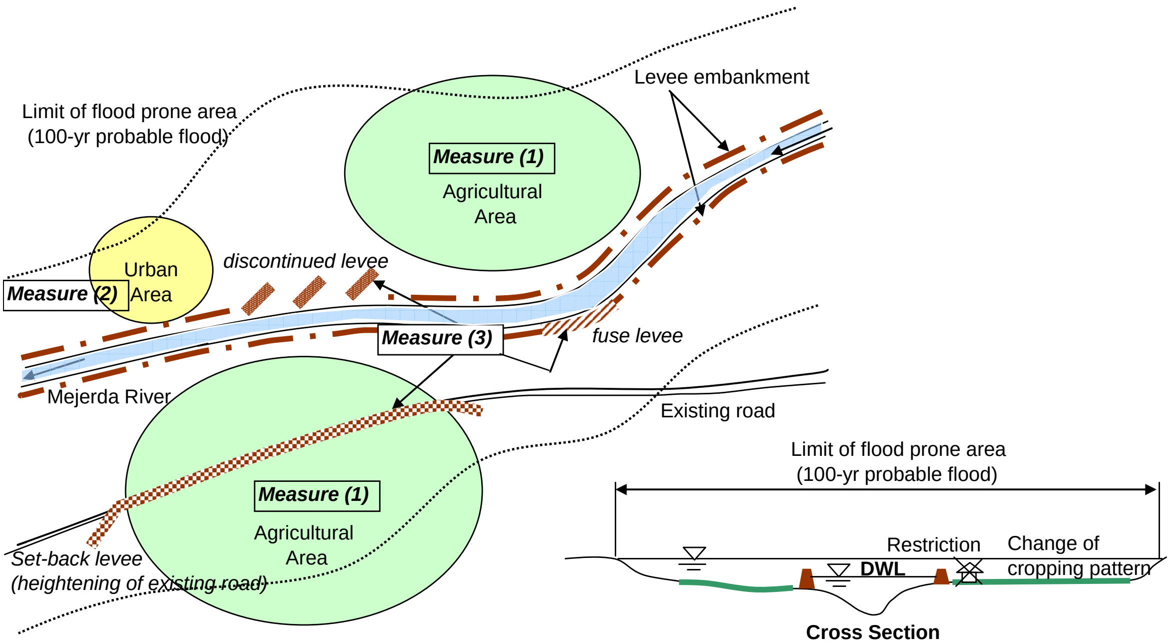
In order to cope with the excessive flood, a concept on minimizing flood damage in urban and rural areas from the aspect of disaster management against flooding is inevitable. In this context, land use with restriction on building construction below a certain elevation, considering flood risk in particularly urban area, is essential. On the other hand, in the rural flood-prone areas, flood-resistant agricultural crops such as olive and tree fruits shall be promoted to reduce potential flood damage based on risk level.

Manner and methodology for appropriate land use are needed and guidelines are to be prepared in order to disseminate the practice to CRDAs or municipalities concerned. After preparation of the guidelines, actual application and evaluation of the recommended manner should be conducted. Furthermore, in order to enhance the expected benefits of the plan, a series of training and seminars need to be organized and conducted periodically.

In order to further mitigate damage due to excessive floods in the flood prone areas, appropriate allocation of the levee structures regulating over flow at banks is important, in connection with the flood plain regulation/management activities. Compared to ordinary dikes which are constructed to protect inundation, these structures have different functions, providing guide and control of the flood flow after over banking. In the master plan, such structures are proposed to mitigate flood damage against excessive floods.

The relation between these structures and flood plain regulation/ management is shown as follows:

Measure (1)	Promotion of flood-resistant crops in agricultural land
Measure (2)	Restriction of new house/building construction in urban area
Measure (3)	Construction of secondary levee (set-back levee), discontinued levee and fuse levee (regulating structures in flood plain)



Layout Image of Regulating Levee Structures in Flood Prone Areas

The following three candidate sites of secondary levee were selected taking into account flood prone areas and flood flow during experienced major floods in 1973, 2003 and 2004 (assuming existing road sections are raised).

Candidate Sites for Secondary Levee

Site	Length (km)	Expected effect (regulation of excessive floods)
El Mabtouh	12.0	Protection of priority farm land from bank over overflow due to excessive floods in El Mabtouh plain (left bank of the Mejerda River) by regulating the flood flow spreading towards north of the plain.
Sidi Thabet	7.0	Protection of the irrigation area in Sidi Thabet against the overflow by regulating the flow, which rushes to the northeast and increase flood damage in the Kalaat Andarous area (right bank of El Hmada floodway)
Tebrouba	3.0	Protection of the irrigation areas between Tebrouba and Jedeida from flood flows, which over-top downstream of the urban area (left bank), and regulating the flow reaching to Jedeida urban area

The locations of the above candidate sites are shown in **Figure 8.7.1**. Furthermore, as for implementation, the following issues shall be emphasized:

- Prevent increase of inundation damage at the downstream areas by using other regulating structures simultaneously (such as pumps and training canal, etc.)
- Consider compensation measures (resettlement of the people, heightening of residential land, compensation to actual flood damage, etc.) for the area, where inundation damage is accelerated due to construction of regulating structures.
- Clearly designate the area for construction of regulating structures and areas with risk of inundation, and disseminate the information for obtaining consensus from local people
- Introduce, in addition to construction of such regulating structures, compensation rules for damaged farm land and/or flood insurance.

Therefore, the flood plain regulation/management based on the detailed analysis of land use pattern focusing on crop selection and planting/harvest pattern need to be further analyzed and investigated in each zone or smaller unit like delegation.

8.8 Institutional and Organizational Development Plan

8.8.1 General

In Tunisia, flood control management has been executed occasionally and incidentally, depending on flood conditions. Furthermore, the problems and issues concerning river basin planning and management focusing on flood control are identified from institutional and organization viewpoints as stated below:

(a) There are no permanent division or service for flood control activities and management in the central and regional directions, except services for risk and flood announcement.

(b) There are no documented technical guidelines or standards for flood control and water supply planning and design, and reservoir operation rule.

(c) The competence of flood control is separated: the MARH for rural and agriculture areas, and the MEHAT for urban areas.

(d) The competence of flood fighting activities is separated: forecasting and announcing by the MARH, and warning, fighting and evacuation activities by Civil Protection, the Ministry of Interior.

(e) Sediment control in watersheds is insufficient: sedimentation inside river channels and reservoirs becomes a significant factor in causing floods.

(f) Cooperation with Algeria for river basin management is insufficient: in particular, rainfall and discharge data necessary for flood forecasting and warning.

The Study, in due consideration of the above, proposes a broader concept of IFM covering various structural and non-structural measures. The capacity development plan for institution and organization discussed in the Study based on the concept aims to materialize the master plan effectively and efficiently from the planning stage to operation and maintenance stage.

In 1989, the decentralization law was issued in Tunisia. Since the 1990's, the State headed towards the policies of decentralization and transfer of responsibilities to local associations and communities. The Tunisian Government currently envisages the establishment of small governments in central and regional level under these policies. Hence the capacity development plan in the Study is formulated keeping the existing institutional and organizational framework unchanged as much as practicable, along the track of the decentralization policy.

8.8.2 Organizational Framework for IFM

The prospective institutional integration between flood control measures and river administration has three fold under the concept of the IFM:

- Integrated administration and management of flood control activities among organizations concerned,
- Integrated planning and implementation of flood control measures among organizations concerned, and
- Integrated O&M of the Mejerda River basin.

Appropriate combination of flood control measures is expected to be implemented by well managed administration and vertical and horizontal coordination among different agencies and organizations. The Study has identified the following three categories for empowerment through consultation and needs surveys:

- Empowerment of river administration and management of flood control activities under MARH related to the Water Code,

- Empowerment of organizational coordination for effective and efficient planning and implementation of flood control measures, and
- Empowerment of integrated O&M of the Mejerda River basin.

The current organizational framework is reviewed in terms of flood control measures and river administration to achieve the institutional integration of river administration for the IFM as illustrated below.

Management / **Measures**	**Institutional Integration of River Administration**		
	Administration of River Area, River Course and Water Resources	Integrated Planning and Implementation	Integrated O&M
Structural Measures	○	○	○
Non-structural Measures	○	○	○

○: requirement of integration

The attributes of structural and non-structural measures are linked with those of the institutional integrations of river administration classified above. These are mutually correlated and are to be integrated. Various structural and non-structural measures studied for the comprehensive flood control of the Mejerda River are broadly classified as set out below.

Structural Measures

Storing and Regulating Flood Runoff		River Channel Improvement		
a)Construction of dams* & retarding basins	b)Improvement of reservoir operation(partly non-structural)	a)Dikes	b)Channel excavation &widening	c)Bypass channels, flood ways

Non-Structural Measures

Basin Preservation		Flood Plain Management		
a)Forest management* b)Land use management	c)Soil erosion management	a)Land use control (zoning) b)Flood insurance, crop insurance, tax adjustment	c)Flood forecasting and announcing system d)Flood warning, evacuation, fighting activities e)Education and dissemination of people	f)Water proofing (heightening of houses, building& foundation, etc)

*: Measures not covered by the Study for the Master Plan

The prospective organizational framework for the IFM is illustrated in **Figure 8.8.1**. The attributes of these structural and non-structural measures are linked with the attributes of the river administration illustrated in the left half of **Figure 8.8.1**. The organizational integration between the related institutions is meanwhile illustrated in the opposite half of the figure.

8.8.3 Draft Plan on Organizational Capacity Development for Mejerda River Basin

An organizational capacity development plan for the Mejerda River basin is drafted to materialize the necessary actions identified, after close scrutiny of problems and needs in current organization and institution for flood control and river management in the Majerda River basin discussed in Section 5.8. This draft plan consists of eleven programs proposed to promote the IFM under the organizational framework shown in **Figure 8.8.1,** through organizational empowerment in terms of the three attributes of river administration delineated in the Figure: namely, the integrated administration, the integrated planning and implementation, and the integrated operations and maintenance (O&M).

The integrated administration is to empower harmonized river administration related to flood control activities among organizations concerned. The integrated planning and implementation is to empower organizational coordination for effective and efficient planning and implementation of flood control measures among organizations concerned. The integrated O&M is to empower sustainable and coordinated O&M of flood control measures in the Mejerda River basin.

The eleven programs above are summarized as follows.

11 Proposed Programs for Organizational Empowerment

Integrated Administration	Integrated Planning and Implementation	Integrated O&M
1.One management for one river basin (Mejerda River)	5.Integrated planning of structural and non-structural measures for flood control by PSC under DGBGTH	10.Strengthening O&M of exiting water supply system and large dams
2.Permanent organization in central and regional directions to promote IFM	6.Coordination by MARH in design to O/M stage	11.Establish new agency for O&M of river course and river facilities of Mejerda River
3.Supplement of IFM to Mission of National Water Council	7. Implementation and management by PMU under DGBGTH in design and construction stage	
4.Basin-wide environmental management and monitoring	8.Documented technical guidelines, standards and rules	
	9.Arrangement of flood insurance	

<u>Program 1: One Management for One River Basin</u>

The program is expected to resolve existing problems such as illegal issue of residence permits inside the public hydraulic domain (PHD), construction of obstructive structures against river water flow inside the river course, construction of bridge abutments and piers confining flood flow inside the river area, damaging the existing drainage channels by road construction, and insufficient maintenance of the river course. These issues are related to the administration of the PHD, river course, flood control (fighting against flood), and water rights.

Empowerment of the river administrator, MARH, based on a principle of one management for one river basin, will reinforce the river administration effectively and efficiently.

Program 2: Needs of a Permanent Organization to promote IFM

Establishment of permanent divisions or services for flood control activities and their management in the central and regional directions will serve as a foundation for Integrated Flood Management (IFM). Permanent organizations would empower:

a) Regulatory communication and coordination with relevant organizations to clarify the river administration and existing issues,
b) Continuous and integrated cycle management from the planning and design stages to the construction, O&M stages, and
c) Stable budgetary arrangement for new measures and sustainable O&M.

Program 3: Mission of IFM for National Water Council

The National Water Council (CNE) is a special organization whose mission is limited to advisory. Thus it has no other responsibility in the Integrated River Basin Management, including flood management. The CNE also has no independent permanent secretariat office. Its mission however is expected to supplement the IFM.

Program 4: Basin-wide Environmental Management and Monitoring

To ensure compliance of project activities with the legal and social procedures and standards, a basin-wide environmental management, monitoring and evaluation system is necessary.

Program 5: Integrated planning of structural and non-structural measures

Flood control projects should be supervised by a Project Steering Committee (PSC) established under the DGBGTH or the CRDA at the project preparation and planning stage. The role of PSC is to materialize the integrated flood control plan to ensure effective coordination between concerned ministries and their line agencies in the governorates, including the DGRE, the DGACTA, the DGF, the National Agency for the Protection of the Environment (ANPE), the DGDD of the Ministry of Environment, the Ministry of Interior, and the Ministry of Equipment (MEHAT), among others. It is preferable that the PSC continues monitoring activities during the design and construction stages, to ensure effective coordination.

Program 6: Strengthening Coordination Power of MARH with Relevant Organization

It is necessary to strengthen the coordination capacity between the MARH and other relevant organizations such as MEHAT, Ministry of Interior, INM, etc. for effective and efficient planning, implementation, O&M of structural measures (storing and retarding flood runoff, river channel improvement) and non-structural measures (basin preservation, flood plain management). For example, coordination with the MEHAT[2] is required for matters such as land use control, management of PHD, flood control projects and urban and rural drainage projects.

[2] MARH for rural and agricultural areas and MEHAT for Urban areas

Program 7: Implementation and Management in Design and Construction Stages

Under the present organization based on the decentralization policy of the country, the roles of the central government (MARH) and the regional governments (Governorates) are properly delegatd for implementing structural measures at design and construction stages. The DGBGTH takes charge of the implementation of dams, large hydraulic structures and inter-regional hydraulic structures. The CRDAs are responsible for small hydraulic structures which can be managed inside one CRDA's administration area. A project management unit (PMU) is to be established within the DGBGTH or the CRDA to manage the construction and liaison activities on a daily basis.

Program 8: Documented Technical Guidelines and Standards

Documented and unified technical guidelines, standards, manuals or operation rules will be useful for the efficient and effective integrated implementation of flood control projects from planning and design stages to construction and O&M stages, both inside and outside the MARH. The river administration covering the structural measures and the non-structural measures for flood control is all closely related, and also these measures all require highly complex technology and management. The technical guidelines and standards will form the foundation for the rational approach and method for flood control planning and management in the country.

Program 9: Arrangement of Flood Insurance

Flood insurance is basically a supplemental instrument to the flood control structural measures. This forms part of non-structural measures of flood control.

Program 11: Establish new agency for O&M of river course and river facilities of Mejerda River

River Course and Flood Control Facilities

(1) Establishment of New Organization for O&M of Mejerda River

Sustainable O&M of a river basin with the concept of IFM can be achieved effectively and efficiently through the principle of 'one unit of management'. It is anticipated that one permanent river basin unit will be established for the O&M of the river banks, dikes, river channels and flood control facilities in the Mejerda River, under the direction of the DGBGTH. At present there is no such permanent unit for the river works of the Mejerda River.

The mission of the prospective Mejerda River basin agency is first, to provide O&M for the river works, then second, to assume authority to coordinate varying views among stakeholders including ministries, CRDAs, municipalities, associations, companies, residents, etc. The coordination authority is expected to be empowered by the Minister of MARH and the CNE. Financial sustainability of O&M is an important subject to continue consistently and effectively. The O&M cost of a public corporation type will be covered by both the subsidy from the MARH and the revenues from the beneficiaries, such as CRDAs, municipalities, the SONEDE, the SECADENORDE, farmers, etc.

(2) Establishment of New Control Center for Reservoir Operation of Mejerda River

Control and decision by 'one point management' only enables the best coordination of multiple reservoirs in the Mejerda River to eventually ensure safety of dams and effective and safe flood control. It is necessary to establish one control center for the Mejerda River under the direction of dam exploitation of the DGBGTH, with support by the CNE. The control center will have access to all necessary information through an on-line information system. The information includes discharges at gauging stations, current status and operations at all dams, discharge forecast and rainfall forecast. Under this system each dam operator will only follow the decision from the control center instead of local condition at dam site. The operators, however, are responsible in preparing their own operation plan by themselves based on all available information at the site, in cases where the on-line system to the control center is disconnected.

Information Management System

(3) Flood Forecasting and Warning System

Capacity development of the flood forecasting and warning system will be composed of first, upgrading of the telemeter system of rainfall and discharges to improve accuracy of forecast and to confirm timely operation, and second, organizational and personnel empowerment to operate it effectively and efficiently together with the Civil Protection, the CRDAs, the INM and other relevant organizations.

(4) Cooperation with Algeria for River Basin Management

At present the storm rainfall and flood discharge data observed hourly at the major stations inside the Algerian territory are not promptly made available to the MARH for its flood forecasting and warning, due to technical and financial constraints in the Algerian side. It is expected that cooperation with Algeria will be strengthened in terms of river basin management which covers rainfall, discharge, reservoir operation, and dam construction plans.

8.9 Outline of the Master Plan

According to the basic strategies set up in the Study for formulating the master plan, the study on the alternative plans for both structural and non-structural measures designated in the master plan framework was worked out, as discussed in the preceding Sections 8.2 to 8.8. This aims to clarify the current flood problems/issues that were encountered in the Mejerda River basin, and identify possible measures/solutions. After thorough consideration of the study outputs, the Study proposed that the flood control master plan be composed of the following six projects, which include two projects for structural measures and four for non-structural measures. These were proposed in order that the flood control project could firmly and timely produce results by 2030, the target year of the Study.

(1) Structural measures: to focus on protecting cities/towns/villages and also agricultural land along the Majerda River from flooding up to design floods

1-1 Project on strengthening flood control function of reservoirs: to minimize flood peaks released from seven reservoirs (Sidi Salem, Mellegue, Bou Heurtma, Siliana, Mellegue 2, Sarrath and Tessa Reservoirs) and also in their downstream rivers

1-2 Project on river improvement: to prevent detrimental flood overtopping from rivers up to design floods

(2) Non- structural measures: to focus on mitigating flood damage caused by excess floods and also sustain flood protection provided by the structural measures

2-1 Project on strengthening existing flood forecasting and warning system: to effectuate earlier dissemination of flood information required for the projects on strengthening (i) flood control function of reservoirs (1-1) and (ii) evacuation and flood fighting system (2-2)

2-2 Project on strengthening evacuation and flood fighting system: to avoid loss of lives and minimize damage of properties during flood events

2-3 Project on organizational capacity development: to provide well-organized and empowered institutional arrangements facilitating effectuation of other flood control projects proposed in the master plan from planning to O&M stages

2-4 Project on flood plain regulation/management: to minimize flood risk/damage in low land areas subject to inundation during excess floods along the Mejerda River

It should be noted that above six projects must be closely complementary to each other, as explained below, to achieve full and permanent effectuation. The interrelationship among the schemes is schematically illustrated in **Figure 8.9.1**.

(1) Project 1-1 and Project 1-2

Both projects are planned to protect the floods together up to the design flood correspondent to “flood protection level” so as to prevent inundation. Project 1.1 is intended to strengthen the flood control function of the seven selected reservoirs, 4 existing reservoirs (Sidi Salem, Mellegue, Bou Hertma and Siliana Reservoirs) and 3 future reservoirs (Mellegue 2, Sarrath and Tessa Reservoirs) through the improvement of current reservoir operation rules during floods, and reduce flood peaks as much as possible from reservoirs.

The reservoirs, however, can not entirely prevent the flood inundation in their downstream, because their downstream rivers receive flood runoff from their own basins as well. For this reason, Project 1-2 is necessary to successfully prevent flood overtopping from the downstream rivers.

(2) Project 1-1 and Project 2-1

The enhancement of flood control function of reservoirs contemplated in Project 1-1 requires relevant and accurate flood information as early as possible. Therefore, Project 2-1 is necessary to provide Project 1-1 with such information, including flood forecast, through strengthening of the existing FFWS.

(3) Project 2-1 and Project 2-2

The evacuation and flood fighting activities, which are essential to avoid loss of lives due to flooding, also require timely information on flood. Hence, Project 2-1 is necessary to provide Project 2-2 with relevant information as early as possible, including flood forecast, through strengthening of the existing FFWS.

(4) Project 2-3 and other projects

It is indispensable under the concept of IFM to provide the well-organized and empowered institutional arrangements which shall support O&M as well as planning and design/construction of other projects in the master plan, in order to secure sustainable effects expected from other projects. Hence, Project 2-3 is included in the master plan.

(5) Structural measures and Project 2-4

The structural measures, namely Project 1-1 and Project 1-2, could ensure protection against the floods up to the flood protection level, as mentioned above. This means that the flood control plan formulated in the master plan allows inundation during floods that exceed the design flood for river improvement works.

Then, the low lying areas located along the Mejerda River are subject to inundation during the excess floods. Currently, some of the low lying areas have been developed for cultivation as well as dwelling, and hence flood plain regulation/management is essential to minimize flood risk/damage in the low land areas due to the excess floods. With such consideration, this project is incorporated into the master plan.

Figure 8.9.2 presents an overview of the master plan composed of the six proposed projects for flood control in the Mejerda River basin.

CHAPTER 9 PROJECT DESIGN

9.1 Structural Measures

9.1.1 River Improvement

(1) Principle of facilities design

Principle of facilities design for river improvement works are as follows:

(a) From a technical viewpoint, river channel improvement includes levee embankment, channel excavation/dredging and construction of retarding basins so as to fully utilize the in-channel flow capacity up to its maximum, which is to be prioritized over other structural measures.

(b) No relocation of household/building is allowed to minimize social environmental impact. Therefore, it is assured that the least numbers of people will be affected by implementation of river improvement works. If enough spaces for construction of levee embankment/channel widening are not available, masonry/concrete parapet walls or retaining walls are adopted instead of earth works for levee embankment and channel widening.

(c) If the above treatment is still insufficient bypass channels and/or flood retarding basins are built to mitigate the shortage of river channel capacity.

(2) Survey data for facilities design

The following topographic survey data obtained through the Study were used for facilities design. A series of topographic maps with scales of 1:25000 and 1:50000 and aero-photos prepared by MARH were also used.

List of Survey Data Used for Facilities Design

Name of River/Structure	Location	Kind of data	Coverage	Nos. of cross sections
Mejerda	U/S Sid iSalem	Profile and cross sections	L=158.3 km	360
	D/S Sidi Salem	Profile and cross sections	L=148.5 km	447
Chaffrou		Cross sections	L=2.0 km	8
Lahmer		Cross sections	L=2.0 km	8
Kalled		Cross sections	L=2.0 km	8
Siliana		Cross sections	L=2.0 km	8
Kesseb		Profile and cross sections	L=20.3 km	86
Bou Heurtma		Profile and cross sections	L=17.3 km	79
Tessa		Profile and cross sections	L=20.3 km	87
Mellegue		Profile and cross sections	L=45.0 km	160
El Mabtouh Retarding Basin	Inlet to outlet channels	Profile and cross sections	L=29.8 km	9
	Basin	Cross sections	varied	7
Mejez El Bab Bypass		Profile and cross sections	L=4.5 km	14
Bou Salem Bypass		Profile	L=7.7 km	
Bridges for reconstruction		Cross section	varied	6

Source: the Study team

(3) Design standard and criteria

National Institute for Standardization and Industrial Property (INNORPI) has provided the general Tunisian standards and other related standards/specifications such as ISO, Norme Francaise, etc. However, technical guidelines for river improvement have not been established in Tunisia, while design standard and criteria for river structures are usually prepared on a project basis.

In the Study, the Japanese standards and criterion could be referred to as the result of inspection of the site situations and existing structures through field reconnaissance. These standards were used as reference in deciding the dimensions of river structures.

The standard geometry of levee embankment and river channel applied based on the Japanese Standards are summarized below:

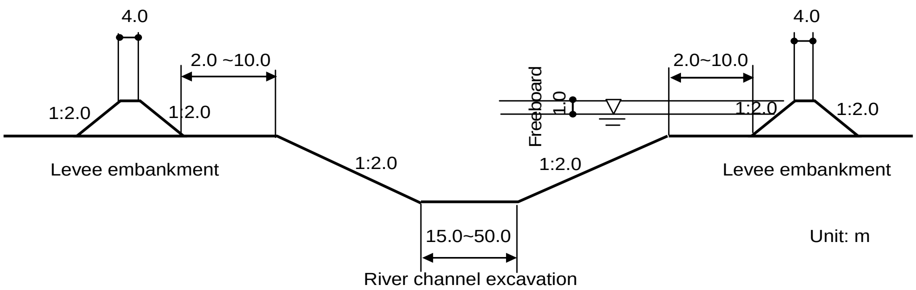
Design Criteria for Levee Embankment and River Channel

Category No.	1	2	3	4	5	6
Design Discharge Q (m^3/s)	Q < 200	200 ≤ Q < 500	500 ≤ Q < 2000	2000 ≤ Q < 5000	5000 ≤ Q < 10000	10000 ≤ Q
Free Board (m)	0.6	0.8	1.0	1.2	1.5	2.0
Crest width of levee (m)	3.0		4.0	5.0	6.0	7.0

Source: "Manual for River Works in Japan", edited by River Bureau of former Ministry of Construction (Presently Ministry of Infrastructure, Land and Transportation)

The side slope of levee embankment shall be 1:2.0 or greater. The design discharge of river channel based on the hydrological analysis varies from 570 m3/s to 1,860 m^3/s in the Study Area. In relation to the table above, a standard cross section of levee embankment is set in the Mejerda River as follows:

(a) Crest width : 4.0 m wide
(b) Freeboard : 1.0 m high
(c) Side slope : 1:2.0



Typical Cross-section of Channel Excavation and Levee Embankment

In the detailed design stage, stability analysis of levee embankment shall be conducted to verify the appropriateness of the dimensions. For river channel excavation in the Mejerda River, determining the side slope of river channel is to be based on (i) the improved stability of the present bank slope against sliding, and (ii) the safety for maintenance work of river channel.

As for the soil-mechanical conditions at planned structure sites for levee, bypass channels, sluices, etc., no particular difficulty of design/construction works has not been identified based on ocular inspections through site reconnaissance at candidate sites along the river channels. In general, sub-surface soil along the river courses consists of alluvial deposit transported and cumulated by the Mejerda River with distribution of sandy to silty soil. Therefore, no special criteria for foundation design of the proposed structures were applied at this stage. However, boring and soil investigation will be required in the feasibility or detailed study stages to determine the soil properties for structural/stability analyses.

(4) Structural design

(a) River channel improvement works

River channel improvement works for the Mejerda River are designed with a combination of the following three measures:

(i) Channel excavation/dredging and widening,
(ii) Levee embankment, and
(iii) Reservation of retarding areas.

These measures are studied through the whole stretches of the Mejerda River during flood analysis considering land use, topography and hydraulic conditions for the most advantageous situation. The longitudinal profile along the lowest river bed based on hydraulic analysis is shown in the drawings on Data Book.

The river stretches of MD29 to MD24, MU 53 to MU 79, MU207 to MU304 and ME 19 to ME 106 are allowed to overtop to lessen the peak and volume of flood discharge in their downstream river channels.

The table below shows the current flow capacity and design flood discharge by river stretches.

Current Flow Capacity and Design Flood by River Stretches

River Stretches	Flow Capacity (m^3/s)	
Mejerda River	Current Flow Capacity	Design Flood Discharge
Ghardimaou – confluence with Rarai R.	250	250
Confluence with Rarai R. – Jendouba	400	790
Jendouba – Confluence with Mellegue R.	200	520
Confluence with Mellegue R. – Confluence with Tessa R.	250	1480
Confluence with Tessa R. – Bou Salem	400	1840 (1140)
Bou Salem – U/S end of Sidi Salem Res.	300~350	1840
Sidi Salem Dam – Slouguia	250~500	410~700
Slouguia – Mejez El Bab	600	700 (500)
Mejez El Bab – Laroussia Dam	250	760

Source: the Study Team

The general plans of the proposed river improvement works are shown in **Figures 9.1.1** and **9.1.2**.

(b) Bypass Channel

The El Battane, Mejez El Bab, Bou Salem and Jendouba areas, situated on the Mejerda River, were examined to determine the need of a bypass channel, considering the insufficient river flow capacity and difficulty of river channel widening along the areas of the river. Hydraulic study was further carried out and results were superimposed on the topography and land use. It was concluded that bypass channels for Mejez El Bab City and Bou Salem City are necessary to cope with the design flood discharge.

In the case of Mejez El Bab City, the river section at the historical old bridge (Andarrous Bridge) is a critical bottle neck. However, the bridge shall be preserved as it is without removal in accordance with the request of the Tunisian side.

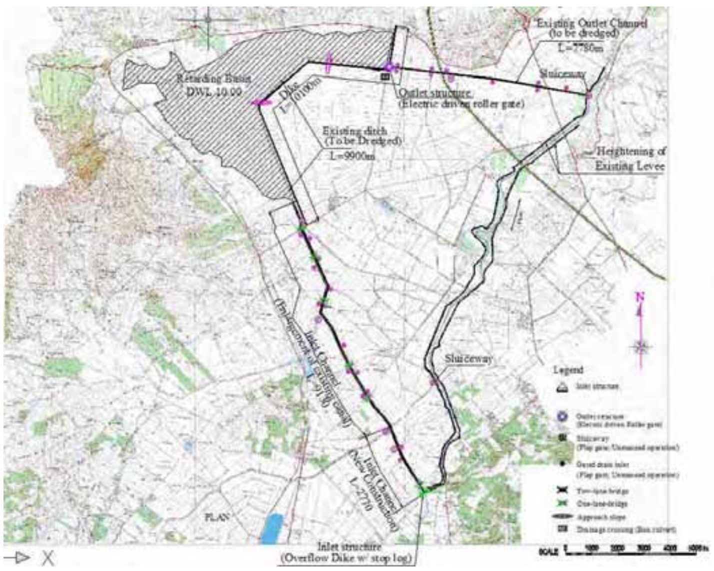
Bou Salem City is developed on both sides of the Mejerda River. The available space for river improvement works between both banks is quite limited. Almost all of Bou Salem City is in a flood prone area along the Mejerda River. The bypass channel is an effective measure to lower the risk of flood from the topographic point of view.

The structural design of the Mejez El Bab and Bou Salem bypass channels is shown in **Figures 9.1.3** to **9.1.7** and **Figures 9.1.8** to **9.1.11,** respectively.

(c) Retarding basin

(i) Basic concept and general layout

The El Mabtouh plain will benefit in constructing a new retarding basin since the existing retarding system seems primitive. The existing structures can be improved by upgrading existing ones so that land acquisition can be minimized. The inlet channel needs to be renewed and the surrounding dike should be upgraded. Meanwhile, the outlet channel will remain usable after dredging and widening. Besides, the inlet structure is to be newly provided. The existing bridges on the inlet channel and existing sluice/drain inlets along the inlet and outlet channels must as well be modified. General layout of the El Mabtouh Retarding Basin is shown in the figure below:

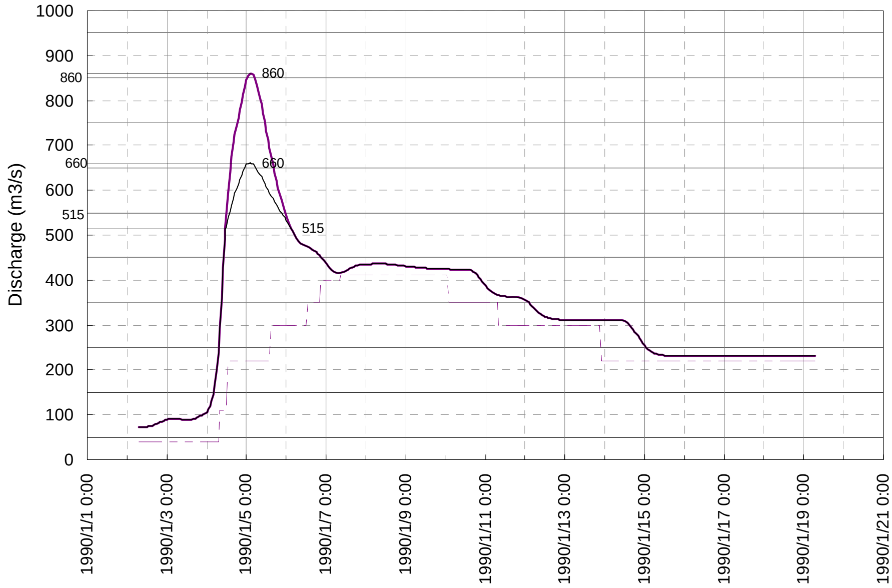


Source: the Study Team

General Layout of El Mabtouh Retarding Basin

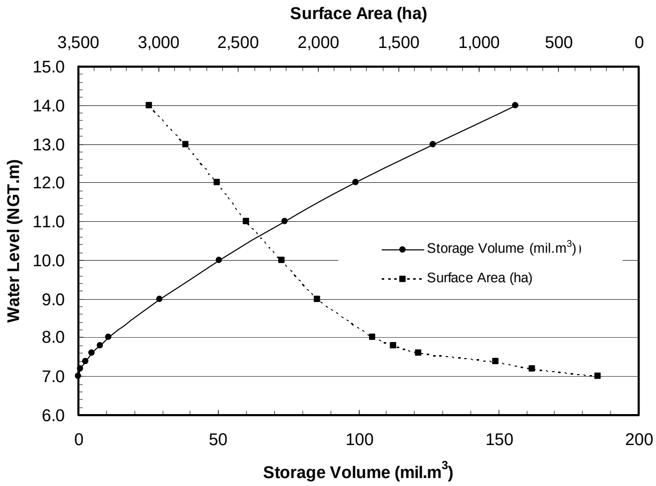
(ii) Hydraulic conditions

A maximum discharge of 200 m^3/s is planned to be diverted to the retarding basin, out of the 860 m^3/s peak discharge at the upstream side of the inlet structure in the Mejerda River. Therefore, 660 m^3/s will flow to the downstream stretch after diversion. The inlet structure is designed as an unmanned operating overflow dike lined with concrete. The river discharge for the commencement of diversion is set at 515 m^3/s, which corresponds to the river flow capacity at the crest elevation of the overflow dike at the inlet structure. The design flood hydrograph at the inlet structure is shown in the graph below. A total volume of 14 million m^3 is diverted to the retarding basin. The capacity of retarding basin is about 50 million m^3 including a sediment volume and the runoff inflowing from its own catchment. An elevation-area-storage curve is illustrated below. The layout and facility design is shown in **Figures 9.1.12 to 9.1.17** and **Drawings Sheet Nos. E1-28 to E1-35 in the Data Book**.



Source: the Study Team

Design Flood Hydrograph at Inlet Structure of El Mabtouh Retarding Basin



Source: Prepared by the Study Team based on topographic survey results in the Study

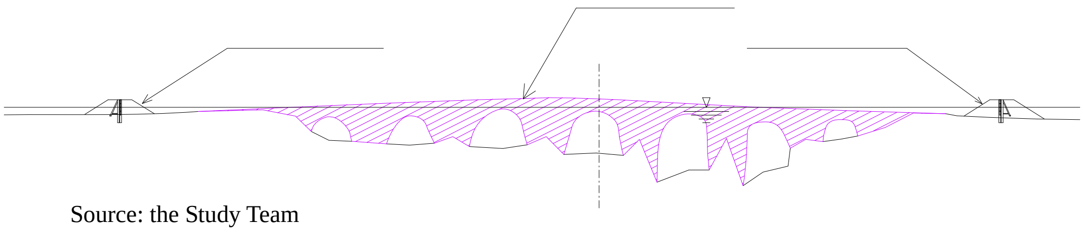
Elevation – Area – Storage Curve of El Mabtouh Retarding Basin

(d) Parapet wall and retaining wall

The levee embankment is basically constructed with earth material. When the available land is limited in residential areas for construction of levee, a parapet wall made of concrete/masonry is an alternative solution to avoid relocation of residents. A low water channel is also formed with concrete retaining wall to maximize the flow area in the narrow section. **Drawings with Sheet Nos. E1-59 to E1-64** of the Data Book show the design of the structures to be provided in Jedeida City and El Battane City.

(e) Detachable Stop Log Structure

Although this is not a preferable measure, this might be one of the simple solutions to avoid inundation where the bridge is submerged under the design high water level. Both banks of the historical Anderous Bridge in Mejez El Bab and the ancient El Battane Weir are subjected to this situation as shown below. The stop log is planned to be placed at the approach roads of bridges in between discontinued part of levee. This structure is made of detachable posts with stop log slots and movable steel stop log leaves. Actual operation should be related with the warning system, and the stop log must be installed timely. Otherwise spilled water will flow to the residential area. **Sheet No.E1-69 in the Data Book** shows typical design for this structure.



Source: the Study Team

Typical Section of Stop Log Structure at Historical Bridge Site

(f) Revetment for slope protection

Nominal river bank protection works have been carried out in the Mejerda River. Erosion is worsening at most meandering portions. The following criteria for provision of slope protection adjacent to the structures shall be applied:

(i) Dense housing area with risk of damage due to erosion,
(ii) Public properties such as a national road, railway and trunk structures serving as lifeline support, close to eroded river bank, and
(iii) Upstream and downstream sides of structures, (if necessary).

As for the agricultural land areas, requirement of revetment needs to be verified during the maintenance period based on the actual erosion conditions.

Three types of revetment for bank protection are proposed with design particulars, which are:

(i) Concrete frame / wet cobble masonry
This is a solid structure and to be applied to dense residential areas, such as Bou Salem City, Jedeida City.

(ii) Gabion / stone pitching

To be applied to transition between a solid structure and earth material.

(iii) Fascine mattress / fascine hurdle

To be applied to protection of the public and/or private properties that are close to the eroded bank, as discussed in Section E2.6.

Sheet Nos. E1-65 to E1-68 in the Data Book show the design drawings of concrete frame-type revetment for Bou Salem City. Typical design drawings of fascine mattress / fascine hurdle is shown in **Sheet Nos. E1-70 and E1-71 in the Data Book**.

(g) Ground sill

Ground sill is a measure to stabilize the riverbed in a river channel regime. The proposed scheme of river improvement excludes short-cut channel so that the gradient of present riverbed profile is not drastically changed before and after improvement works. The present riverbed is anticipated to rise due to sedimentation. Consequently, it is judged that a ground sill is not necessary on the Mejerda River except on special cases, which are in the bypass channels, at inlet and outlet structures and at the inlet of El Mabtouh Retarding Basin.

(h) Sluiceway

The construction of levee interrupts the existing continuous draining system connected to the river. It is necessary that sluices shall be properly provided at the crossing point of levee and drainage canals to the Mejerda River. Most of the structures are located at remote areas and thus operation shall be generally unmanned. The gate must react with water level fluctuation inside and outside. Therefore, a flap gate is adapted. The number, type and size of sluiceway are preliminarily determined based on the available aerial photos. The typical design of sluiceway is shown in **Sheet Nos. E1-79 to E1-88 in the Data Book**.

(i) Bridges

Based on the hydraulic analysis with the latest river cross sections, four road bridges, one aqueduct with a foot path and two railway bridges would be affected. The elevations of these superstructures are lower than the design high water levels. The elevation of the railway bridge at Jedeida (Zone D2) can be raised by jacking up the superstructures and placement of additional concrete on the top of substructure. The other six bridges should be replaced with new bridges. In Tunisia, road bridges are managed by the Ministry of Equipment, while railway bridges are separately managed by SNCFT.

A 100-year return period flood discharge shall be applied to the design of the bridges in the Study. Existing bridges subject to reconstruction are listed below. Cross sections of these structures are shown in attached **drawing in Sheet Nos. E1-72 to E1-78 in the Data Book**.

Bridges affected by the Proposed River Improvement

Name of Zone	Category	Location		Length (m)
		Reconstruction	Heightening	
Zone D2	Road bridge	MD436		140
	Road bridge	MD406		160
	Road bridge	MD401		140
	Railway bridge		MD338	75
Zone D1	Aqueduct with foot bridge	MD134		110
Zone U2	Railway bridge	MU40		110
	Road bridge	MU153		100

Source: the Study Team

(5) Maintenance of river channel

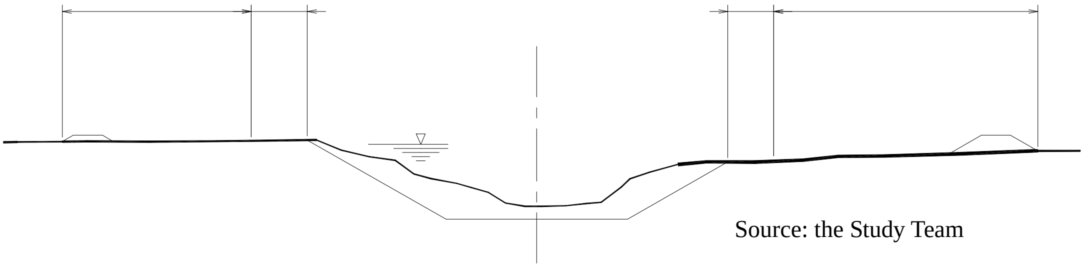
The thick bush prevailing in the high water channel, mainly consists of a tree called "Tamarix". These are found in almost all stretches along the Mejerda River. Tamarix narrow the flow area and hinder smooth flow in the river channel. This is a serious problem on flood prevention. On the contrary, it is observed that they are somewhat contributing in the prevention of river bank erosion.

After the devastated flood in last January to February 2003, each CRDA recognized the importance of removal of Tamarix. They provided budget to remove Tamarix from the river channel and was eventually implemented by cutting down the trunks and then by burning. However, according to the interviews at CRDA Manouba, a problem is still caused by the remaining stubs and roots, which quickly branched off and grew 3 to 4 m high within only 2 to 3 years. The prepared budget was insufficient to remove all from the subject river stretches.

Tamarix can spread through its roots or submerged stems, and by seeds. If the root is not removed, they will return to its former conditions quickly. The right picture shows a high water channel widely covered with Tamarix, which had been cleared by cutting them down two years ago. They seem to have already grown completely again.

Current Condition at Downstream of Jedeida

It is concluded that the Tamarix must be cleared by means of grubbing its roots. However, roots must be left in a range of 5.0 m from the shoulder of channel section to prevent bank erosion as shown in the figure below:



Source: the Study Team

Area of Tamarix to be Left for Bank Protection (Tentative)

According to the information from CRDAs, Tamarix started to grow in the high water channel after the construction of the Sidi Salem Dam. This proves that the Tamarix can grow fast on the silted surface with sediment.

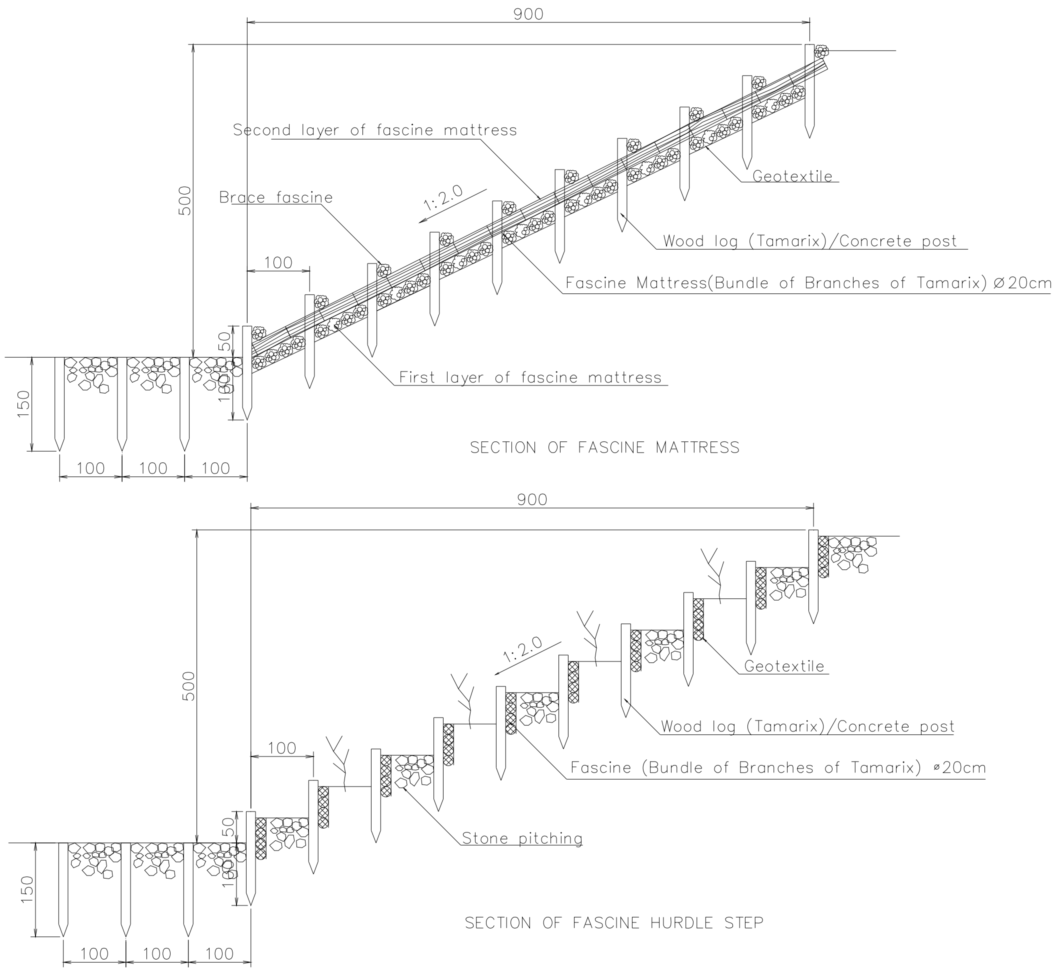
Tamarix is not suitable for charcoal nor fire wood because of its smell when burned. It is somewhat usable as raw material for manufacturing plywood. However there is very limited demaud and no factory operates in the vicinity of the project area. The disposal cost is not negligible while disposal by burning has negative impacts to the environment in the area.

On the other hand, there is a construction method for the slope protection utilizing wood as materials. This is widely adopted as a traditional way of river bank protection in Japan. This construction method seems to be applicable to the Mejerda River using Tamarix. There were requests in many places concerning bank protection, according to the interview at the site. If this method is effectively applicable with cut Tamarix, the cost of slope protection in the maintenance period can be reduced. Residents, who want to protect their land from erosion can themselves apply the method using Tamarix, if they know on the technique how to implement it. It should be noted that no heavy machinery is required for its construction.

Branches of “Tamarix”

Maintenance works for the river channel can be implemented to some extent through participatory approach with the local people. This is possible, if a certain mechanism is established between CRDAs and cities/villages concerned. This method is expected to contribute to saving the limited maintenance budget of the local government. The photo above shows the branches of Tamarix that seem to be usable for fascine mattress.

However, unless the efficiency and applicability of this method is confirmed through a pilot project, this can not be immediately implemented for construction. A typical design of Japanese traditional slope protection works made of wood logs and branches is shown in the following figure below. Drawings are also attached in **Sheet Nos. E1-70 and E1-71 in the Data Book.**



Source: the Study Team

Typical Cross Section of Slope Protection (Traditional type in Japan)

(6) Salient feature of proposed structures

Based on the design drawings prepared as mentioned in the previous sections, the salient features of major structures proposed in the Study is summarized for each zone in the following table. Further detailed dimensions of each structure are tabulated in **Table 9.1.1**.

Salient Feature of Major Structures (River Improvement Works)

Zone D2

I. Mejerda River				
1) Embankment				
a) Length				
Whole river stretches under planning			60,310	m
(Heightening of existing levee)			20,280	m
Actual construction plan of embankment			55,843	m
		(Left bank)	29,365	m
		(Right bank)	26,478	m
b) Height			0.5-2.5	m
2) Channel excavation/widening		Length	63,838	m
		Volume	10.0	mil. m^3
3) Sluice gate			47	Nos.
4) Revetment	Concrete frame type		2,200	m
	Stone pitching type		500	m
	Fascine mattress type		2,400	m
5) Renewal of existing bridge			3	Location
6) Raising of existing railway bridge			1	Location
7) Raising of existing road			4,600	m
II. El Mabtouh Retarding Basin				
1) Inlet channel	Improvement of existing channel		9,130	m
	New channel construction		2,770	m
2) Outlet channel			7,780	m
3) Surrounding dike		Length	10,100	m
		Height	2.0-4.0	m
4) Design storage capacity			50 million	m^3
5) Design discharge		Inlet channel	Q=200	m^3/s
		Outlet channel	Q=50	m^3/s
6) Overflow dike of inlet channel (with stop log		Length	80	m

Zone D1

I. Mejerda River				
1) Embankment				
a) Length				
Whole river stretches under planning			79,552	m
Actual construction plan of embankment			70,580	m
		(Left bank)	36,671	m
		(Right bank)	33,909	m
b) Height			0.5-2.5	m
2) Channel excavation/widening		Length	81,224	m
		Volume	9.4	mil. m^3
3) Sluice gate			72	Nos.
4) Revetment	Concrete frame type		1,000	m
	Stone pitching type		500	m
	Fascine mattress type		2,700	m
5) Renewal of existing bridge			1	Location
II. Majez El Bab Bypass Channel				
1) Bypass channel		Length	4,512	m
		Excavation volume	2.7	mil. m^3
2) Channel bottom width			15	m
3) Design Discharge	Mejerda River		Q = 450	m^3/s
	Bypass channel		Q = 250	m^3/s

Zone U2

I. Mejerda River				
1) Embankment				
a) Length				
Whole river stretches under planning			54,971	m
Actual construction plan of embankment			67,499	m
		(Left bank)	34,833	m
		(Right bank)	32,666	m
b) Height			2.5-4.5	m
2) Channel excavation/widening		Length	42,726	m
		Volume	9.6	mil. m^3
3) Sluice gate			42	Nos.
4) Revetment	Concrete frame type		1,000	m
	Stone pitching type		500	m
	Fascine mattress type		3,300	m
5) Renewal of existing aqueduct with foot bridge			1	Location
II. Bou Salem Bypass Channel				
1) Bypass channel		Length	7,736	m
		Excavation volume	3.5	mil. m^3
2) Channel bottom width			25	m
3) Design Discharge	Mejerda River		Q = 1,140	m^3/s
	Bypass channel		Q = 700	m^3/s

Zone U1

I. Mejerda River				
1) Embankment				m
a) Length				
Whole river stretches under planning			5,124	m
Actual construction plan of embankment			5,124	m
		(Left bank)	2,264	m
		(Right bank)	2,860	m
b) Height			1.0-3.0	m
2) Channel excavation/widening		Length	48,217	m
		Volume	4.2	mil. m^3
3) Sluice gate			3	Nos.
4) Revetment	Stone pitching type		250	m
	Fascine mattress type		1,500	m

Zone M

I. Mellegue River				
1) Embankment				
a) Length				
Whole river stretches under planning			8,895	m
Actual construction plan of embankment			7,405	m
		(Left bank)	4,195	m
		(Right bank)	3,210	m
b) Height			1.0-3.0	m
2) Channel excavation/widening		Length	12,871	m
		Volume	0.6	mil. m^3
3) Sluice gate			3	Nos.

9.1.2 Project on Strengthening Flood Control Function of Reservoirs

All reservoirs in the Tunisian territory of the Mejerda River basin must be operated as one coordinated system in order to enhance their flood control functions, paying special attention to the seven important reservoirs for flood control (4 existing reservoirs: Sidi Salem, Mellegue, Bou Heurtma and Siliana Reservoirs and 3 reservoirs under construction or in a design/plan stage: Sarrath, Mellegue 2 and Tessa Reservoirs). For this reason, it is needed to provide the system with fundamental rules for well coordinated operation and to follow the rules at any time to realize optimized coordination of dam operation to achieve the most effective flood control and successful water supply.

Under the above condition of reservoir operation in the Mejerda River basin, the real secrets of strengthening flood control function of reservoirs is to use an available flood control storage provided above the normal water level (NWL) as effectively as possible and to minimize flood peaks downstream of dams, through the following recommendations for future operation of reservoirs during floods, as discussed in Section 8.2:

- Maintain the water level in reservoirs at normal water levels, particularly during the rainy season,
- Give the highest priority to the safety of dam in all operations,
- Pre-release reservoir water as soon as the information about an upcoming flood attack is given. The discharge to be released shall be equal to the flow capacity of the downstream river channels, and
- Coordinate reservoir operation and control outflows from the reservoirs based on knowledge of flood propagation times downstream of the dams. This aims to avoid joining of flood peaks from two or more sub-basins at one site and minimize the flow in the downstream.

In order to effectively realize the above secrets, this project is incorporated into the master plan. The major programs and activities of the project are as listed below.

Main Programs and Activities	
1.	Improvement of simulation model for coordinated operation of dams
2.	Drafting improved operation rules of 7 selected reservoirs for flood control
3.	Trial application (2 rainy seasons), review and improvement of the draft improved reservoir operation rules for flood control
4.	Coordination of institution arrangements related to improved reservoir operation rules for flood control
5.	Strengthening function of collection, storing, analysis and dissemination of data/information
6.	Preparing monitoring plan to sustain project effect

Table 9.1.2 shows the action plan for this project. In the plan, a project term is 2.5 years and seven expatriate experts are to be input to the project.

9.2 Non-structural Measures

(1) Project on strengthening existing flood forecasting and warning system (FFWS)

In the Study, the development and improvement plan for strengthening the existing FFWS is recommended as discussed in Section 8.5:

- As immediate measures to minimize the flood risk and mitigate flood damage before completion of the planned structural measures,
- As measures to minimize the risk and mitigate damage due to excess floods (sever floods exceeding the planning/design level of the structural measures), and
- As measures to contribute to coordinated operation of dams by providing

hydrological information timely and accurately.

Therefore, the objectives of FFWS for the Mejerda River basin are:

- To provide hydrological information in order to conduct integrated management of river structures including coordinated operation of dams, which would contribute to damage mitigation in inundation areas, and
- To provide hydrological information in order to make decisions of required actions for evacuation / flood fighting system.

Major programs and activities are as presented below to realize the strengthening of the existing FFWS. The action plan of this project is formed as shown in **Table 9.2.1**.

Main Programs and Activities	
1.	Scrutiny on additional installation of telemetric rainfall and water-level gauges to existing telemetry system
2.	Installation of additional telemetric rainfall and water-level gauges
3.	Study on flood forecasting method and model
4.	Development of flood forecasting model
5.	Installation of measuring device of dam release discharge
6.	Improvement of FFWS based on trial application and review of the draft improved reservoir operation rules for flood control
7.	Preparing system operation manual
8.	Preparing monitoring plan to sustain project effect

The project term is 3 years and seven expatriate experts are planned to be input.

In the Programs 3 and 4, a flood forecast model using "the river water stage correlation method" is proposed to be studied/developed initially. For the flood forecast model developed by a flood runoff analysis method using telemetric rainfall data, a prototypic model is to be studied/developed in both programs, because in the latter model case, the development requires substantial time for improving and rectifying through a trial and error process based on various floods with different temporal/spatial distributions and magnitudes, which is a known prerequisite in developing a flood forecast model of the latter type.

(2) Project on strengthening evacuation and flood fighting system

The current evacuation and flood fighting system for the Mejerda River basin needs to be reconsidered to strengthen its function from the following points of view, as discussed in Section 8.6:

(a) In order to decide well-timed commencement of evacuation / flood fighting activities, it is important to clarify precise commencement criteria.

(b) Raising peoples' awareness on disaster mitigation is essential, since understanding and cooperation of the public and their communities are indispensable for evacuation activities.

Therefore, the following are proposed to be executed in the project.

Main Programs and Activities	
1.	Improvement of information sharing system among official agencies and communities regarding flood disaster management and evacuation plan
2.	Study and setting of alert levels at key water-level gauging stations for evacuation/flood fighting activities
3.	Formulation of precise criteria to commence evacuation/flood fighting activities
4.	Development of understandable evacuation procedures and drilling at pilot areas
5.	Preparing monitoring plan to sustain project effect

Table 9.2.2 shows the action plan of this project. The project term is one year and the input of four expatriate experts is contemplated in the plan.

(3) Project on organizational capacity development

The problems and issues concerning river basin planning and management focusing on flood control in the Mejerda River basin as explained in Section 8.8, from institutional and organization viewpoints are identified below.

(a) There are no permanent division or service for flood control activities and management in the central and regional directions except the services related to risk and flood announcement.

(b) There are no documented technical guidelines or standards for flood control and water supply planning and design, and reservoir operation rule.

(c) The competence of flood control is separated: the MARH for rural and agriculture areas, while the MEHAT for urban areas.

(d) The competence of flood fighting activities are separated: forecasting and announcing by the MARH, while warning, flood fighting and evacuation activities by Civil Protection under the Ministry of Interior.

(e) Sediment control in watersheds is insufficient: sedimentation inside river channels and reservoirs becomes a significant factor in causing floods.

(f) Cooperation with Algeria for river basin management is insufficient: particularly the rainfall and discharge data necessary for flood forecasting and warning.

An organizational capacity development plan for institution and organization in the Mejerda River basin is drafted to materialize the necessary actions for the above-mentioned problems/issues. This draft plan consists of the following eleven programs, classified into three attributes of institutional integration of river administration, namely (i) integrated administration, (ii) integrated planning and implementation and (iii) integrated operation and maintenance, as discussed in detail in Sub-section 8.8.3.

(i) Integrated administration

- Program 1: One management for one river basin (Mejerda River)
- Program 2: Permanent organization in central and regional directions to promote IFM
- Program 3: Supplement of IFM to Mission of National Water Council
- Program 4: Basin-wide environmental management and monitoring

(ii) Integrated planning and implementation
- Program 5: Integrated planning of structural and non-structural measures for flood control by Project Steering Committee under DGBGTH
- Program 6: Coordination by MARH in design to O/M stages
- Program 7: Implementation and management by PMU under DGBGTH in design and construction stages
- Program 8: Documented technical guidelines, standards and rules
- Program 9: Arrangement of flood insurance

(iii) Integrated operation and maintenance,
- Program 10: Strengthening O&M of exiting water supply system and large dams
- Program 11: Establishment of new agency for O&M of river course and river facilities of Mejerda River

It is practical to implement the drafted plan in three stages as shown below because there are limited experiences and practices on flood management and O&M for the river works in Tunisia.

Main Programs and Activities	
First Stage	
1.	Scrutiny and establishment of permanent division or direction in charge of Mejerda River basin inside DGBGTH
2.	Detailed study on 11 proposed programs for organizational capacity development
3.	Initiating the proposed programs
4.	Selection of a pilot project to be conducted in the second stage
5.	Provision of documented technical guidelines, standards and rules
Second Stage	
1.	Conducting a pilot project under proposed river improvement project of the Mejerda River
Third Stage	
1.	Scrutiny and establishment of an agency in charge of O/M of the Majerda River basin, if the pilot project justifies the viability of the agency
2.	Preparing monitoring plan to sustain project effect

Table 9.2.3 shows the action plan of the programs and activities. The project term is 2.5 years, excluding the second stage, and seven expatriate experts are to be input.

(4) Project on flood plain regulation/management

Based on the planning concept discussed in Section 8.7, the following four aspects shall be focused on in implementation of the project:

- Delineation of the flood prone area for a flood risk map, based on inundation analysis, latest land use and demographic information, which shall be supported by the GIS system developed in the Study. The GIS system will be updated in the project implementation.
- Examination of future land use plan on the flood risk map in order to mitigate the vulnerability to inundation and to enhance the productivity of agricultural development
- Preparation of guidelines through the above activities to enable sustainable flood management including proper maintenance of structural measures as proposed in the

Study

- Disseminate and promotion of the concept of the flood plain regulation/management over the Mejerda River basin (CRDAs and other local governments) by means of training and seminars

In order to realize the concept of the project, the following activities will be contemplated:

Main Programs and Activities	
1.	Delineation of flood prone area through review of runoff and inundation analysis of the Mejerda River basin
2.	Updating of GIS data base with current cropping information
3.	Preparation of flood risk map with zoning and regulating structural plan by risk level
4.	Analysis on improved cropping pattern based on current prevailing land use
5.	Preparation of guideline for flood risk mapping
6.	Preparation of guideline for enhanced land use control for urban and rural areas
7.	Dissemination, application, evaluation and validation of the guidelines in target CRDAs and local governments
8.	Training and seminar

Duration of the project term is set for 3 years and eight expatriate experts are planned to be input. An action plan of the proposed activities is shown in **Table 9.2.4**. This project would need to be effectuated keeping close linkage with the soil preservation programme in the Mejerda River basin.

CHAPTER 10 COST ESTIMATE

10.1 General

Based on the preliminary design drawings of river improvement works, bill of quantities were calculated by each work item. The unit costs of corresponding work items were determined based mainly on bid prices of the past projects performed by MARH as well as current and dominant prices in the domestic and international construction markets. The direct construction cost of the proposed river improvement works was estimated and compiled for each zone.

The other associated costs such as land acquisition, engineering services, contingencies and taxes, etc. are discussed in Chapter 12.

10.2 Bill of Quantities of Earth Works

The work quantities of earth works of the proposed river improvement are summarized as follows:

Summary of Work Quantities of Major Items

No.	Work Item	Unit	Zone				
			D2	D1	U2	U1	M
A	**Earth Works**						
(1)	Clearing and grubbing	1,000 m^2	1,921	2,115	3,078	88	18
(2)	Stripping	1,000 m^2	1,951	2,115	3,563	206	18
(3)	Excavation	1,000 m^3	10,138	12,121	12,848	4,234	655
(4)	Embankment	1,000 m^3	1,735	848	3,395	88	128
(5)	Disposal of excavated materials	1,000 m^3	8,958	11,288	8,671	4,155	410
B	**Concrete Works**						
(1)	Concrete	1,000 m^3	30	14	24	0.2	0.2
(2)	Reinforcement bars	ton	2,132	724	1,442	13	13
(3)	Stone masonry	1,000 m^3	16	0.0	8	0.0	0.0
C	**Stone Works**						
(1)	Gabion mattress	1,000 m^3	9	11	18	0.2	0.2
(2)	Stone pitching	1,000 m^3	47	74	103	10	0.5
(3)	Fascine mattress	1,000 m^2	72	81	99	45	0.0
D	**Other Major Works**						
(1)	Prestressed concrete beams (L=20m, 25m, 30m)	Unit	120	48	72	0	0
(2)	Cast-in place concrete pile	Unit	140	30	72	0	0
(3)	Steel sheet pile	m^2	6,500	3,010	2,560	150	150
(4)	Heightening and removal of existing railway	m	1,200	0	3,000	0	0
E	**Metal Works**						
(1)	Slide gate (Max size W=1.5m, H=1.5m)	ton	34.5	24.7	19.2	0.4	0.4
(2)	Slide gate/Roller gate (Larger than W=2.0m, H=2.0m)	ton	10.8	2.0	0.0	0.0	0.0

Source: the Study Team

10.3 Unit Cost

The unit cost of each work item was calculated based mainly on bid prices of the past projects performed by MARH. The major work items were initially selected to simplify estimation of the construction cost considering the requirements at the master plan study level. All unit prices were converted and adjusted to the price level as of June 2008. The unit price of 41 work items in total were examined and prepared as listed below. A breakdown of some of the major work items among the abovementioned 41 items is compiled in Data Book.

Summary of Unit Costs for Cost Estimate

No.	Work Item	Description	Unit	Unit price (TND)
	EARTH WORKS			
A1	Clearing and grubbing (Dense bush)	with average hauling distance of 1.00 km	m^2	2.267
A2	Clearing and grubbing (Thin bush)	with average hauling distance of 1.00 km	m^2	1.491
A3	Stripping	with average hauling distance of 1.00 km	m^2	0.267
A4	Excavation for river channel, common soil	with average hauling distance of 0.50 km	m^3	2.300
A5	Excavation for river channel, indurated	with average hauling distance of 0.50 km	m^3	3.840
A6	Excavation for river channel, rock	with average hauling distance of 0.50 km	m^3	8.180
A7	Excavation for bypass channel, common soil	with average hauling distance of 1.00 km	m^3	2.414
A8	Excavation for structures		m^3	3.580
A9	Embankment	with average hauling distance of 2.00 km	m^3	3.759
A10	Embankment	Directly from excavation site	m^3	2.039
A11	Backfill to structures w/o haul		m^3	4.160
A12	Gravel metalling for inspection roads		m^3	27.310
A13	One-way hauling distance per 1.00 km		m^3	0.477
A14	Disposal of excavated materials	Directly from excavation site	m^3	0.250
A15	Disposal of excavated materials	with average hauling distance of 2.00 km	m^3	1.220
	CONCRETE WORKS			
B1	Lean concrete (32/10)	0.1 m^2 of form included	m^3	82.000
B2	Concrete Type A (63/17), Plain concrete	0.5 m^2 of form included	m^3	114.000
B3	Concrete Type B (32/26), Reinforced concrete	2.5 m^2 of form included	m^3	173.545
B4	Concrete Type C (16/26), Reinforced concrete	4.0 m^2 of form included	m^3	215.846
B5	Reinforcement - plain round bar		kg	1.791
B6	Reinforcement - deformed bar		kg	1.791
B7	Stone masonry Type A, with 1:3 mortar		m^3	75.386
	STONE WORKS			
C1	Gabion mattress		m^3	94.225
C2	Stone pitching (Rough finishing)		m^3	26.822
C3	Stone pitching (Fine finishing)		m^3	42.862
C4	Fascine mattress		m^2	17.907
C5	Cobble stone fill		m^3	16.360
C6	Graded sand and gravel filter		m^3	16.360
C7	Demolition and disposal of existing masonry and concrete		m^3	155.720
C8	Asphalt concrete			250.000
	OTHER MAJOR WORKS			
D1	Prestressed concrete beam L=30m		Unit	26,300.000
D2	Prestressed concrete beam L=25m		Unit	20,300.000
D3	Prestressed concrete beam L=20m		Unit	12,700.000
D4	Cast-in place concrete pile with steel pipe pile casing		Unit	6,900.000
D5	Steel sheet pile (Permanent cutoff)		m^2	46.610
D6	Heightening and removal of existing railway		m	400.000
	Metal Works			
E1	Slide gate (manual operation hoist), Max size W = 1.50m, H = 1.50m		kg	4.680
E2	Slide gate/Roller gate (electric driven hoist), larger than W = 2.00m, H = 2.00m		kg	6.240
E3	Other metal works		kg	3.230
	Miscellaneous			
F1	Restoration of affected existing structures, etc.		%	3.000
F2	Miscellaneous works such as drainage crossing, inspection road, accessories of bridge, sod facing, etc.		%	7.000

Source: the Study Team

10.4 Direct Construction Costs of River Improvement Works

The summary of the direct construction costs based on the work quantities and unit costs is shown in the table below:

Summary of Direct Construction Cost

Work Item	Zone				(Unit: 1,000 TND)
	Zone D2	Zone D1	Zone U2	Zone U1	Zone M
Earth works	43,244	49,203	54,093	15,427	2,352
Concrete works	9,937	641	7,038	52	52
Stone works	4,656	5,524	7,160	1,182	28
Other major works	4,273	1,466	3,553	7	7
Metal Works	229	128	90	2	2
Miscellaneous	6,234	5,996	7,193	1,667	244
Total	**68,572**	**65,958**	**79,127**	**18,337**	**2,685**
Total of all zones = 234,679					

Source: the Study Team

Work quantities and direct construction costs of each zone are presented in **Tables E3.4.1 to E3.4.5 in Supporting Report E**.

CHAPTER 11 INITIAL ENVIRONMENTAL EXAMINATION

11.1 General

Environmental Impact Assessment (EIA) in the planning stage is not legally required in Tunisia. The Study, however, is required to execute an Initial Environmental Examination (IEE) in planning stage in accordance with the JICA's position on "Strategic Environmental Assessment" and its Guidelines for Environmental and Social Consideration. The IEE is the first review of reasonably foreseeable effects of the proposed project of flood control on the natural and social environment. There is a possibility that structural and non-structural measures proposed through the Study may have risks to induce adverse effects on the local people and the environment to some extent. IEE has been undertaken to identify key issues that require full investigation and screen out issues that are not likely to be significant based on the measures. The Study has followed the basic concept and procedures of the environmental laws and decrees relating to EIA in Tunisia as well.

The main purposes of the IEE are:

(1) To grasp the current physical, natural and socio-economic conditions in the Mejerda River basin and its surrounding areas,

(2) To examine probable environmental and social impacts caused by implementation of the river improvement works envisaged as the structural measures in the master plan for flood control of the Mejerda River, and

(3) To develop an outline of the environmental management plan including mitigation measures and monitoring plan to be integrated into the master plan.

The river improvement works envisaged in the master plan are divided into the following four categories for the IEE, including "No action considered for flood control":

- Measures for the upper area (Jendouba, Le Kef Governorates and West part of Beja Governorate),
- Measures for the middle area (East part of Beja Governorate),
- Measures for the lower area (Ariana, Manouba and Bizerte Governorates), and
- No action for flood control.

An outline of the river improvement works planned for each of the areas mentioned above, including some conceivable impacts, and locations are described in **Table 11.1.1** and **Figure 11.1.1**.

Detailed descriptions of the river improvement works and their conceivable impacts are given in Supporting Report J as well as the environmental management plan.

11.2 Observation on Negative Impacts

(1) Impacts on physical and biological environment

The impacts of the river improvement works on the physical environment will be minor and will mostly occur during construction. Soil disturbance will occur during construction with the greatest disturbance in areas where new structures are to be built. This will lead to temporary and local incidence of high turbidity levels in local watercourses especially during the dry season with increase of dust in the air. Once the works are stabilized, the impacts will be negligible over the long term.

Localized and minor permanent changes to the landform will occur with the new construction of bypass channels; however, the bridges that are planned to improve access along the structures will alleviate the negative impacts.

The impacts on terrestrial vegetation and fauna will be restricted to the riparian areas adjacent to the rivers or to the areas neighbouring the new structures where the construction will require removal of vegetation. These areas support planted vegetation. In addition, afforesting some of the path of the channels and canals will restore vegetation to be cleared during construction.

Though IUCN has presently identified about 80 species of mammals, 362 birds' species and more than 500 species of reptiles and fishes in the country, endangered species of flora and fauna are not confirmed in the flood plain and irrigable areas of the Mejerda River basin. The Study has confirmed that several fish species were introduced in the reservoirs built over the years. It is therefore evident that several fish species are living in the Mejerda River and the reservoirs. Among these, one can cite the berbel (Barbus callensis), which is endemic in North Africa, the common Tilapia (Cyprinus carpis), several species of mullets and the catfish.

Any increase in river turbidity levels or other pollutants (oils, etc) during construction will have a temporary impact on aquatic biota, including fish. But following the construction, it is expected that the disturbed areas will quickly become re-colonized.

Borrow areas will be required for the works, and will pose potential impacts regarding erosion, dust and aesthetics. Spoil disposal will be required in certain areas where the amount of excavation is anticipated to exceed that needed for construction.

(2) Socioeconomic impacts

The major impact of the river improvement works will be on socioeconomic conditions. The size of the structures to be built might cause local people's unrest and some conflict and/or opposition against them before the construction works. In addition, it is necessary to procure the areas for disposal of excavated material generated by channelling, which may require land acquisition. Most of the impacts will occur during the pre-construction period.

In addition, there is likely to be temporary disruption and minor losses during construction to the local agricultural communities due to reduced access to the dike areas and sections of the floodplains used for agricultural activities and livestock grazing. There will also be temporary localized disruptions to road transport in the vicinity of the construction sites. In the long term, however, there will be significant benefits to transportation from flood protection.

Minor health and safety impacts are also likely to occur during construction, with noise and dust affecting communities adjacent to work sites, particularly when heavy equipment is in use.

The proposed measures will not affect any historical or archaeological sites.

During the operation stage of the bypass channel, discharge of excess flood water back into the Mejerda River downstream of the channel would increase water flow more in these downstream areas. Therefore, proper countermeasures will be considered in this Project so that the increased water flow might cause no flood problems on agricultural lands or habitations in those areas.

11.3 Evaluation of the Impacts

The conceivable impacts caused by the implementation of the river improvement works as structural measures are evaluated using the Impact Matrix. The magnitude of impacts is ranked in the following grades: negligible, minor, medium and significant, based on the scale of the structures and the natural conditions surrounding them.

The results of the evaluation are compiled in **Table 11.3.1** and summarized as follows with the outline of natural and social conditions in the upper, middle and lower areas:

(1) <u>The upper area of the Mejerda River</u> includes Jendouba City and the western part of Jendouba Governorate, the Mellegue lower reaches, Bou Salem City and the upstream of Sidi Salem Dam covering the whole area between Sidi Ismail to Bou Salem City. The area is generally mountainous in the upper catchment reaches of the river with extensive areas of hilly uplands and forests located in the left bank of the Mejerda River. The ground water resources are well developed in the upstream area around Jendouba Governorate due to the proximity of the Sidi Salem Reservoir and other reservoirs located upstream, and due to the contribution of the rich forest reserves observed on the left bank, including the Feija National Park which would be secured from the floods of the Mejerda River because of being located in high lands. The area is essentially agricultural with some vestiges of old Roman city and some archaeological sites around Jendouba City, which are far away from the river basin. The structural measures applied for the upper area aim to mitigate flood inundation damage and protect residents and farmlands on both banks of the river, while minimizing economic losses and personal casualties. These structural measures show negative impacts ranging from negligible to minor and medium with no significant ones. Medium negative impacts are observed during the construction works through noises and vibrations and the generation by the works of too much spoil material waste to be disposed of, with the exception of Mellegue improvement works, which are of smaller scale. The bypass channel at Bou Salem, where the path of the channel crosses public land, scores only minor negative impacts for the possible people unrest. Furthermore, medium negative impacts are anticipated in the water quality near the watercourses during construction of the bypass channel. Positive impacts of the measures are

anticipated through reduction of soil erosion through the dike construction and river improvement works as well as the increase of income of the riparian populations who can be offered jobs during construction.

(2) The middle area of the Mejerda River covers parts of the Mejerda lower reaches, including the Medjez El Bab City on the eastern part of Beja Governorate. The area has dominant agricultural characteristics marked by a more undulating relief dominated by plains and plateaus. The structural measures applied for the middle area aim to mitigate flood damage in Medjez El Bab City and to conserve a historical property (an old bridge dating back from the 17^{th} century) of which destruction or relocation seems difficult. These measures would cause relatively medium negative impacts via noises and vibrations during construction. Also for the planned bypass channel at Mejez El Bab, the magnitude of adverse impacts would be medium, including the following elements: waste, water quality, aquatic organisms, land acquisition and people’s unrest and conflict/opposition. Positive impacts include erosion control through the dikes construction and river improvement works and job opportunities during construction works.

(3) The lower area of the Mejerda River includes the lowest reaches of the river, covering the cities of El Battane and Jedeida, and the vast plains of El Mabtouh down to the estuary area. It covers the fertile alluvial floodplains about 50 km wide, lying between the middle area and the Mediterranean Sea. It also covers the coastal plains consisting of streams, rivers and sea deposits, which are dominantly clay and silt layers often more than 50 m deep. Thus, the plains have been quasi-impervious to the percolation of flood waters and recharge of the groundwater. The population density is particularly higher in the plains near the river mouth. The structural measures applied for the lower area aim to primarily mitigate flood inundation damage and to conserve the vast agricultural land spreading along the Mejerda lowest reaches, including the El Mabtouh area. These also aim to protect against flood damage in and around El Battane and Jedeida Cities and to conserve the historical vestiges (El Battane weir dating back from the 17^{th} century) of which destruction or relocation seems difficult. Similar to the other two areas, noises and vibrations during construction would cause medium negative impacts for the measures applied for the lower area, namely El Battane, Jedeida and El Mabtouh Cities. For the retarding basin in El Mabtouh, all adverse impacts are minor. Positive impacts of the measures are anticipated through reduction of soil erosion after the dike construction and river improvement works and the increase of income of the riparian populations who can be offered jobs during construction.

No action (no river improvement) would leave the existing problem of sedimentation as it is in the river courses and the inability of the Mejerda River to accommodate big floods, which can cause huge economic losses.

11.4 Conclusion and Recommendations

Through the IEE for river improvement works envisaged as structural measures in the master plan, every conceivable environmental and social impact was described and evaluated at pre-construction, construction and operation and maintenance stages. It was shown that there would be several negative impacts whose magnitude is negligible, minor or medium as shown in **Table 11.3.1**. On the other hand, the “no action” scenario for the existing erosion and sedimentation of the Mejerda River would further reduce its capacity to accommodate big floods as seen in recent times, causing huge economic losses.

All of the river improvement works are evaluated from the environmental and social points of view and the results are shown in **Table 11.4.1**. As a result of the IEE, the following conclusions and recommendations were obtained:

As for the river improvement works planned for the upper area, the Mellegue improvement works are recommended due to its smaller scale causing the least negative environmental and social impacts. Also all other works are recommendable since their negative medium impacts can be controlled through adequate mitigation measures and proper monitoring (see **Table 11.4.2**).

As for the river improvement works planned for the middle area, all works are also recommendable considering that proper mitigation and monitoring measures (see **Table 11.4.2**) can alleviate their negative medium impacts.

The same thing as above can be said for the river improvement works planned for the lower area. However, with regard to the El Mabtouh improvement works and retarding basin, only minor impacts are anticipated on the natural and social environment, requiring less mitigation and monitoring measures than the other countermeasures for the area. It is however recommended, during construction and operation of the basin, to strictly execute supervisor control system, guarantee construction quality, effectively manage the sewage discharge upstream during abundant water period, patrol the reservoir, and detect problems to be solved on time.

CHAPTER 12 IMPLEMENTATION PROGRAMME

12.1 Implementation Schedule

12.1.1 Structural Measures

(1) Project on river improvement

Since the study area (the Mejerda River basin in the Tunisia territory) is as wide as 15,830 km^2, the regional importance and development level as well as regional flood characteristics are uneven in the area. Therefore, the study area was divided into five zones (D1, D2, U1, U2 and M) and a flood protection level has been prepared by zone for river improvement works as discussed in Chapter 8. The implementation of the river improvement is planned in the order of Zone D2, Zone U2, Zone D1, and Zone (U1+M), giving careful consideration to the following basic rules of river improvement, economic viability of the project and higher risk of flood damage to the Bou Salem area in Zone U2:

(a) Since the Sidi Salem Dam has a huge flood control volume, the dam breaks the hydraulic continuity of the flooding phenomenon along the Mejerda River. For this reason, the study area can be largely divided into two independent sub-basins; the upstream and downstream sub-basins of the dam site from the hydraulic viewpoint of flood inundation. The upstream and downstream sub-basins are composed of Zones U1, U2 and M, and Zones D1 and D2, respectively.

Under such specific conditions of the study area, river improvement in the lower zone has to be implemented prior to that in its upper zone(s) in each sub-basin so as to avoid river improvement which has any risk of detrimental artificial flooding in downstream areas.

(b) In order to assess the order of economic viability of the river improvement in each zone, an economic index of EIRR has been calculated, as shown in the table below. The same project commencement year of 2011 is used for each zone. Zone D2 shows the highest EIRR of 33.7%, followed by Zone D1 (20.3%), Zone U2 (12.1%), and Zone U1+M (10.0%).

Summary of Economic Analysis (river improvement projects start in 2011)

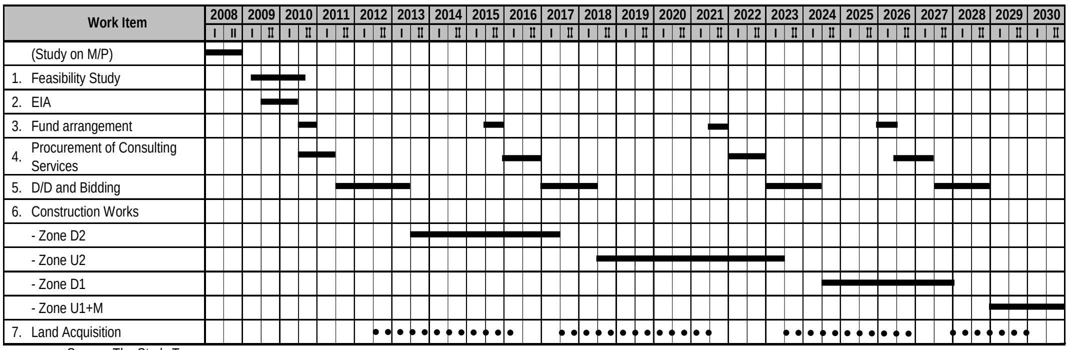
	Zone D1	Zone D2	Zone (U1+M)	Zone U2
EIRR	20.3%	33.7%	10.0%	12.1%
NPV (million TND)	42.23	230.31	-8.02	1.04
B/C Ratio	2.14	5.83	0.76	1.01

Source: the Study Team
Note: discount rate of 12% for NPV

(c) There is a high risk of flooding in U2, particularly the Bou Salem area, because the Bou Salem area is under such topographical and hydrological disadvantages that three major tributaries having several experiences of terrible flood attack join the

Mejerda River adjacently upstream of the area. Therefore, the people in the area have earnest request for earlier implementation of flood measures.

The following chart shows the proposed implementation schedule of the project, where 2.5 years are allotted immediately after this M/P study for the preparatory activities (i.e. feasibility study, EIA, fund arrangement, procurement of consulting services, etc.), which are required prior to the detailed design (D/D) and bidding in Zone D2. The project term is planned to be 20 years from 2011 through 2030 (the target year of the Study).

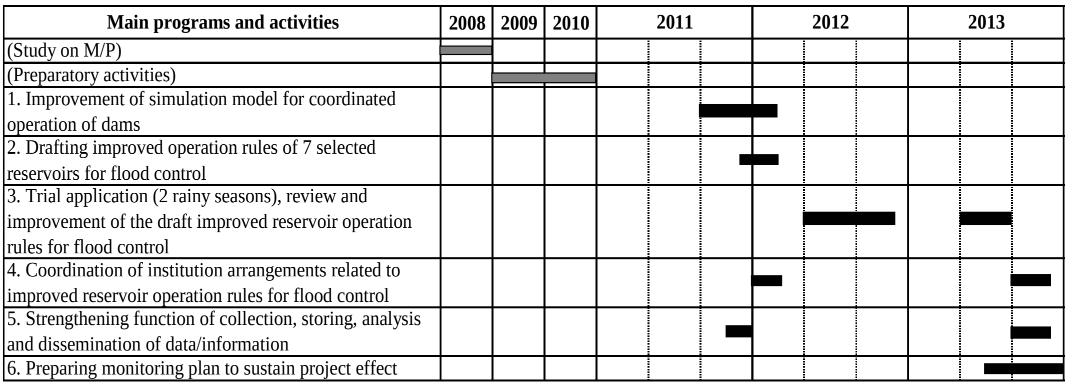


Source: The Study Team

(2) Project on strengthening flood control function of reservoirs

The following chart shows the proposed implementation schedule of this project, wherein two years (2009 and 2010) are allotted immediately after this M/P study for the preparatory activities (i.e. fund arrangement, procurement of expatriates experts, etc.) prior to the project implementation.

Since this project closely links, in terms of its contents of project programs and activities, with those of the project on strengthening the existing flood forecasting and warning system (FFWS), discussed in the next sub-section, it would be considered necessary that this project commence in the latter half of the year 2011 after "Program 3: Study on flood forecasting method and model" in the project on strengthening the existing FFWS. The project term is planned to be 2.5 years.



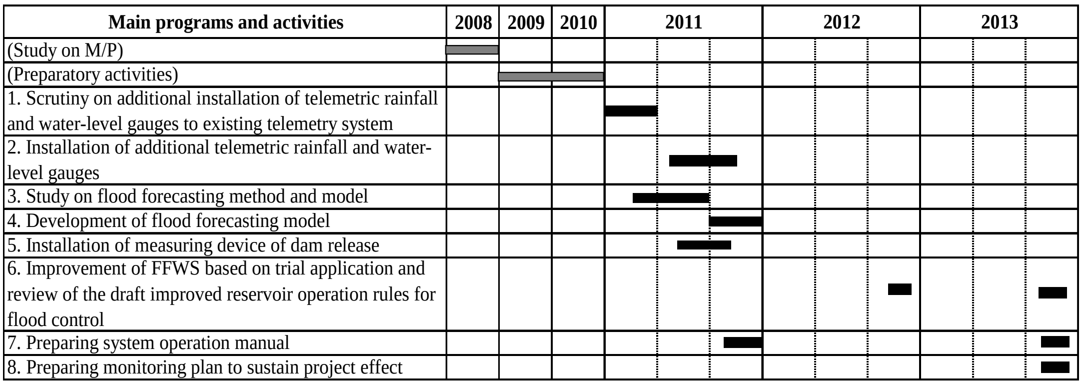
12.1.2 Non-structural Measures

(1) Project on strengthening the existing flood forecasting and warning system

The implementation schedule as shown in the chart below proposes that this project commence in the year 2011 immediately after completion of the preparatory activities (i.e.

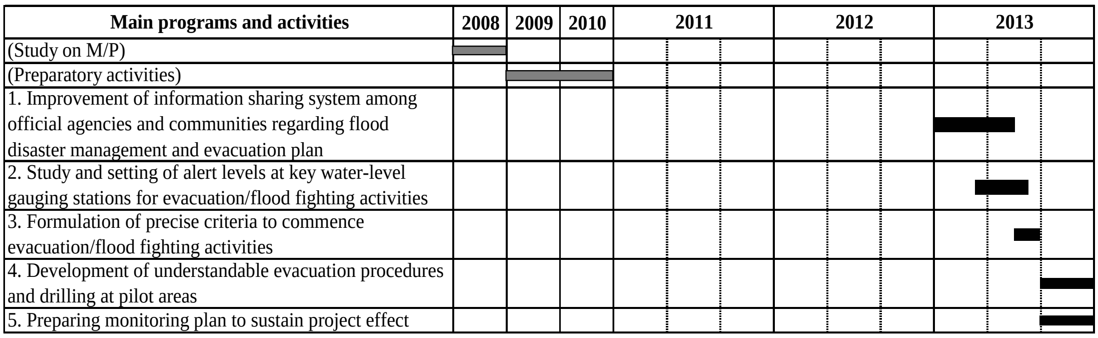
fund arrangement, procurement of expatriate experts, etc.), because the Tunisian Government requires earlier strengthening of the existing FFWS.

This project includes "Program 6: Improvement of FFWS based on trial application and review of the draft improved reservoir operation rules for flood control", which is planned in the years 2012 and 2013, since "Program 6." needs to be executed based on the result of "Program 3. Trial application (2 rainy seasons), review and improvement of the draft improved reservoir operation rules for flood control", which is part of Project (2) discussed in Sub-section 12.1.1.



(2) Project on strengthening evacuation and flood fighting system

This project is closely linked with Project (1) in Sub-section 12.1.2. The programs and activities of this project are required to be conducted based on the FFWS to be strengthened. Hence, the implementation of this project is planned in the year 2013.



(3) Project on organizational capacity development

As shown in the following chart, the years 2009 and 2010 are allotted immediately after this M/P study for the preparatory activities.

It is envisaged that this project will be implemented stepwise in three stages: the first stage for two years starts after the preparatory activities; the second stage is for conducting a pilot project for organizational capacity development and proposed to be carried out in the project of river improvement, discussed in Sub-section 12.1.1; and the third stage will be implemented, if the pilot project in the second stage justifies the viability of a new agency to be in charge of O/M of the Mejerda River basin, and is planned in the year 2019 after the second stage.

Main Programs and Activities	2008	2009	2010	First Stage 2011			First Stage 2012			(Second Stage)			Third Stage 2019		
First Stage															
(Study on M/P)	▒														
(Preparatory activities)		▒	▒												
1. Scrutiny and establishment of permanent division or direction in charge of Mejerda River basin inside				■	■										
2. Detailed study on 11 proposed programs for organizational capacity development					■	■									
3. Initiating the proposed programs						■	■	■	■						
4. Selection of a pilot project to be conducted in the second stage									■						
5. Provision of documented technical guidelines, standards and rules						■	■	■	■						
Second Stage															
Conducting a pilot project under proposed river improvement project of the Mejerda River										■	■	■			
Third Stage															
1. Scrutiny and establishment of an agency in charge of O/M of the Majerda River basin, if the pilot project justifies the viability of the agency													■	■	
2. Preparing monitoring plan to sustain project effect													■	■	

(4) Project on flood plain regulation/management

The implementation of the proposed activities for this project can be commenced as soon as possible in parallel with the implementation of river improvement works to assure and enhance the project benefits. In particular, flood plain regulation/management cannot be separated from other non-structural measures in the aspect of disaster management in the vulnerable areas along the Mejerda River. A three-step annual implementation of the program to be commenced from the year 2011 up to the year 2013 is envisaged, considering a steady progress and consistent evaluation by the executing agency of the Tunisian side.

Main Programs and Activities	2008	2009	2010	Step 1 2011			Step 2 2012			Step 3 2013		
(Study on M/P)	▒											
(Preparatory activities)		▒	▒									
1. Delineation of flood prone area through runoff and inundation analyses of the Mejerda River basin				■								
2. Updating of GIS data base with current cropping information				■	■	■						
3. Preparation of flood risk map with zoning by risk level						■						
4. Analysis on improved cropping pattern based on current prevailing land use						■	■	■				
5. Preparation of guideline for flood risk mapping							■					
6. Preparation of guideline for enhanced land use control for urabn and rural areas								■	■			
7. Dissemination, application, evaluation and validation of the guidelines in target CRDAs and local governments										■	■	■
8. Training and seminar				▒	▒	▒	▒	▒	▒	▒	▒	▒

12.2 Project Costs

The project cost of each scheme in the master plan is estimated as referred to in **Tables 12.2.1 to 12.2.6** and summarized in the following Table.

(x10^3)

Schemes	TND Equiv.	USD Equiv.	Yen Equiv.
(1) Structural measures			
1.1 Project on river improvement			
- Zone D2	133,574	114,068	12,181,000
- Zone D1	173,657	148,298	15,837,000
- Zone U2	186,475	159,244	17,005,000
- Zone U1+M	60,079	51,306	5,479,000
Sub-total of 1-1	553,785	472,916	50,502,000
1.2 Project on strengthening flood control function of reservoirs	5,772	4,934	527,000
Total of (1)	**559,557**	**477,850**	**51,029,000**
(2)Non-structural measures			
2.1 Project on strengthening FFWS	5,592	4,775	510,000
2.2 Project on strengthening evacuation/flood fighting system	2,910	2,485	265,000
2.3 Project on organizational capacity development	7,135	6,093	651,000
2.4 Project on flood plain regulation/management	5,238	4,473	478,000
Total of (2)	**20,875**	**17,826**	**1,904,000**
Grand Total: (1)+(2)	**580,432**	**495,676**	**52,933,000**

Source: the Study Team

The project cost is estimated on the basis of the price level as of June 2008 and the exchange rates are TND 1 = JPY 91.20 = USD 0.854.

The project cost of “1.1 Project on river improvement” consists of (i) costs of construction, land acquisition, government administration and engineering services, (ii) physical and price contingencies, and (iii) taxes, as shown in **Table 12.2.1**.

The government administration and engineering services costs are calculated as 3% of the sum of construction and land acquisition costs, and 10 % of the construction cost, respectively. The physical contingency is computed applying 10% of (i) above. In the calculation of the price contingency, annual price escalation rates of 2.1% and 3.2% are applied to foreign and local currency portions, respectively, for the cost components of (i) above and the physical contingency.

The project costs of “1.2” and “2.1 to 2.4” consist of (i) costs of engineering services and government administration, (ii) physical and price contingencies, and (iii) taxes, as shown in **Tables 12.2.2 to 12.2.6**. The engineering services cost is estimated based on the staffing schedule of expatriates planned in **Table 9.1.2** and **Tables 9.2.1 to 9.2.4**. The government administration cost is calculated as 30% of the engineering services cost. The physical and price contingencies are estimated in the same manner used for “1.1’.

12.3 Project Fund Arrangement

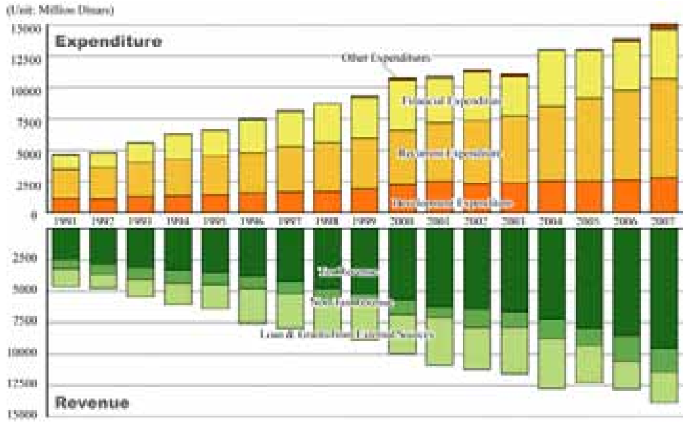
12.3.1 Review of Budget Allocation of the Tunisian Government

The chart below illustrates the revenue and expenditure of the Tunisian Government during the years 1991 – 2007. The general account budget of the Tunisian Government was 15.1 billion TND in 2007, while, the governmental revenue stood at 13.9 billion TND, and thus resulted in an excess expenditure of 1.2 billion TND. Primary balance[*1] of Tunisia has also been negative throughout the period from 1991 to 2007.

During the past decade, the governmental revenue consists of tax revenues (57% ~ 69%),

[1] Primary balance describes the condition where expenditures (excluding principal payment of external loans and redeeming of national bond) are covered by tax and non-tax revenues.

and non-tax revenues (7%~10%). The remaining 17%～32% includes the national bond, grants and loans from the bilateral/multilateral development agencies. On the other hand, development expenditures occupied 20% ~ 23% of the total general account expenditures of Tunisia.



Source: Institute National de la Statistique, Tunisia

Revenue and Expenditure for Tunisian Government during 1991- 2007

The percentage of financial expenditures (i.e. principal and interest payments of existing debts and redeeming of national bond) to the total general account budget has been gradually reducing during the last decade from 35% in 1998 to 28% in 2007. Also, the ratio of total external debt, including both short-term and long-term debts) to the Gross Domestic Product (GDP) was reduced from 65% in 2002 to 55% in 2007[*2]. The Tunisian Government aims to reduce a total external debt up to 51% of GDP by the end of the 11th Development Plan. To achieve such target, the Tunisian Government intends to continue to limit reliance on external assistance at a reasonable level.

12.3.2 Amount of Financial Assistance Received from the Major Donors

Major donors providing financial and technical assistance to Tunisia are France, Japan, Germany and Italy, as well as the multilateral development agencies of World Bank, EU and African Development Bank. The amount of foreign assistance received per year was between US$ 460 million and US$ 660 million during the last 5 years (2002 ~ 2006). In recent years, the amount of loan assistance received was almost the same as that of grant assistance.

The French Government is the biggest donor of Tunisia in terms of an aid amount of both grant and loan assistance. The aid amount of loan assistance from the French Government was US$ 61 ~ 131 million per year during the past 5years, and occupied 25% ~ 41% of the total loan assistance received. Also the amount of grant assistance from the French Government was US$ 63 ~ 103 million, which accounted for 27% ~ 38% of the total grant assistance received.

In the case of the Japanese Government, the amount of grant assistance during the past 5 years, occupied only 3% ~ 7% of the total grant assistance received by Tunisia, while loan assistance occupied 17% ~ 41%.

[2] Source: International Monetary Fund

Since the sum of the loan assistance from the French and the Japanese Governments accounted for 53% ~74% of the total loan assistance received during 2002 ~ 2006, loans from the both countries are considered to be important fund sources for Tunisia in executing large-scale infrastructure projects.

12.3.3 Donor's Assistance Strategy for Tunisia

(1) Multilateral Development Agencies

Financial assistance received from multilateral development agencies was US$ 100 ~ 175 million per year during the past 5 years. Most of financial assistance from multilateral development agencies are on a grant basis. Since the amount of loan assistance was relatively small (US$ 8 ~ 49 million per year during the past 5 years), there is not much hope for receiving financial assistance on a large-scale infrastructure project.

Assistance strategies of major multilateral development agencies for Tunisia are as compiled in **Table 12.3.1**. Their priority sectors include neither disaster prevention projects nor flood control projects.

(2) France

According to the DCP (Document Cadre de Partenariat: Partnership Frameworks), 2006-2010, prepared by the Inter- ministerial Committee for International Cooperation and Development (CICID), their strategic assistance areas for Tunisia are: 1) modernization of industries and strengthening of their competitiveness (including loan assistance for participants of modernization program, modernization of vocational training programs for manufacturing, tourism, and agricultural sectors, and infrastructure development), 2) improvement of living standard (urban development mainly by sewerage improvement projects, and rural development through mainly water supply projects), and 3) sustainable environment (conservation of natural resources, conservation of energy resources, etc).

(3) Germany

The amount of loan assistance provided for Tunisia has been in an increasing tendency, between US$ 14 million and 25 million per year for the recent 5 years. In the year 2001, the following two priority areas for future cooperation were agreed between the German and the Tunisian Governments.

1) Environmental protection and resource conservation: includes construction of landfill sites and sewage disposable plants, establishment of monitoring and control system for the hazardous waste area, provision of finance to private companies for air pollution control measures and also waste and recycling plants, and assistance for anti-erosion measures and enhancement of water catchments' capacity through afforestation and encouraging the sustainable use of agricultural land.

2) Economic development: includes providing two-step loan for modernization measures for companies, and provision of advice to a selected number of small and medium-sized enterprises

(4) Japan

The Japanese Government has been providing loan assistance mainly for the irrigation, communication, transport, and water supply sectors. The total amount of loan assistance for Tunisia stood at 224 billion Japanese yen or about US$ 2 billion (as of end of 2006). During the past 5 years, loan assistance for Tunisia was between US$ 65 million and 119 million per year.

According to the country assistance strategy for Tunisia announced by the Ministry of Foreign Affairs of Japan, six issues were selected as the major problems to be addressed: 1) strengthening the competitiveness of industries, 2) water resource management/ development, 3) modernization of agriculture and fishery industries, 4) tourism sector development, 5) environmental conservation, and 6) alleviation of regional disparity.

Out of which, 1) strengthening the competitiveness of industries, 2) water resource management/ development, and 5) environmental conservation were selected as priority areas for Japanese assistance from the medium to long term perspective.

"2) water resource management/ development" aims to provide not only water resource development projects but also demand-side management projects and comprehensive water resource management projects fully utilizing Japanese technologies and experiences in the fields.

The Gross National Income (GNI) per capita of Tunisia increased from US$ 2,090 in the year 2000 to US$ 2,970 in 2006. Thus, Tunisia will be classified into an upper-middle income country in the near future.

Sectors and fields of assistance for upper-middle income countries are principally limited to environment, human resource development, anti-seismic measures and measures to reduce disparities in low-income regions. "Anti-seismic measures" involve disaster protection and recovery measures, which are deemed to also include flood control projects.

12.3.4 Expected Funding Arrangements for the Project

(1) Capital Cost for Project on River Improvement

The total capital cost of the project on river improvement proposed in the master plan study is about 554 million TND, of which Zones D2 and U2 having higher priority for implementation require capital costs of 134 million TND and 186 million TND, respectively. Annual funds requirements are expected to vary from 22 to 44 million TND during the construction periods.

Since the project on river improvement need sizable capital investment, it is desirable that part of the capital cost will be covered by loan assistance from the donor agencies. On the other hand, as a result of the general review on the assistance strategies as well as the amounts of past loan assistance from the major donors, it is considered that except for the French and the Japanese Governments, sizable assistance for a flood control project cannot be expected.

Even if the Tunisian Government successfully receives loan assistance from international development agencies, the government generally needs to allocate about 20% ~ 30% of the capital cost (4 million ~ 13 million TND per year).

(2) Soft Components of Flood Control Project

The costs of soft components proposed in this master plan study, composed of strengthening the flood control function of reservoirs, strengthening the existing flood forecasting and warning system, organizational capacity development, strengthening evacuation and flood fighting system and flood plain regulation/management, is about 27 million TND in total.

The soft components consist mainly of technical assistance activities. Thus it requires relatively smaller capital expenditure. The soft components are considered to be suitable for grant-based technical cooperation projects in the light of the contents of project activities as well as the smaller capital costs.

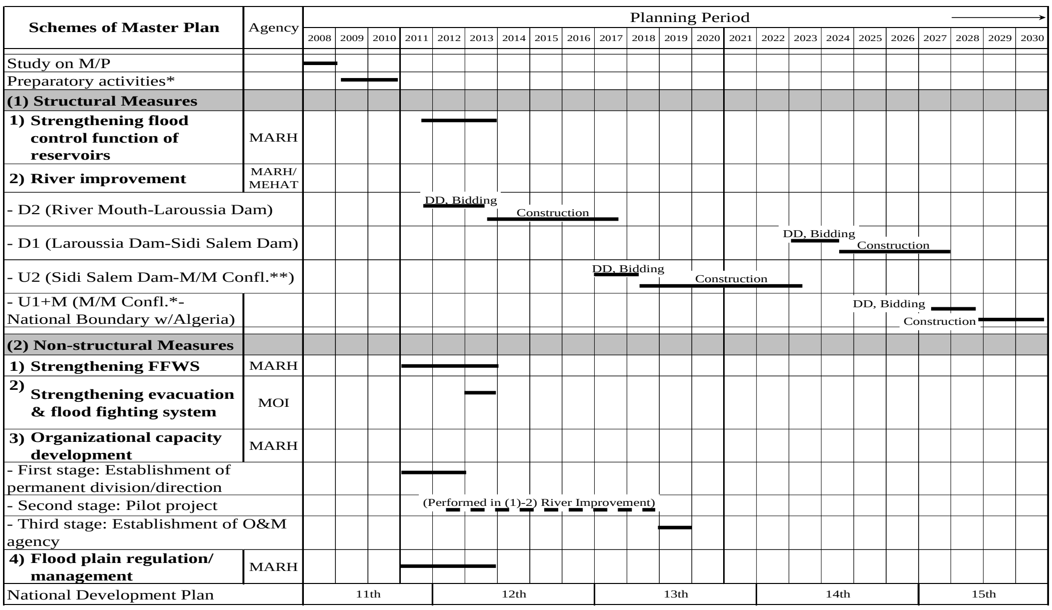
(3) Budget for Maintenance Activities

In order to properly maintain the function of the flood control project and achieve sustainable effects from the project, adequate financing for maintenance cost will be required. Routine maintenance cost for each zone, such as the cost for maintenance of civil structures, tree/grass cutting, and sediment removal in the river channels, is estimated to be 0.3 ~ 1.1 million TND per year. In addition, 0.01 ~ 1.8 million TND will be required for every 5 years as periodic maintenance costs in order to grub trees in and along the river channels.

Allocation of the necessary budget should be made through the recurrent budget of MARH and/or CRDAs of the governorate concerned.

12.4 Overall Implementation Schedule

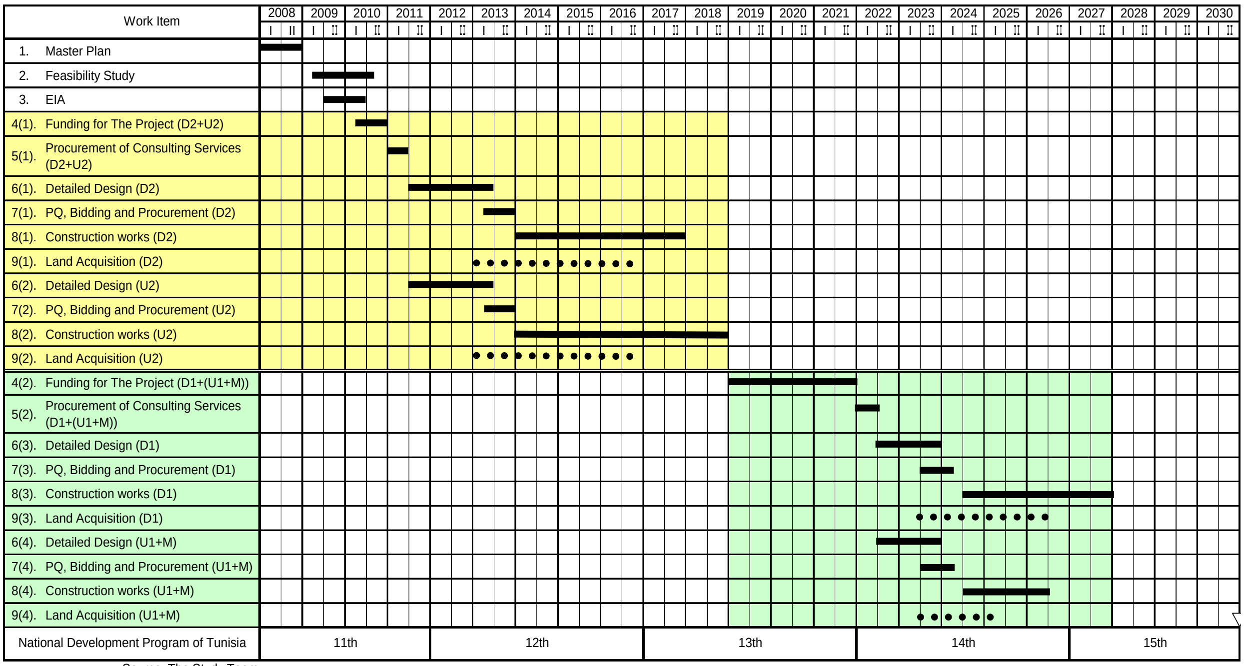
The overall implementation schedule for the master plan is presented below.



Notes: * including Feasibility & Detailed Studies, fund arrangements, procurement of consulting services, etc. ** M/M Confl.=Mejerda-Mellegue Confluenc

Aside from the recommendation on the overall implementation schedule proposed in the master plan as mentioned above, an alternative idea (implementation of two zones in parallel to be conducted firstly D2 and U2, and then D1 and U1+M) was conveyed to the Study Team by the Tunisian side at the Seventh Steering Committee Meeting at Tunis on September 01, 2008. The implementation schedule of the combined plan can be set based on the required periods of each activity as shown below:

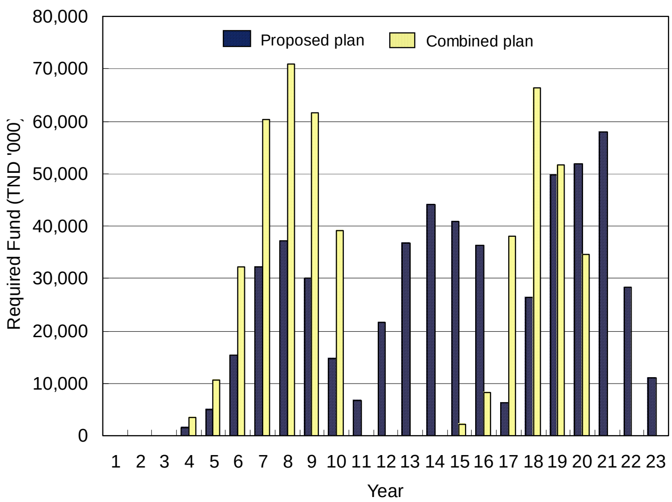
Implementation Schedule of Combined Plan (River Improvement Works)



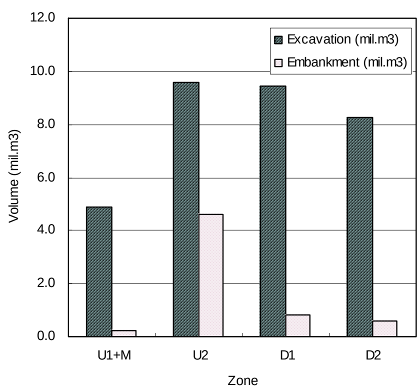
Source: The Study Team

In accordance with the schedule, annual disbursement of financial cost for the 23 years of implementation is illustrated in comparison with those for the proposed master plan as follows:

Annual Disbursement of Budget (Financial Cost)



Earth Work of Volume Each Zone



As seen in the illustrations above, maximum annual outlay (approx. TND 71 million/year at maximum) of the combined plan will be 22% higher than that of the amount in the proposed plan (approx. 58 million/year at maximum). Even if the amount is secured by financial loans from donor(s), the Government of Tunisia must prepare the equivalent budget for project implementation.

On the other hand, the magnitude of earth works such as channel excavation and levee embankment will simply become twice the volume for one zone as shown in the figure above. The construction works of moving and disposing such a huge volume of earth materials (ex: approx. 18 million m^3 of excavation) will have adverse effects on the social and natural environments in the project area.

Furthermore, viability of the combined plan was assessed through an economic analysis to compare EIRRs of the whole project (structural and non-structural measures) and obtained the results as presented below. Thus, from the economic viewpoint as well, the proposed stage-wise implementation is more advantageous.

Item	Whole Projects	
	Proposed IP (stage-wise plan)	Alternative IP (combined plan)
EIRR	**25.0%**	23.1%

Source: the Study Team

In conclusion, the stage-wise implementation plan for the river improvement works as recommended in the master plan was finally selected.

CHAPTER 13 OVERALL EVALUATION OF THE MASTER PLAN

13.1 Economic Evaluation

(1) Economic Analysis for the Flood Control Project

The implementation schedule of the flood control project, which is divided into four zones, was determined taking into account the project's economic viability, a basic rule/theory of river improvement works and also a high risk of flood damage on the Bou Salem area in Zone U2.

Economic analysis of the whole project and each zone was finalized following the implementation schedule. Economic costs and benefits during the evaluation period are shown as an annual stream in **Table 13.1.1** (whole project only). The EIRRs of the whole project as well as individual projects in each zone were calculated, as shown below, ranging between 12.1% and 33.7%, which are above the economic discount rate of 12.0%. In addition, the economic net present value (ENPV) and benefit-cost ratio (B/C) adopting 12.0% of discount rate exceeds "0" and "1", respectively.

Summary of Economic Analysis (river improvement project)

	Zone D1	Zone D2	Zone U1+M	Zone U2	Whole Projects
EIRR	20.5%	33.7%	12.1%	14.6%	25.0%
ENPV (million TND)	19.96	230.31	0.29	13.60	264.16
B/C Ratio	2.73	5.83	1.01	1.28	3.04

Source: the Study Team

These calculation results have proved that all the proposed flood control projects are feasible from the economic point of view.

(2) Sensitivity Analysis

The values of variables used for the economic analysis are estimated based on the most probable forecasts, which cover a long period of time. However, these variables for the most probable outcome scenario are usually influenced by a great number of factors, and their actual values may differ considerably from the forecasted values, depending on future developments/changes.

The sensitivity of the EIRR and ENPV to several adverse changes in the project cost was computed to assess the robustness of the economic viability of the project. A switching value analysis was also made to ascertain the cost required to reduce ENPV to 0 and the minus benefit to make the EIRR equal to economic opportunity cost of 12.0%.

Summary of Sensitivity Analysis

	Adverse Scenarios	EIRR	ENPV (million TND)	Switching Value
Zone D1	Base Case	20.5%	20.0	-
	a. Capital Cost Increase 20%	18.9%	17.7	+ 175%
	b. Flood Control Effect by -20%	18.5%	13.7	- 63%
	c. GDP Growth - 1% point	18.1%	11.8	-
	d. a + b + c	14.5%	4.8	-
Zone D2	Base Case	33.7%	230.3	-
	a. Capital Cost Increase 20%	30.7%	220.9	+ 487%
	b. Flood Control Effect by -20%	30.1%	174.7	- 83%
	c. GDP Growth - 1% point	31.9%	185.3	-
	d. a + b + c	25.5%	129.3	-
Zone U1+M	Base Case	12.1%	0.3	-
	a. Capital Cost Increase 20%	10.7%	-4.3	1.4%
	b. Flood Control Effect by -20%	10.4%	-4.0	1.4%
	c. GDP Growth - 1% point	10.5%	-3.5	-
	d. a + b + c	7.6%	-11.3	-
Zone U2	Base Case	14.6%	13.6	-
	a. Capital Cost Increase 20%	12.6%	3.9	+ 28%
	b. Flood Control Effect by -20%	12.2%	1.1	- 22%
	c. GDP Growth - 1% point	12.5%	2.2	-
	d. a + b + c	8.7%	-17.8	-
Whole Project	Base Case	25.0%	264.2	-
	a. Capital Cost Increase 20%	22.4%	238.3	+ 204%
	b. Flood Control Effect by -20%	21.8%	185.4	- 67%
	c. GDP Growth - 1% point	23.1%	195.8	-
	d. a + b + c	17.6%	105.0	-

Source: the Study Team

As shown in the above table, the sensitivity analysis shows that the economic viability of the proposed flood control projects in Zones D1, D2 and the whole project are robust under the various adverse assumptions.

Also, economic viability of Zone U2 has sufficient robustness. When overrun of capital cost is within the range of 28% to the base case or if the economic benefit decreases within minus 22% of the base case, the project sustains its economic viability.

However, in the case of Zone U1+M, any move of the assumption to an adverse direction will cause the project to easily lose its economic viability.

(3) Conclusion

The whole flood control project as well as individual projects in the four zones were judged to be economically viable, and thus all the proposed flood control projects are worth implementation.

Also, the economic viability of the whole project and individual projects was sufficiently robust, with the exception of Zone U1+M. In the case of the Zone U1+M project, since its implementation is scheduled to start in the year 2027, it is recommended for the project to be subjected to economic analysis again before the implementation, taking into consideration changes in the economic development of the zone as well as the asset values in the probable flood area.

13.2 Environmental Evaluation

The conceivable impacts to be caused by implementation of the project on river improvement as structural measures are evaluated through an IEE. The results of the evaluation are summarized in the upper, middle and lower areas as follows:

(1) The upper area of the Mejerda River

The structural measures in the upper area aim to mitigate flood inundation damage and protect residents and farmlands along the river, minimizing economic losses and personal casualties. These structural measures show negative impacts ranging from negligible to minor and medium with no significant ones. Medium negative impacts are observed during the construction works with noises, vibrations and too much spoil material waste to be disposed of with the exception of Mellegue improvement works which are of smaller scale. Furthermore, medium negative impacts are anticipated in water quality near the watercourses during construction of the bypass channel. Positive impacts of the measures are anticipated in the increase of income of the riparian populations who can be offered jobs during construction.

(2) The middle area of the Mejerda River

The structural measures applied for the middle area aim to mitigate flood damage along the river and to conserve a historical property (an old bridge dating back from the 17^{th} century) of which the destruction or relocation seems difficult. These measures would cause relatively medium negative impacts via noises and vibrations during construction. Positive impacts include job opportunities during construction works.

(3) The lower area of the Mejerda River

The structural measures in the lower area aim to principally mitigate flood inundation damage and to conserve the vast agricultural land spreading along the Mejerda lowest reaches and to conserve the historical vestiges (El Battane weir dating back from the 17th century) of which the destruction or relocation seems difficult. Similarly to the above two areas, noises and vibrations during construction would cause medium negative impacts for the measures applied for the lower area. For the retarding basin in El Mabtouh, all adverse impacts are minor. Positive impacts of the measures include increased income of the riparian populations who can be offered jobs during construction.

According to the results of IEE, the following conclusions and recommendations were obtained:

(a) As for the river improvement works planned in the upper area, the Mellegue improvement works are recommended due to its smaller scale and causing the least negative environmental and social impacts. All other works are recommendable because their negative medium impacts can be controlled through adequate mitigation measures and proper monitoring.

(b) As for the river improvement works planned for the middle area, all works are also recommendable considering that proper mitigation and monitoring measures can alleviate their negative medium impacts.

(c) The same thing as above can be said for the river improvement works planned for the lower area.

13.3 Technical Evaluation

(1) Water is limited precious resources in Tunisia and there is never a drop of water to waste. Hence, the State has developed a national water management plan placing precedence to water use. In this view, the flood control master plan formulated in the Study has carefully harmonize with the water use plan in the Mejerda River basin assigning higher priority to realization of water supply with required security, because there would be a tradeoff relationship between the water supply and flood control risks.

(2) An absolute protection from flooding is neither technically feasible nor economically or environmentally viable. Thus, the proposed flood control master plan has appropriately combined both structural and non-structural measures with the aim to minimize flood damage. The structural measures focus on preventing inundation up to a design flood of the measures, while the non-structural measures focus on alleviating flood damage due to excess floods exceeding the design flood. In addition, the non-structural measures are also planned to sustain the flood preventing function of the structural measures. In other words, the proposed flood control plan duly contemplates that the structural and non-structural measures must be effectively complementary to each other for their full and permanent effectuation with close coordination.

(3) The flood control measures composed of the master plan have been formulated in principle by employing rather technically conventional knowledge and approaches which have been commonly applied to ordinary flood control projects and hence there would be no technical difficulties encountered in the project implementation as well as its operation and maintenance stages.

(4) The said flood control measures, in particular the projects on river improvement and on strengthening the existing FFWS, have satisfactorily reflected the technical opinions and desires obtained from the local people who actually suffered from serious damage caused by the past floods. These were obtained through the interview survey on public acceptance of flood risk and two stakeholders' meetings, which were conducted in the Study.

(5) In the project on river improvement, the Study has proposed a kind of construction

method for riverbank protection made with wood materials, which is widely adopted as a traditional way of riverbank protection in Japan. This construction method seems to be applicable to the Mejerda River by using trees, so-called "Tamarix" which have grown thick in the high water channels of the Mejerda River. If this method is effectively applicable with Tamarix, the cost of riverbank protection in the maintenance period can be significantly reduced. Furthermore, inhabitants who want to protect their own land from riverbank erosion will be able to make the protection with Tamarix by themselves, if they acquire the technical know-how to make it. No heavy machinery is needed. Therefore, maintenance works of river channel could be expected to be handled by participatory approach by the local people to some extent, if a certain implementation mechanism is created between CRDAs and cities/villages concerned.

13.4 Conclusions and Recommendations

The projects proposed in the master plan have been formulated to effectively resolve the flooding problems in the Mejerda River basin, of which the schemes are as enumerated below in consideration of the target year of 2030. It has been attested through the Study that the projects will alleviate the serious flood damage experienced in the recent years and are technically, economically and environmentally feasible.

(1) Structural measures

1-1 Project on strengthening flood control function of reservoirs,
1-2 Project on river improvement

(2) Non- structural measures

2-1 Project on strengthening existing flood forecasting and warning system,
2-2 Project on strengthening evacuation and flood fighting system,
2-3 Project on organizational capacity development, and
2-4 Project on flood plain regulation/management

In due consideration of the disastrous conditions in the study area having been frequently devastated by the recent serious floods and also quite poor flow capacity in river channels, it is strongly recommended for the Government of Tunisia to immediately take necessary actions for further steps such as securing finance, technical assistance and so forth, so as to actually realize the following positive effects among others:

- Prevention of long duration of flooding and health hazards,
- Alleviation of losses in the project area due to extended stagnant flooding,
- Resolution of paralysis in civic function due to traffic congestion caused by flood inundation in urbanized areas,
- Improvement of living environment conditions and boosting of local economy under less risk of flood damage.

Among the proposed projects, the following 4 projects are recommendable as the priority projects that need to conduct feasibility/detailed studies without any relay.

Priority projects	Project costs (10^3 TND)	Implementation schedule
1) River improvement for Zone D2 (between the estuary of the Mejerda River and Laroussia Dam)	133,574	2011 to 2017
2) Strengthening flood control function of reservoirs	5,772	2011 to 2013
3) Strengthening existing flood forecasting and warning system	5,592	2011 to 2013
4) Strengthening evacuation and flood fighting system	2,910	2013
Total	147,848	

Source: the Study Team

Tables

Table 1.5.1 List of Members of JICA Study Team and Tunisian Counterpart Personnel

Positions		Members of JICA Study Team	Tunisian Counterpart Personnel
1	**Team Leader/Integrated Basin Management**	Koji KAWAMURA	Dr. Louati M.H.
2	**Deputy Team Leader/Flood Control Measures**	Yoshihiro MOTOKI	
3	**Hydrology/Hydraulics/Runoff and Sediment Analyses**	Natsuko TOTSUKA	Dr. Bergaoui M. et Mme Abid
4	**Water Supply Operation System**	Robert DESPAULT	Dr. Louati et un representant de I INAT
5	**River Planning/Reservoir Operation**	Petr JIRINEC	Mr. Bel Haj et un representant de I INAT
6	**Flood Forecasting and Evacuation / Flood Protection Plan**	Hikaru SUGIMOTO	Mr. Saadaoui et Dr. Mahjoub
7	**Facility Design/Cost Estimates**	Atsuro TAKAOKA	Mr. Belgaied T.
8	**Organization/Institution/Operation & Maintenance**	Yukihiro MIZUTANI	Mr. Daoud A.
9	**Econonmics/Finance**	Takeshi YAMASHITA	Mr. El Euchi M.L.
10	**Environmental & Social Consideration**	Massamba GUEYE	Mme Messai
11	**Coodinator/Basin Preservation**	Yukari NAGATA/Syunsaku OKAMOTO/ Masahito MIYAGAWA	Un representant de la DGACTA

Table 3.3.1 Summary of Operation and Maintenance Survey (1/2)

Item	Total Number In The Inventory	O&M Data Sheets Collected	O&M Responsibility
Rain gauging	183	20 main stations	CRDA/MARH
O&M Budget	**O&M Schedule**	**Typical Problems**	**Recent Upgrades**
• 500 TDN per station/year	• inspected at 2 month intervals • power supply maintained at 6 month intervals	• rainwater collection system plugged with dirt • power supply system and solar panel damaged • serious lack of maintenance caused by shortage of manpower and funds	• automation and GSM telemetry in 2003/2004 for improved data acquisition and early flood warning • 3000 TDN/station

Item	Total Number In The Inventory	O&M Data Sheets Collected	O&M Responsibility
Stream gauging	71	22 main stations	CRDA/MARH
O&M Budget	**O&M Schedule**	**Typical Problems**	**Recent Upgrades**
• 1200 TDN per station/year	• inspected at 2 month intervals by CRDA • inspected at 6 month intervals by DGRE • power supply maintained at 6 month intervals	• water level probes and data loggers damaged by floodwater • power outages resulting in loss of data acquisition • insufficient storage space when data loggers are not downloaded at the required interval resulting in loss of data acquisition	• automation and GSM telemetry in 2003/2004 for improved data acquisition and early flood warning • 5000 TDN/station

Item	Total Number In The Inventory	O&M Data Sheets Collected	O&M Responsibility
Large dams	8 existing	8	6 dams DGBGTH/MARH and 2 dams SONEDE
O&M Budget	**O&M Schedule**	**Typical Problems**	**Recent Upgrades**
• dam monitoring approx. 10000 TDN per year per dam • bathymetric survey: 50,000 TDN per dam • operating budget unreported	• yearly monitoring program for dam safety • bathymetric surveys at 5 year intervals • no information on scheduled preventive maintenance	• leaking gates and valves • corrosion • failure of motorized valve operators and controls • damaged concrete on spillways and abutments	• planned repair/replacement of gates, valves and electrical control equipment as required • planned repairs to concrete and hydraulic structures as required • budget for planned repair activities varies from year to year • 10,000 to 60,000 TDN per dam

Table 3.3.1 Summary of Operation and Maintenance Survey (2/2)

Item	Total Number In The Inventory	O&M Data Sheets Collected	O&M Responsibility
Control structures	13	2: Laroussia and Tobias	CRDA/ SECADENORD
O&M Budget	**O&M Schedule**	**Typical Problems**	**Recent Upgrades**
• unreported	• no information on scheduled preventive maintenance	• sedimentation • corrosion • failure of motorized valve operators and controls	• planned repair/replacement of gates, valves and electrical control equipment as required • planned repairs to concrete and hydraulic structures as required • dredging • corrosion protection for dam sheet piles • budget for planned repair activities varies from year to year • 10,000 to 60,000 TDN per dam

Item	Total Number In The Inventory	O&M Data Sheets Collected	O&M Responsibility
Levees	5 locations	1 at Pont Bizerte	CRDA/MARH
O&M Budget	**O&M Schedule**	**Typical Problems**	**Recent Upgrades**
• unreported	• inspected about 5 times per year based on flow conditions in river	• erosion • overtopping • man-made breach	• repairs to existing levee at Kalaat Andalous in 3 successive years: • 2005: 5km : 50000 TDN • 2006: 7km : 60000 TDN • 2007: 10km : 80000 TDN

Item	Total Number In The Inventory	O&M Data Sheets Collected	O&M Responsibility
Small hill dams Check dams	68 496	35 16	CRDA/CES/MARH
O&M Budget	**O&M Schedule**	**Typical Problems**	**Recent Upgrades**
• unreported	• inspected monthly and after every large rainfall • bottom outlet opened to discharge sediment during peak inflows	• erosion of spillway and reservoir embankment • sedimentation deposits in the bottom outlet pipe	• planned repairs to gates, outlet piping and surrounding earth embankments

Table 4.1.1 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	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*		2 years Rain		3 years Rain	
	Year	mm/year	Year	mm in 2 years	Year	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 4.1.2 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 4.4.1 Annual Inflow, 2 Consecutive Year Inflow and 3 Consecutive Year Inflow

(a) Chronicled Inflow

year	Inflow 1 year	% of ave	Consecutive years 2 years	Consecutive years 3 years	Interval 2 years	Interval 3 years
	M m3	%	M m3	M m3	M m3	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

Rank	1 year N= 52 Year	Inflow	Thomas T	Thomas F	% of ave
		M m3			%
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

Typical drought 1960	1044.0	Million m3
% of average	54.6	%

2 years (interval)

N= 25 Year	Inflow	Thomas T	Thomas F	interval (2 yrs)	**One cycle once in N years
	M m3			*	
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

Typica	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	Thomas T	Thomas F	interval (3 yrs)	++One cycle once in N years
	M m3			+	
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

Table 5.1.1 Reservoir Yields and Timeframes for Implementation

	Reservoir Yield	Presence (+) or absence (-) of the dam			
Dam	10^6 m^3	2005	2010	2015-20	2025-30
1. Extreme North					
Zerga	19	+	+	+	+
Sidi El Barrak	167	+	+	+	+
Sejnane	80	+	+	+	+
Joumine	74	+	+	+	+
Ghezala	5.6	+	+	+	+
Kebir	24	-	+	+	+
El Moula	17	-	+	+	+
Ziatine	16	-	+	+	+
Gamgoum	6	-	-	+	+
Harka	7	-	-	+	+
Douimis	5	-	-	+	+
Melah	12	-	-	+	+
Tine	13	-	-	+	+
Total Yield 10^6 m^3		345.6	402.6	445.6	445.6
2. Ben M'Tir and Kasseb					
Ben Metir	38	+	+	+	+
Kasseb	34	+	+	+	+
Total Yield 10^6 m^3		72	72	72	72
3. Upper Medjerda					
Zouitina	80	+	+	+	+
Bou Heurtma	75	+	+	+	+
Mellegue	127	+	+	-	-
Mellila	25	-	-	+	+
Mellegue II	107	-	-	+	+
Sub-total 10^6 m^3		282	282	287	287
4. Lower Medjerda					
Sidi Salem	348	+	+	+	+
Lakhmes	4.6	+	+	+	+
Siliana	26	+	+	+	+
R'Mil	7	+	+	+	+
Sarrath	13	-	-	+	+
Tessa	24	-	-	-	+
Beja	14	-	-	-	+
Khaled	13	-	-	-	+
Sub-total 10^6 m^3		385.6	385.6	398.6	449.6
Total Mejerda 10^6 m^3		739.6	739.6	757.6	808.6
Grand Total 10^6 m^3		1085.2	1142.2	1203.2	1254.2

Source: Yields reported by MARH. The yield represents the amount of water that can be withdrawn from the reservoir annually with a 20% risk of deficit (i.e. water supply guarantee of 80%)

Table 5.1.2 Calculation of Active Storage Volumes

Region	Name of dam	Year: Storage Volume at HWL (Mm3)	2010: Storage Volume at NWL (Mm3)	2010: Dead Storage (Mm3)	2010: Active Storage (Mm3)	2020: Storage Volume at NWL (Mm3)	2020: Dead Storage (Mm3)	2020: Active Storage (Mm3)	2030: Storage Volume at NWL (Mm3)	2030: Dead Storage (Mm3)	2030: Active Storage (Mm3)	Siltation rate (10^6 m^3 per year)	
Extreme North	Kebir	65.7	64.40	10.60	53.80	64.40	12.70	51.70	64.40	14.80	49.60	0.21	Eau2000
	Zerga	34.8	22.00	2.00	20.00	22.00	3.28	18.72	22.00	4.56	17.44	0.13	Eau2000
	El Moula	26.3	26.30	7.40	18.90	26.30	9.40	16.90	26.30	11.40	14.90	0.20	Eau2000
	Sidi Barrak	325.0	264.50	39.16	225.34	264.50	57.66	206.84	264.50	76.16	188.34	1.85	Eau2000
	Ziatine	42.0	33.00	9.60	23.40	33.00	11.50	21.50	33.00	13.40	19.60	0.19	Eau2000
	Gamgoum	21.2	-	-	-	18.30	4.90	13.40	18.30	5.07	13.23	0.02	Eau2000
	Harka	45.5	-	-	-	30.30	10.00	20.30	30.30	11.20	19.10	0.12	Eau2000
	Sejnane	165.7	137.50	23.92	113.58	137.50	34.42	103.08	137.50	44.92	92.58	1.05	Eau2000
	Douimis	58.0	-	-	-	45.60	4.60	41.00	45.60	5.52	40.08	0.09	Eau2000
	Melah	43.0	-	-	-	41.00	8.70	32.30	41.00	10.40	30.60	0.17	Eau2000
	Joumine	165.8	129.90	8.39	121.51	129.90	11.99	117.91	129.90	15.59	114.31	0.36	DBGTH actual
	Ghezala	16.5	11.70	0.97	10.73	11.70	1.17	10.53	11.70	1.37	10.33	0.02	DBGTH actual
	Tine	54.5	-	-	-	34.00	3.20	30.80	34.00	3.84	30.16	0.06	Eau2000
Mejerda River Basin Study Area	Zouitina	132.7	74.82	15.64	59.18	74.82	16.84	57.98	74.82	18.04	56.78	0.12	Eau2000
	Sarrath	48.53	20.95	0.47	20.48	20.95	4.57	16.38	20.95	8.67	12.28	0.41	study report DGB
	Mellegue	147.5	44.40	16.87	27.53	44.40	44.40	-	44.40	44.40	-	2.81	DBGTH actual
	Mellegue2	334.0	-	-	-	195.00	34.00	161.00	195.00	68.00	127.00	3.40	Eau2000
	Tessa	125.0	-	-	-	44.43	10.10	34.33	44.43	15.30	29.13	0.52	Eau2000
	Ben Metir	73.4	57.20	5.92	51.28	57.20	7.32	49.88	57.20	8.72	48.48	0.14	DBGTH actual
	Bou Heurtma	164.0	117.50	7.70	109.80	117.50	8.90	108.60	117.50	10.10	107.40	0.12	DBGTH actual
	Kasseb	92.6	81.88	19.86	62.02	81.88	21.86	60.02	81.88	23.86	58.02	0.20	DBGTH actual
	Beja	46.0	-	-	-	26.40	3.70	22.70	26.40	7.40	19.00	0.37	Eau2000
	Sidi Salem	959.5	814.00	170.90	643.10	814.00	215.90	598.10	814.00	260.90	553.10	4.50	Eau2000
	Khalled	37.0	-	-	-	34.00	9.50	24.50	34.00	12.70	21.30	0.32	Eau2000
	Lakhmes	8.4	7.22	0.18	7.04	7.22	1.30	5.92	7.22	1.60	5.62	0.03	Eau2000
	Siliana	125.1	70.00	20.14	49.86	70.00	30.74	39.26	70.00	41.34	28.66	1.06	DBGTH actual
	Rmil	6.0	4.00	-	4.00	4.00	0.50	3.50	4.00	1.00	3.00	0.35	Note 1

Note 1: The sedimentation rate reported by Eau2000 would fill the complete reservoir shortly after 2020.
R'Mil does not contribute to downstream demands therefore sedimentation rate has been assumed for clarity of presentation.

Table 5.1.3 Target Salinity for Demand Centers

Code	Description	Name	Max Salinity g/liter
BA01	Agricultural demand	Mornag CMCB	1.50
BE01	Agricultural demand	Testour	2.00
BE02	Agricultural demand	Tebourba Mjez	2.00
BE05	Agricultural demand	Goubellat	2.00
BE07	Agricultural demand	Sidi Ismail	2.00
BE08	Agricultural demand	Nefza Ouechtata	2.00
BE10	Agricultural demand	Skhira	2.00
BE11	Agricultural demand	El-Herri	2.00
BI02	Agricultural demand	Utique	2.00
BI03	Agricultural demand	Tobias Bizerte	2.00
BI04	Agricultural demand	El Aalia Menzel Jmil	2.00
BI05	Agricultural demand	Cap Serrat	2.00
BI06	Agricultural demand	Ghezela	2.00
BI07	Agricultural demand	Teskraya	2.00
BI09	Agricultural demand	Sejenane (Sidi Barak)	2.00
BI10	Agricultural demand	Mateur	1.00
BI11	Agricultural demand	Ras Jebel - Ousja	1.00
BI12	Agricultural demand	Zouaouine	1.00
JE01	Agricultural demand	Bouhertma sect I et II	1.50
JE03	Agricultural demand	Bouhertma sect IV	1.50
JE04	Agricultural demand	Badrouna	2.00
JE07	Agricultural demand	Bouhertma sect VI	2.00
JE08	Agricultural demand	Sidi Shili	2.00
JE09	Agricultural demand	Tabarka Mekna	2.00
JE11	Agricultural demand	Bouhertma phase III	2.00
JE12	Agricultural demand	Hammam Bourguiba Fernana	2.00
KF02	Agricultural demand	Sidi Khiar	2.00
KF10	Agricultural demand	Nebeur	2.00
LA03	Agricultural demand	Kalaat Landlous	3.00
LA09	Agricultural demand	Borj Toumi Nouveau	3.00
LA34	Agricultural demand	Basse Vallée (ancien)	3.00
LA35	Agricultural demand	Tobias Ariana	3.00
NA03	Agricultural demand	Grombalia	1.50
NA04	Agricultural demand	Nouvelle Sauvegarde	1.50
NA06	Agricultural demand	Soliman-Ml Bouzelfa	1.50
NA07	Agricultural demand	Korba Menzel Temim	1.50
NA08	Agricultural demand	Ancienne Sauvegarde	1.50
SL01	Agricultural demand	Lakhmes	1.00
SL02	Agricultural demand	Gaafour-Laroussia	1.00
SL09	Agricultural demand	Rmil	1.00
UBER	Urban water demand	Towns along the pipeline (Ben M'Tir)	1.50
UBIZ	Urban water demand	Bizerte	1.50
UCTU	Urban water demand	Tunis	1.50
UNAB	Urban water demand	Cap Bon (Nabeul)	2.50
USFA	Urban water demand	Sfax & Sidi Bouzid	1.50
USAK	Urban water demand	Sahel & Kairouan	1.50
EN02	Environmental demand	Lake Ichkeul	2.00

Table 5.9.1 Appendix 1 for Decree No1991-2005 regarding EIA Study (1/2)

APPENDIX 1

Units (facilities and/or projects) obligatorily submitted to an Impact Study on the Environment (EIA).

Category A: Units which require a consulting period which does not exceed 21 working days

1) Units of domestic and assimilated waste with a capacity that does not exceed 20 tons per day.
2) Units of treatment and manufacture of building materials of ceramics and glass
3) Units of drugs manufacturing
4) Units of manufacturing non ferrous metals
5) Units of metal treatment and surface treatment
6) project of exploration and extraction of oil and natural gas
7) Industrial quarries of ballast and sand which output do not exceed 300000 tons per year, and the industrial quarries of clay and marble stones.
8) Manufacturing unit of sugar refinery and yeast
9) Unit of thread textile dyeing, of clothing, knitting and jeans fading and completion
10) Project of development of industrial areas the surface of which does not exceed five (5) hectares
11) Project of urban allotment which surface is comprised between five (5) and twenty (20) hectares
12) Project of development of tourist areas the surface of which is comprised between ten (10) and thirty (30) hectares
13) Manufacturing units of mineral fibre
14) Units of manufacturing, transformation, conditioning and conservation of foodstuff
15) Slaughterhouses
16) Manufacturing or construction unit of car, lorries or their motors
17) Shipyard projects
18) Project of manufacturing and maintenance of aircraft
19) Units of shellfish farming
20) Water desalination units in industrial and tourist units
21) Units of spa and hydrotherapy industry
22) Hotel units with a capacity exceeding three hundred beds (300)
23) Manufacturing unit of paper and cardboard
24) Manufacturing unit of elastomer and peroxide

Source: ANPE, MEDD

Table 5.9.1 Appendix 1 for Decree No1991-2005 regarding EIA Study (2/2)

Category B: Units which require a consulting period that does not exceed three working months (3 months)

1) Unit of raw oil refinery and installation of gasification and liquefaction of at least 500 tons of coal or bituminous schist oil per day
2) Unit of electricity manufacturing with at least a capacity of three hundred MW
3) Units of domestic and assimilated waste with a capacity that does not exceed 20 tons per day.
4) Unit of management of hazardous wastes
5) Manufacturing unit of concrete, whitewash and gypsum
6) Manufacturing unit of chemicals, pesticides, painting, polish and bleach category 2 according to the nomenclature of establishments known as hazardous, unhealthy and inconvenient.
7) Steel units
8) Industrial quarries of ballast and sand which output do not exceed 300000 tons per year, and the extraction of water resources.
9) Manufacturing unit of paper pulp and treatment of cellulose
10) Project of construction of railways, motorways, express roads, bridges and grade separation
11) Project of airport construction with a takeoff and landing track longer than two thousand one hundred meter (2100).
12) Project of commercial, fishing and pleasure ports
13) Project of development of industrial areas with a surface exceeding five (5) hectares
14) Project of urban allotment with a surface that does not exceed twenty (20) hectares
15) Project of development of tourist areas the surface of which exceeds thirty hectares (30)
16) Transport facilities of raw oil and gas
17) Units of treatment of urban waste water
18) Collective units of treatment of industrial waste water
19) Units of tannery and tanning
20) Project of irrigated areas through treated waste water
21) Projects of big dams
22) Aquaculture project not mentioned in category A of Appendix 1
23) Desalination unit of drinking water supply in urban areas
24) Project of vacation village with a capacity exceeding one thousand bed (1000)
25) Units of extraction, treatment, and washing of mineral and non mineral products
26) Units of phosphate transformation and its by products

Source: ANPE, MEDD

Table 5.9.2 Appendix 2 for Decree No1991-2005 regarding EIA Study

APPENDIX II Units (facilities and/or projects) submitted to Terms and Conditions

1) Projects of urban allotment with a surface area which does not exceed five (5) hectares and projects of tourist area with a surface area which does not exceed ten (10) hectares
2) Projects of construction of schools and teaching establishments
3) Projects of construction of canals for water conveyance or diversion
4) Projects of energy transport which are not mentioned in Appendix 1 and which do not cross legally protected areas such as natural and significant areas
5) Project of costal development not mentioned in Appendix 1
6) Oil mil units
7) Units of animal and vegetal oil extraction
8) Units classified of animal breeding
9) Unit of textile industry not mentioned in Appendix 1
10) Unit of stamping,, cutting and big metal parts
11) Units of storage, hydrocarbon distribution or the stations of washing and greasing vehicles
12) Manufacturing units of starchy
13) Traditional quarries
14) Units of storage of gas and chemical products
15) Boiler making industry, tank construction and other parts of sheet-metal works
16) Laundries using water for washing clothes and blankets
17) Lake occurring between hills
18) Manufacturing units of toiletries and vitamins

Source: ANPE, MEDD

Table 7.2.1 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)

	HY-M Mellgue, Mejerda Conf	HY-U1 Mellgue, Mejerda Conf	HY-U2 Sidi Salem	HY-D1 Larrousia Dam	HY-D2 Estuary	HYd-Bh BouHeurtma Dam
Catchment	4561	1154	10414	14172	15968	390
Return Period	km2	km2	km2	km2	km2	km2
2	55	75	60	56	55	143
5	82	101	84	80	79	185
10	104	121	100	98	96	215
20	128	141	118	116	113	246
30	143	155	129	127	124	264
50	164	171	143	141	137	289
100	195	196	163	162	156	324
200	230	224	184	184	175	361
Disribution	LP3	LP3	LP3	LP3	LP3	LP3

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

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

	K13	Ghardimaou
Catchment	9000	1480
Return Period	km2	km2
2	470	250
5	940	520
10	1430	790
20	2080	1150
30	2200	1410
50	3340	1830
100	4710	2550
200	6620	3540
Distribution	GEV	GEV

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

Flood	date				6day rain / Return period	HY-M Mellgue, Mejerda Conf	HY-U1 Jendouba	HY-U2 Sidi Salem	HY-D1 Larrousia Dam	HY-D2 Estuary	BouHeurtma Dam
1973 Mar Fl.	6 day rainfall	1973/3/24	to	1973/3/29	mm/6days	115	130	121	120	111	213
					year	15	15	22	25	20	10
2000 May Fl.	6 day rainfall	2000/5/22	to	2000/5/27	mm/6days	74	121	70	62	64	32
					year	4	10	3	2.5	3	<1.01
2003 Jan Fl.	6 day rainfall	2003/1/8	to	2003/1/13	mm/6days	110	89	98	100	94	112
					year	12	4	10	12	10	1.01-2
	6 day rainfall	2003/1/16	to	2003/1/21	mm/6days	27	88	46	41	41	155
					year	1.01-2	4	1.01-2	1.01-2	1.01-2	3
	6 day rainfall	2003/1/22	to	2003/1/27	mm/6days	41	72	62	56	51	121
					year	1.01-2	1.01-2	2	2	1.01-2	1.01-2
	6 day rainfall	2003/1/31	to	2003/2/5	mm/6days	16	61	37	32	31	118
					year	<1.01	1.01-2	1.01-2	1.01-2	1.01-2	1.01-2
2004 Jan Fl.	6 day rainfall	2003/12/8	to	2003/12/13	mm/6days	139	175	139	142	140	223
					year	28	50	40	50	60	13
	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
					year	1.01-2	1.01-2	1.01-2	1.01-2	1.01-2	2
	6 day rainfall	2004/1/20	to	2004/1/25	mm/6days	14	24	30	23	23	127
					year	<1.01	<1.01	1.01	1.01	1.01	1.01-2

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

Flood		K13	Ghardimaou
1973 Mar Fl.		1280	2370
		8	80
2000 May Fl.		4480	737
		90	10
2003 Jan Fl.	2003/1/8 - 2003/1/13	2600	1090
		30	18
	2003/1/16 - 2003/1/21	692	334
		3	3
	2003/1/22 - 2003/1/27	154	419
		<1.01	4
	2003/1/31 - 2003/2/5	80	131
		<1.01	1.01-2
2004 Jan Fl.	2003/12/8 - 2003/12/13	2480	938
		28	15
	2003/12/19 - 2003/12/24	-	-
	2003/12/29 - 2004/1/3	645	1470
		3	32
	2004/1/20 - 2004/1/25	-	190
			<1.01

Note : - : Negligibly small

Table 7.2.2 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 8.1.1 Achievements of Interview Survey on Public Acceptance of Flood Risk and Stakeholders' Meetings (1/4)

(1) Interview Survey on Public Acceptance of Flood Risk

The survey on the acceptance of flood risk was carried out in the Mejerda River basin (upper, middle and lower) with 400 sampled respondents. The major survey results are enumerated below.

(a) The government provided assistance to the victims of the floods (1973, 2003, etc.); this help was varied, it included compensation in money for the undergone damage but also food, clothes and mobilization of support staff; however, the surveyed people, in their great majority estimate that this help was insufficient and did not satisfy them because it could not cover the total of damage which they suffered.

(b) Almost all the surveyed people, except 3 people, have declared frightened by return of floods. The imperative reasons of this fear are especially explained by fear that necessary measures have not been taken to protect them. Fears relate to the destruction of property, the destruction of houses and loss of human lives. This fear results in the largely widespread belief (more than 84% of the cases) that serious floods are foreseeable in the future.

(c) Indeed, 88.3% of the surveyed people believe that there will be risks in future flood. Only a small minority of 5% were quiet because it is persuaded that necessary measures will be taken to face the future floods.

(d) Questioned on the causes of risk of floods to come, the surveyed people are especially worried because they are in the fear that necessary measures will not be taken (40.7% of the questioned cases) or because there are many houses and cultivated lands in the lower areas. People tend to in general believe that the next flood will be more catastrophic, considering necessary measures are not taken.

(e) Questioned if they can cohabit with a certain level of risk, the great majority of the questioned people reject this possibility, considering that the tolerance level is equal to zero flood. However, a minority of more than 20% thinks that it can live with a minimum of risk. Thus, the acceptability of risk of floods is very low. The fear of floods and the risk which they generate is dominant in the population.

(f) People know the majority of structural measures, in particular improvement of riverbeds, dams and levees. However, they know much less about a retarding basin.

(g) In their great majority, they believe that these measures should be applied. The minority which does not believe in this need considers that it was not convinced of the effects of these measures in the past.

(h) Those who believe on the contrary in the need for these measures want to live in safety, to reduce flood damage and to preserve their sources of income.

(i) People know well some non-structural measures and less better some others. They know more about alarm systems and to a lesser extent about the lawful control of land use. They know much less about the system of fighting against floods with participation of population and an insurance flood system.

(j) An important majority slightly higher than that for the structural measures considers that it is necessary to apply non-structural measures, while a minority of 23% does not see the need of it, convinced of their low effectiveness.

(k) Questioned if the Government will take necessary measures to protect the population during future floods, a simple majority believe that it will take them. They are persuaded

Table 8.1.1 Achievements of Interview Survey on Public Acceptance of Flood Risk and Stakeholders' Meetings (2/4)

that the Government has budgetary constraint which prevents it from taking such measures.

(l) Structural and non structural measures shown in the survey are in harmony with the expectation of two thirds of the surveyed people, while the remaining 1/3 estimate that they are not completely in harmony with their expectations and propose supplementary measures, in particular better monitoring of reservoir water level and better help of evacuation.

(m) People are relying much on the assistance of the Government; this means that they have high hopes on the Government, although they do not have complete confidence in its firm decision to take necessary measures at an appropriate time.

(n) Half of the people surveyed are laid out to assume a share of responsibility with respect to the danger of future floods, while about the other half is not laid out yet to assume this responsibility. As to what are the reasons for refusal to assume the self-responsibility, more than half of people estimate that the management of floods concerns the Government strictly, while the others estimate that the individuals cannot do anything against the phenomenon of flood.

(o) The great majority do not want to come to a conclusion about the amount of money which they agree to pay and estimate that they will make the decision at the time of the advent of flood and a minority is laid out to pay less than 100 DT; another minority more than 100 Dinars.

(p) Concerning structural measures to apply, the surveyed people gave the absolute priority to the improvement of riverbed and the construction of farm roads to avoid being surrounded in the event of floods; they also estimate that the establishment of rules of more rigorous management at the reservoir water level is desirable.

(q) Concerning non-structural measures, the surveyed people give priority to the regulation which would prohibit construction in low zones to avoid the danger from the floods; they are also persuaded of the importance of alarm system for the evacuation at the time of floods.

People do not seem to be familiar with a hazard map, house resistant to floods, a system of flood fighting with community participation and especially a flood insurance system.

(2) First Stakeholders' Meeting

The stakeholders' meeting was carried out also in the upper, middle and lower regions of the Mejerda River with 138 participants in total. The major discussion results are as enumerated below.

(a) As regards non-Structural Measures

1) Populations have pointed out insufficiency of flood measures and have suggested that the good management of reservoir water release should not be cumulated with big floods or strong rainfalls considering that the decreased capacity of the Mejerda River could not longer accommodate big discharges, sedimentation being one of the main causes.

2) They have stressed failed civil protection measures, which are too late and slow to act; therefore it needs strengthening and good coordination to help reduce the extent of flood damage.

Table 8.1.1 Achievements of Interview Survey on Public Acceptance of Flood Risk and Stakeholders' Meetings (3/4)

3) Other non-structural measures to be implemented include development of an optimum level of coordination between various administrations to avoid disorderly and counter-productive actions such as the authorizations delivered by local government to allow building houses, factories or projects in the public hydraulic domains. These measures also include prohibiting plantation of trees in river channels under a pretext of fixing the soil as well as the disorderly construction of dyke in river channels, obstructing the flow and also deteriorating proper function of automatic water level gauges.

4) Follow-up measures, such as information of public and sensitization campaigns, would be necessary at the time of major decisions to establish confidence between the administration and the populations.

All of these issues raised suggest that a good organizational and institutional strengthening and capacity building program is necessary in the plan formulation before any sustainable implementation of the measures is ensured.

(b) As regards Structural Measures

1) As most urgent structural measures, river widening and river course cleaning to remove sediment and anarchical vegetation growing inside river courses have been suggested. Construction of farm roads or rehabilitation of existing ones, are suggested to prevent people from being surrounded by water during floods. This measure has been an opinion widely expressed in the interview survey and public consultations.

2) The construction of a shortcut channel to rectify the route of the Mejerda River has also been suggested to avoid meandering of river which invades cultivated lands and make them easily flooded.

3) The construction of a bypass channel to control big discharge during floods has been highly suggested as well.

4) The populations are unanimous to preserve the historical monuments and to find a friendly solution so as not to put in danger the historical inheritance of Tunisia, referring particularly to the Muradi bridge (built in 1088; 11th century 1088) of Medjez el Bab. Construction of a bypass channel or a floodway outside of the city has been suggested.

5) Most of the populations denounced the anarchical behaviours of people who build in flood prone areas, destroy levees along river channels and throw wastes into rivers. Any implementation of structural measures should first deal with these people and find a way through sensitization or other means to solve these problems, some of which, such as building houses in the hydraulic public domain, are very complex issues considering involvement of some local authorities.

(3) Second Stakeholders' Meeting

The stakeholders' meeting was carried out also in the upper, middle and lower regions of the Mejerda River with 187 participants in total. The major discussion results are as enumerated below.

(a) A large majority expressed its concern at the impact of the measures on the socio-economic life in particular. Indeed, the farmers and breeders who live on the edge of the Mejerda River are concerned that the construction works related to the measures take too long, which could negatively influence their sources of income that are

Table 8.1.1 Achievements of Interview Survey on Public Acceptance of Flood Risk and Stakeholders' Meetings (4/4)

depending on the water of the Mejerda River: irrigation of agricultural land and water for livestock.

(b) The fear of water pollution is the main source of concern, especially in the middle and lower areas of the Mejerda River basin.

(c) A large majority gave their approval to the presented structural measures (85%), but 17.7% of them did agree only if there are no serious impact of the planned structural measures.

(d) It is also important to take into account the 15% minority who refuses the measures or who do not understand them well enough. Their refusal resulted mainly from the fear that compensation would not be applied fairly.

(e) At the regional level, the understanding and adherence to the structural measures is not homogeneous; there are different levels depending on the locations of meetings. At Bou Salem, the level of understanding and adherence is very satisfactory; it is gratifying at Sidi Thabet and quite satisfying at Testour. This is due to three reasons:

1) First reason: At Testour and Sidi Thabet, it is noted that there are large numbers of farmers and breeders who live mainly on the use of water of the Mejerda River for irrigated agriculture and for livestock. These people are worried about their sources of income which would be affected if the construction works take a long time. At Bou Salem, it is noted that there are large numbers of residents (employees, officials, etc.) who have suffered especially due to the urban flooding destroying their homes.

2) Second reason: At Bou Salem, the participants felt that the structural measures would adequately meet their expectations; to the contrary at Testour and Sidi Thabet, there are localities, such as Slouguia, Mastouta, Sidi Thabet and Kalat Landalous which felt that the measures had not taken into consideration their localities.

3) Third reason: At Testour, some participants felt that in the past they had not been adequately compensated for the construction of the Sidi Salem Dam. They are afraid that the bad experience would be repeated in the future.

Table 8.2.1 Fundamental Rules for Coordinated Reservoir Operation during Floods (1/3)

Dam name	**Sidi Salem Dam (Existing)**
Dams to be coordinated	Mellegue (Mellegue2), Bou Heurtma and Siliana Dams.
Reference points of discharges	Ghardimaou, Jendouba, Bou Salem, Jebel Laoudj, Gauging Stations (GSs)
Reservoir operation	- If the actual water level in the Sidi Salem Reservoir (the Reservoir) is at the normal water level (or close to this level) and the discharge upstream of the Reservoir (e.g. outflow from the Mellegue Dam, at Jendouba or Bou Salem GSs) is higher than the maximum river channel capacity downstream of the Reservoir, it is recommended to pre-release the Reservoir by releasing the maximum river channel capacity. - Pre-release of the Reservoir is limited by the inflow from the Khalled River and the Siliana River. The pre-release must be coordinated with the discharge at Jebel Laoudj GS. - If the outflow from the Mellegue Dam or the discharge at Ghardimaou, Jendouba or Bou Salem GSs increases 3,000 m^3/s, it is recommended to immediately and completely open both bottom outlets and one sluice of main spillway. - If the outflow from the Mellegue Dam or the discharge at Ghardiamou, Jendouba or Bou Salem GSs increases 5,000 m^3/s and the discharge at such a check point has still an increase tendency, it is recommended to immediately and completely open both bottom outlets and all 3 sluices of main spillway and release as much outflow as possible from to the Reservoir. - As soon as the water level in the Reservoir reaches the maximum high water level (MHWL) = 119.50 m, it is needed to immediately open as many outlets or spillway gates as necessary for stopping increase of water level.
Dam name	**Mellegue Dam (Existing)**
Dams to be coordinated	Bou Heurtma, Tessa Dams
Reference points of discharges	Border with Algeria, the Sarrath River, K 13 GS, Jendouba GS
Reservoir operation	- If the actual water level in the Mellegue Reservoir (the Reservoir) is at the normal water level (or close to this level) and the discharge upstream of the Reservoir (e.g. inflow from Algeria, measured discharge on the Sarrath River or in K 13 GS) is higher than the maximum river channel capacity downstream of the Reservoir, it is recommended to pre-release the Reservoir by releasing the maximum river channel capacity. - Pre-release of the Reservoir must be coordinated with the actual discharge at Jendouba GS and according to flood situation on the Bou Heurtma and the Tessa Rivers, so that the maximum river channel capacity in the Mejerda River reaches from Jendouba to the Sidi Salem Reservoir is not exceeded. - If the discharge upstream of the Reservoir (the Mellegue River at Algerian border, the Sarrath River, etc.) exceeds 1,500 m^3/s it is recommended to immediately and completely open both bottom outlets, i.e. to release up to 600 m^3/s. - As soon as the water level in the Reservoir reaches MHWL (269.00 m), it is needed to immediately open as many outlets or spillway gates as necessary for stopping increase of water level.
Dam name	**Bou Heurtma Dam (Existing)**
Dams to be coordinated	Mellegue (Mellegue2), Tessa, Ben Metir, Mellegue Dams
Reference points of discharges	Fernana, Jendouba GSs
Reservoir operation	- If the actual water level in the Bou Heurtma Reservoir (the Reservoir) is at the normal water level (or close to this level) and the discharge upstream of the Reservoir (e.g. outflow from the Ben Metir Reservoir or at Fernana GS) is higher than the maximum river channel capacity downstream of the Reservoir, it is recommended to pre-release the Reservoir by releasing the maximum river channel capacity through the bottom outlet. - Pre-release of the Reservoir must be coordinated with the actual discharge at Jendouba GS, releasing of the Mellegue Reservoir and according to flood situation on the Tessa River, so that the maximum river channel capacity in the Mejerda River reaches from Jendouba to the Sidi Salem Reservoir is not exceeded. - As soon as water level in Reservoir reaches the uncontrolled spillway crest (221.00 m), the bottom outlet of the Bou Heurtma Dam is gradually closed to release a constant outflow (equal to the maximum river channel capacity downstream of the Reservoir) as long as possible. The bottom outlet is completely closed during culmination of flood wave.

Table 8.2.1 Fundamental Rules for Coordinated Reservoir Operation during Floods (2/3)

	- As soon as the water level in the Reservoir reaches MHWL (226.00 m) it is needed to immediately open the bottom outlets (partly or completely) as necessary for stopping increase of water level. - After water level culmination in the reservoir, it is necessary to release flood control storage. During the first releasing period, the water automatically spills over the uncontrolled spillway. After storage decreasing through the spillway, the water in the Reservoir is released with the maximum river channel capacity in the Bou Heurtma River downstream of the Reservoir. During this second period, the bottom outlet is gradually opened and releasing of reservoir continues until the actual normal water level in the Reservoir is reached (i.e. the flood control storage of the Reservoir is empty).
Dam name	**Siliana Dam (Existing)**
Dams to be coordinated	Sidi Salem, Lakhmes Dams
Reference points of discharges	Jendouba, Bou Salem, Oussafa, Slouguia GSs
Reservoir operation	- If the actual water level in the Siliana Reservoir (the Reservoir) is at the normal water level (or close to this level) and the discharge upstream of the Reservoir (e.g. outflow from the Lakhmes Reservoir or at Oussafa GS) is higher than the maximum river channel capacity downstream of the Reservoir, it is recommended to pre-release the Reservoir by releasing the maximum river channel capacity through the bottom outlet. - Pre-release of the Reservoir must be coordinated with the actual discharge at Slouguia GS and releasing of the Sidi Salem Reservoir, so that the maximum river channel capacity in the Mejerda River downstream of the Sidi Salem Dam is not exceeded. - As soon as the water level in the Reservoir reaches the uncontrolled spillway crest (388.50 m), the bottom outlet of the Siliana Dam is gradually closed to release a constant outflow (equal to the maximum river channel capacity downstream of the reservoir) as long as possible. The bottom outlet is completely closed during culmination of flood wave. - As soon as the water level in the Reservoir reaches MHWL (395.50 m), it is needed to immediately open the bottom outlets (partly or completely) as necessary for stopping increase of water level. - After water level culmination in the reservoir, it is necessary to release flood control storage. During the first releasing period, the water in the Reservoir automatically spills over the uncontrolled spillway. After storage decreasing through the spillway, the water in the Reservoir is released with the maximum river channel capacity in the Siliana River downstream of the Reservoir. During this second period, the bottom outlet is gradually opened and releasing of reservoir continues until the actual normal water level in the Reservoir is reached (i.e. the flood control storage of the Reservoir is empty).
Dam name	**Mellegue2 Dam (under detailed design)**
Dams to be coordinated	Mellegue, Bou Heurtma and Tessa Dams
Reference points of discharges	Border with Algeria, the Sarrath River, K 13 GS, Jendouba GS
Reservoir operation	- The Mellegue 2 and the Mellegue Reservoirs are operated as cascade reservoirs. It is recommended to fill the upper reservoir at first and during the flood descending period to empty also the upper reservoir at first. - If it is necessary to release a big outflow from the Mellegue Reservoir (e.g. in case of huge flood in the Mellegue River catchment), the bottom outlet of the Mellegue 2 Reservoir (the Reservoir) can be open (up to the maximum capacity) during the flood ascending period to support higher releasing discharge from the Mellegue Reservoir. In such a case, it is recommended to completely close the bottom outlet of the Reservoir again at the moment of peak inflow into the Reservoir. This operation enables to use the maximum volume of flood control storage and decrease and postpone a peak outflow from the Reservoir. - As soon as the water level in the Reservoir reaches MHWL (304.00 m), it is needed to immediately open bottom outlets (partly or completely) as necessary for stopping increase of the water level. During this operation, it is needed to consider safety risk of both dams as well. - After water level culmination in the reservoir, it is necessary to release flood control storage. During the first releasing period, water in the Reservoir automatically spills over the uncontrolled spillway into the Mellegue Reservoir and the Mellegue Reservoir is used as a buffer reservoir. After storage decreasing through the spillway, the water level in the Reservoir is released with the maximum river channel capacity in the Mellegue River downstream of the Mellegue Dam. During this second period, water level in the Mellegue Reservoir remains stable: only the Reservoir is

Table 8.2.1 Fundamental Rules for Coordinated Reservoir Operation during Floods (3/3)

	released. Releasing of the Mellegue Reservoir continues after the Reservoir reaches the normal water level (i.e. the flood control storage of the Reservoir is empty).
Dam name	**Sarrath Dam (under construction)**
Dams to be coordinated	Mellegue (Mellegue 2),Tessa and Ben Metir Dams
Reference points of discharges	Sidi Abdelkader, Sarrath Pont Route, K 13 GSs
Reservoir operation	- If the actual water level in the Sarrath Reservoir (the Reservoir) is at the normal water level (or close to this level) and the discharge upstream of the Reservoir (e.g. at Sidi Abdelkader GS or Sarrath Pont Route GS) is higher than the maximum river channel capacity downstream of the Reservoir, it is recommended to pre-release the Reservoir by releasing the maximum river channel capacity through the bottom outlet. - The pre-release must be coordinated with the actual Mellegue inflow from Algeria or according to the actual discharge or the discharge forecasted for K 13 GS and also according to actual situation of the Mellegue (Mellegue 2) Reservoir. - As soon as the water level in the Reservoir reaches the uncontrolled spillway crest (546.00 m), the bottom outlet of the Sarrath Dam is gradually closed to release a constant outflow (equal to the maximum river channel capacity downstream of the Reservoir) as long as possible. The bottom outlet is completely closed during culmination of flood wave. - As soon as the water level in the Reservoir reaches MHWL (552.00 m), it is needed to immediately open bottom outlets (partly or completely) as necessary for stopping increase of the water level. - After water level culmination in the reservoir, it is necessary to release flood control storage. During the first releasing period, water in the Reservoir automatically spills over the uncontrolled spillway. After storage decreasing through the spillway, the water in the Reservoir is released with the maximum river channel capacity in the Sarrath River downstream of the Reservoir. During this second period, the bottom outlet is gradually opened and releasing of reservoir continues until the actual normal water level in the Reservoir is reached (i.e. the flood control storage of the Reservoir is empty).
Dam name	**Tessa Dam (under detailed design)**
Dams to be coordinated	Mellegue (Mellegue2), Bou Heurtma Dams.
Reference points of discharges	Sers Ville, Jendouba GSs
Reservoir operation	If the actual water level in the Tessa Reservoir (the Reservoir) is at the normal water level (or close to this level) and the discharge upstream of the Reservoir (e.g. Sers Ville GS) is higher than the maximum river channel capacity downstream of the Reservoir, it is recommended to pre-release the Reservoir by releasing the maximum river channel capacity through the bottom outlet. The pre-release must be coordinated with actual discharge at Jendouba GS, releasing of the Mellegue and the Bou Heurtma Reservoirs, so that the maximum river channel capacity in the Mejerda River reaches from Jendouba to the Sidi Salem Reservoir is not exceeded. As soon as the water level in the Reservoir reaches the uncontrolled spillway crest (361.00 m), the bottom outlet of the Tessa Dam is gradually closed to release a constant outflow (equal to the maximum river channel capacity downstream of the Reservoir) as long as possible. The bottom outlet is completely closed during culmination of flood wave. As soon as the water level in the Reservoir reaches MHWL (369.00 m), it is needed to immediately open the bottom outlets (partly or completely) as necessary for stopping increase of the water level. After water level culmination in the Reservoir, it is necessary to release the flood control storage. During the first releasing period, water in the reservoir automatically spills over the uncontrolled spillway. After storage decreasing through the spillway, water level in the Reservoir is released with the maximum river channel capacity in the Tessa River downstream of the Reservoir. During this second period, the bottom outlet is gradually opened and releasing of reservoir water continues until the actual normal water level in the Reservoir is reached (i.e. the flood control storage of the Reservoir is empty).

Table 8.3.1 Summary of Construction Cost for River Improvement Works (1/2)

Scale of River Improvement

Zone	Return period	Peak Discharge (m3/s)	Existing Flow Capacity (m3/s)	River Cross Section No.	Flood Retarding Basin: Peak Q (m3/s)	Flood Retarding Basin: Volume (mil. m3)	River Channel Excavation: Discharge (m3/s)	River Channel Excavation: Bottom width (m)	River Channel Excavation: Length (km)	Embankment Left: Height (m)	Embankment Left: Length (km)	Embankment Right: Height (m)	Embankment Right: Length (km)	Bypass Channel: Discharge (m3/s)	Bypass Channel: Bottom width (m)	Bypass Channel: Depth (m)	Embankment (along Bypass): Height (m)	Embankment (along Bypass): Length (km)	Revetment
U1	5-Year	520	200	MU317~MU306	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
U1	5-Year	370	200	MU248~MU211	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
U1	5-Year	370	200	MU210-MU165	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
U1	10-Year	790	200	MU329~MU306	—	—	790	10	12.4	—	—	—	—	—	—	—	—	—	—
U1	10-Year	570	200	MU248~MU211	—	—	570	15	18.9	—	—	—	—	—	—	—	—	—	—
U1	10-Year	570	200	MU210-MU165	—	—	570	10	16.4	—	—	—	—	—	—	—	—	—	—
U1	20-Year	1,150	200	MU329~MU306	—	—	1,150	15	12.4	—	—	—	—	—	—	—	—	—	—
U1	20-Year	820	200	MU248~MU211	—	—	820	20	18.9	—	—	—	—	—	—	—	—	—	—
U1	Jendouba B													250	25	6.0			
U1	20-Year	820	200	MU210-MU165	—	—	570	35	16.4	—	—	—	—	—	—	—	—	—	—
U1	50-Year	1,830	200	MU329~MU306	—	—	1,830	25	12.4	—	—	—	—	—	—	—	—	—	—
U1	50-Year	1,310	200	MU248~MU211	—	—	1,310	25	18.9	—	—	—	—	—	—	—	—	—	—
U1	Jendouba B													530	55	6.0			
U1	50-Year	1,310	200	MU210-MU165	—	—	780	50	16.4	—	—	—	—	—	—	—	—	—	—
M	5-Year	120	120	MG1~MG8	—	—	120	—	1.6	—	—	—	—	—	—	—	—	—	—
M	10-Year	410	120	MG1~MG52	—	—	410	15	12.9	—	—	—	—	—	—	—	—	—	—
M	20-Year	1,100	120	MG1~MG112	—	—	1,100	25	26.9	—	—	—	—	—	—	—	—	—	—
M	50-Year	2,420	120	MG1~MG112	—	—	2,420	35	26.9	—	—	—	—	—	—	—	—	—	—
U2	5-Year	490	200	MU123~MU164	—	—	490	20	16.6	—	—	—	—	—	—		—	—	—
U2	Bou Salem B	640	400	MU80~MU122	—	—	640	30	14.9	—	—	—	—	—	—	—	—	—	—
U2	5-Year	680	250	MU36~MU79	—	—	680	35	16.7	—	—	—	—	—	—	—	—	—	—
U2	5-Year	680	200	MU1~MU35	—	—	680	—	14.3	○		○	—	—	—	—	—	—	—
U2	Bou Heurtma	40	—	—	—	—	—	—	—	—		—		—	—	—	—	—	—
U2	10-Year	890	200	MU123~MU164	—	—	890	25	16.6	—	—	—	—	—	—	—	—	—	—
U2	Bou Salem B	1,110	400	MU80~MU122	—	—	810	50	14.9	○		○		—	—	—	—	—	—
U2	10-Year	1,140	250	MU53~MU79	—	—	1,140	50	10.4	—	—	—	—	—	—	—	—	—	—
U2	10-Year	1,140	250	MU36~MU52	—	—	1,140	—	15.9	○		○		—	—	—	—	—	—
U2	10-Year	1,140	200	MU1~MU35	—	—	1,140	—	14.3	○		○		—	—	—	—	—	—
U2	Bou Heurtma	40	—	—	—	—	—	—	—		4.6		4.6	—	—	—	—	—	—
U2	20-Year	1,490	200	MU123~MU164	—	—	1,490	40	16.6	○		○					—	—	—
U2	Bou Salem B	1,800	400	MU80~MU122	—	—	1,100	50	14.9	○		○		700	25	8.0	—	—	—
U2	20-Year	1,840	250	MU52~MU79	—	—	1,840	50	10.4	—	—	—	—	—	—	—	—	—	—
U2	20-Year	1,840	250	MU36~MU52	—	—	1,840	—	15.9	○		○		—	—	—	—	—	—
U2	20-Year	1,840	200	MU1~MU35	—	—	1,840	—	14.3	○		○		—	—	—	—	—	—
U2	Bou Heurtma	40	—	—	—	—	—	—	—		6.9		6.9	—	—	—	—	—	—
U2	50-Year	3,330	200	MU123~MU164	—	—	3,330	50	16.6	○		○		–	–	–	–	–	–
U2	Bou Salem B	3,570	400	MU80~MU122	—	—	1,970	50	14.9	○		○		1,600	50	8.0	○	–	–
U2	50-Year	3,870	250	MU53~MU79	—	—	3,870	50	10.4	—	—	—	—	—	—	—	—	—	—
U2	50-Year	3,870	250	MU36~MU52	—	—	3,870	—	15.9	○		○		—	—	—	—	—	—
U2	50-Year	3,870	200	MU1~MU35	—	—	3,870	—	14.3	○		○		—	—	—	—	—	—
U2	Tessa	—	—	TS1-TS72	—	—	—	—	—	—	—	2.0	16.4	—	—	—	—	—	—
U2	Bou Heurtma	300	—	—	—	—	—	—	—		8.6		8.6	—	—	—	—	—	—

Costruction Cost

Unit:TND mil.

Zone	Return period	Flood Retarding Basin	River Channel Excavation	Embankment	Bypass Channel: Excavation	Bypass Channel: Embankment	Revetment	Total	Economic Cost (0.82*0.88)
U1	5-Year	—	—	—	—	—	—	0.00	
U1	5-Year	—	—	—	—	—	—	0.00	
U1	5-Year	—	—	—	—	—	—	0.00	
								0	**0.00**
U1	10-Year	—	5.78	—	—	—	—	5.78	
U1	10-Year	—	8.66	—	—	—	—	8.66	
U1	10-Year	—	15.00	—	—	—	—	15.00	
								29.44	**21.24**
U1	20-Year	—	8.52	—	—	—	—	8.52	
U1	20-Year	—	12.77	—	—	—	—	12.77	
U1	Jendouba B	—	—	—	22.30	—	—	22.30	
U1	20-Year	—	23.40	—	—	—	—	23.40	
								66.99	**48.34**
U1	50-Year	—	11.11	—	—	—	—	11.11	
U1	50-Year	—	16.66	—	—	—	—	16.66	
U1	Jendouba B	—	—	—	36.00	—	—	36.00	
U1	50-Year	—	35.70	—	—	—	—	35.7	
								99.47	**71.78**
M	5-Year	—	0.42	0	—	—	—	**0.42**	**0.30**
M	10-Year	—	2.82	1.21	—	—	—	**4.03**	**2.91**
M	20-Year	—	3.64	6.24	—	—	—	**9.88**	**7.13**
M	50-Year	—	5.46	11.64	—	—	—	**17.1**	**12.34**
U2	5-Year	—	13.27	—	—	—		13.27	
U2	Bou Salem B	—	10.20	—	—	—	3.00	10.20	
U2	5-Year	—	7.13	—	—	—	—	7.13	
U2	5-Year	—	0.00	0.91	—	—	—	0.91	
U2	Bou Heurtma	—	—	0.05	—	—	—	0.05	
								34.56	**24.94**
U2	10-Year	—	19.00	0.00	—	—	—	19.00	
U2	Bou Salem B	—	21.71	0.70	—	—	3.40	25.81	
U2	10-Year	—	12.10	0.00	—	—	—	12.10	
U2	10-Year	—	0.00	0.96	—	—	—	0.96	
U2	10-Year	—	0.00	2.93	—	—	—	2.93	
U2	Bou Heurtma	—	—	0.10	—	—	—	0.10	
								60.90	**43.95**
U2	20-Year	—	26.00	1.94	—	—	—	27.94	
U2	Bou Salem B	—	21.71	1.86	28.00	—	3.80	55.37	
U2	20-Year	—	12.10	0.00	—	—	—	12.10	
U2	20-Year	—	0.00	1.75	—	—	—	1.75	
U2	20-Year	—	0.00	4.43	—	—	—	4.43	
U2	Bou Heurtma	—	—	1.54	—	—	—	1.54	
								103.13	**74.42**
U2	50-Year	—	34.36	3.37	—	—	—	37.73	
U2	Bou Salem B	—	21.71	3.27	40.02	3.00	4.20	72.20	
U2	50-Year	—	12.10	—	—	—	—	12.10	
U2	50-Year	—	0.00	3.97	—	—	—	3.97	
U2	50-Year	—	0.00	9.60	—	—	—	9.60	
U2	Tessa	—	—	2.92	—	—	—	2.92	
U2	Bou Heurtma	—	—	6.36	—	—	—	6.36	
								144.88	**104.55**

Table 8.3.1 Summary of Construction Cost for River Improvement Works (2/2)

Scale of River Improvement

Zone	Return period	Peak Discharge (m3/s)	Existing Flow Capacity (m3/s)	River Cross Section No.	Flood Retarding Basin		River Channel Excavation			Embankment				Bypass Channel			Embankment (along Bypass)		Revetment
										Left		Right							
					Peak Q (m3/s)	Volume (mil. m3)	Discharge (m3/s)	Bottom width (m)	Length (km)	Height (m)	Length (km)	Height (m)	Length (km)	Discharge (m3/s)	Bottom width (m)	Depth (m)	Height (m)	Length (km)	
	5-Year	420	350	MD1-MD-64	–	–	420	10	20.8	–	–	–	–	–	–	–	–	–	–
	5-Year	420	350	MD65-MD116	–	–	420	10	17.1	–	–	–	–	–	–	–	–	–	–
	Mejez El Bab B	360	350	MD117-MD132	–	–	360	20	4.2	–	–	–	–	–	–	–	–	–	–
	5-Year	360	180	MD133-MD194	–	–	360	20	19.3	–	–	–	–	–	–	–	–	–	–
	5-Year	360	300	MD195-MD252	–	–	360	20	21.2	–	–	–	–	–	–	–	–	–	–
	10-Year	610	350	MD1-MD-64	–	–	610	20	20.8	○	○	○	○	–	–	–	–	–	–
	10-Year	610	350	MD65-MD116	–	–	610	20	17.1	○	○	○	○	–	–	–	–	–	–
	Mejez El Bab B	540	350	MD117-MD132	–	–	360	20	4.2	○	○	○	○	190	15		–	–	–
	10-Year	540	180	MD133-MD194	–	–	540	25	19.3	○	○	○	○	–	–	–	–	–	–
	10-Year	540	300	MD195-MD252	–	–	540	25	21.2	○	○	○	○	–	–	–	–	–	–
D1	20-Year	890	350	MD1-MD-64	–	–	890	25	20.8	–	–	–	–	–	–	–	–	–	–
	20-Year	890	350	MD65-MD116	–	–	890	25	17.1	–	–	–	–	–	–	–	–	–	–
	Mejez El Bab B	820	350	MD117-MD132	–	–	360	20	4.2	–	–	–	–	460	50		–	–	–
	20-Year	820	180	MD133-MD194	–	–	820	30	19.3	–	–	–	–	–	–	–	–	–	–
	20-Year	820	300	MD195-MD252	–	–	820	30	21.2	–	–	–	–	–	–	–	–	–	–
	50-Year	2,330	350	MD1-MD-64	–	–	2,330	30	20.8	–	–	–	–	–	–	–	–	–	–
	50-Year	2,330	350	MD65-MD116	–	–	2,330	30	17.1	–	–	–	–	–	–	–	–	–	–
	Mejez El Bab B	2,250	350	MD117-MD132	–	–	540	20	4.2	○	○	○	○	1,710	70		–	–	–
	50-Year	2,250	180	MD133-MD194	–	–	2,250	40	19.3	–	–	–	–	–	–	–	–	–	–
	50-Year	2,250	300	MD195-MD252	–	–	2,250	40	21.2	–	–	–	–	–	–	–	–	–	–
	5-Year	340	800	MD253-MD281	–	–	340	Non-imp't	9.6	–	–	–	–	–	–	–	–	–	–
	El Battane B	340	700	MD282-MD290	–	–	340	Non-imp't	2.2	–	–	–	–	–	–	–	–	–	–
	5-Year	340	350	MD291-MD328	–	–	340	Non-imp't	10.5	–	–	–	–	–	–	–	–	–	–
	5-Year	300	250	MD329-MD356	–	–	300	20	9.5	–	–	–	–	–	–	–	–	–	–
	El Mabtouh RB	300	250	MD357-MD410	–	–	300	20	18.9	–	–	–	–	–	–	–	–	–	–
	5-Year	290	200	MD411-MD433	–	–	200	–	7.1	–	–	–	–	–	–	–	–	–	–
	5-Year	440	200	MD434-MD477	–	–	200	–	5.2	–	–	–	–	–	–	–	–	–	–
	10-Year	490	800	MD253-MD281	–	–	490	Non-imp't	9.6	–	–	–	–	–	–	–	–	–	–
	El Battane	490	700	MD282-MD290	–	–	490	Non-imp't	2.2	–	–	–	–	–	–	–	–	–	–
	10-Year	490	350	MD291-MD328	–	–	490	20	10.5	–	–	–	–	–	–	–	–	–	–
	10-Year	470	250	MD329-MD356	–	–	470	25	9.5	○	○	○	○	–	–	–	–	–	–
	El Mabtouh RB	470	250	MD357-MD410	170	86	300	25	18.9	○	○	○	○	–	–	–	–	–	–
	10-Year	460	200	MD411-MD433	–	–	200	–	7.1	–	–	–	–	–	–	–	–	–	–
	10-Year	650	200	MD434-MD477	–	–	200	–	5.2	–	–	–	–	–	–	–	–	–	–
D2	20-Year	820	800	MD253-MD281	–	–	820	Non-imp't	9.6	–	–	–	–	–	–	–	–	–	–
	El Battane	820	700	MD282-MD290	–	–	490	20	2.2	–	–	–	–	330	20	–	–	–	–
	20-Year	820	350	MD291-MD328	–	–	820	25	10.5	○	○	○	○	–	–	–	–	–	–
	20-Year	800	250	MD329-MD356	–	–	800	30	9.5	○	○	○	○	–	–	–	–	–	–
	El Mabtouh RB	800	250	MD357-MD410	250	86	550	30	18.9	○	○	○	○	–	–	–	–	–	–
	20-Year	780	200	MD411-MD433	–	–	200	–	7.1	–	–	–	–	–	–	–	–	–	–
	20-Year	930	200	MD434-MD477	–	–	200	–	5.2	–	–	–	–	–	–	–	–	–	–
	50-Year	2,190	800	MD253-MD281	–	–	2,190	20	9.6	–	–	–	–	–	–	–	–	–	–
	El Battane	2,190	700	MD282-MD290	–	–	1,470	30	2.2	○	○	○	○	720	50	–	–	–	–
	50-Year	2,190	350	MD291-MD328	–	–	2,190	35	10.5	○	○	○	○	–	–	–	–	–	–
	50-Year	2,160	250	MD329-MD356	–	–	2,160	35	9.5	○	○	○	○	–	–	–	–	–	–
	El Mabtouh RB	2,160	250	MD357-MD410	580	86	1,580	35	18.9	○	○	○	○	–	–	–	–	–	–
	50-Year	2,070	200	MD411-MD433	–	–	200	–	7.1	–	–	–	–	–	–	–	–	–	–
	50-Year	2,250	200	MD434-MD477	–	–	200	–	5.2	–	–	–	–	–	–	–	–	–	–

Source: The Study Team

Costruction Cost

Unit:TND mil.

Flood Retarding Basin	River Channel Excavation	Embankment	Bypass Channel		Revetment	Total	Economic Cost (0.82*0.88)
			Excavation	Embankment			
—	6.00	—	—	—	—	6.00	
—	4.00	—	—	—	—	4.00	
—	2.57	—	—	—	—	2.57	
—	12.70	—	—	—	—	12.70	
—	13.80	—	—	—	—	13.80	
						39.07	**28.19**
—	10.30	0.48	—	—	—	10.78	
—	7.20	0.18	—	—	—	7.38	
—	2.57	0.12	11.50	—	—	14.19	
—	14.00	1.12	—	—	—	15.12	
—	14.50	0.20	—	—	—	14.70	
						62.17	**44.86**
—	12.20	—	—	—	—	12.20	
—	12.00	—	—	—	—	12.00	
—	2.60	—	17.02	—	—	19.62	
—	19.10	—	—	—	—	19.10	
—	19.40	—	—	—	—	19.40	
						82.32	**59.40**
—	15.00	—	—	—	—	15.00	
—	14.70	—	—	—	—	14.70	
—	2.57	2.40	19.20	—	—	24.17	
—	26.00	—	—	—	—	26.00	
—	26.50	—	—	—	—	26.50	
						106.37	**76.76**
–	–	–	–	–	–	0.00	
–	–	–	–	–	0.50	0.50	
–	–	–	–	–	4.00	4.00	
–	12.60	–	–	–	–	12.60	
–	6.00	–	–	–	–	6.00	
–	–	–	–	–	–	0.00	
–	–	–	–	–	–	0.00	
						23.10	**16.67**
–	–	–	–	–	–	0.00	
–	–	–	–	–	0.50	0.50	
–	6.30	–	–	–	4.70	11.00	
–	13.80	1.10	–	–	–	14.90	
12.90	7.00	1.42	–	–	–	21.32	
–	–	–	–	–	–	0.00	
–	–	–	–	–	–	0.00	
						47.72	**34.43**
–	–	–	–	–	–	0.00	
–	1.70	–	8.40	–	0.60	10.70	
–	7.20	–	–	–	5.30	12.50	
–	15.40	0.51	–	–	–	15.91	
16.30	8.30	5.51	–	–	–	30.11	
–	–	–	–	–	–	0.00	
–	–	–	–	–	–	0.00	
						69.22	**49.95**
–	2.00	–	–	–	–	2.00	
–	2.40	0.24	11.40	–	1.00	15.04	
–	8.80	2.80	–	–	6.10	17.70	
–	17.80	1.13	–	–	–	18.93	
35.90	9.80	9.47	–	–	–	55.17	
–	–	–	–	–	–	0.00	
–	–	–	–	–	–	0.00	
						108.84	**78.54**

Table 9.1.1 Salient Feature of Proposed Structures (River Improvement Works)(1/3)

No.	Work Item	Sub Item (Type)	Location/Stretches/Length	Dimentsion	Unit
	Zone U2				
I. Mejerda River					
(1)	River channel length				
	MD447 to MD252		0.00m to 64,974.36 m	64,974	m
(2)	Scope of construction boundary of levee embankment (Left bank and right bank)				
	MD434 to MD252		4667.73m to 64,974.36 m	60,307	m
	(Heightening of existing levee)		4667.73m to 24,943.85 m	-20,280	m
	(Actual construction length)	(Left bank)		29,365	m
		(Right bank)		26,478	m
			Total	55,843	m
(3)	Low water channel excavation		0.00 m to 31,306.69 m		
	MD447 to MD356, B=25 m		31,306.69 m to 40,801.18 m	31,307	m
	MD356 to MD329, B=35 m		40,801.18 m to 51912.36 m	9,494	m
	MD329 to MD290, B=20 m		51912.36 m to 53,110.71 m	11,111	m
	MD290 to MD285, No excavation		53,110.71m to 64,974.36 m		
	MD285 to MD252, B=25 m			11,864	m
			Total length of channel excavation	63,776	m
(4)	Sluice gate				
	2.00x2.00x2 barrels to 2.50x2.50x3 barrels			9	Nos.
	2.00x2.00x1 barrel to 1.50x1.50x1 barrel			21	Nos.
	1.00x1.00x1barrel			17	Nos.
(5)	Slope protection				
		Concrete frame	Jedeida city (Left bank)	1,000	m
			Jedeida city (Right bank)	1,000	m
			El Battane city (Left bank)	100	m
			El Battane city (Left bank)	100	m
		Stone pitching		10,000	m^3
		Fascine mattress		72,000	m^2
(6)	Reconstruction of existing bridge				
	MD 434		Road bridge, L=140 m	1	Site
	MD 406		Road bridge, L=160 m	1	Site
	MD 401		Road bridge, L=140 m	1	Site
(7)	Heightening of existing railway bridge				
	MD 338		L=90 m	1	Site
(8)	Heightening of existing road				
	Length of heightening		Bituminous pavement	4,600	m
II. El Mabtouh Retarding Basin					
(1)	Inlet channel				
		Construction of earth canal			
			Improvement of existing channel	9,130	m
			New construction	2,770	m
(2)	Outlet channel				
	Dredging of existing canal			7,780	m
(3)	Reservoir				
	Surrounding dike			10,100	m
	Design storage capacity			50,000,000	m^3/s
(4)	Outlet structure				1 set
	Sluice, roller gate	Design discharge		Q=50	m^3/s max
		Size	3.00x3.00x3nos		
(5)	Inlet structure				
	Overflow dike with stop log	Design discharge		Q=200	m^3/s
		Crest length of overflow dike		80	m
(6)	Bridge				
	Renewal of existing bridge				
	25m x 2 spans = 50m	One-lane-type		6	Sites
		Two-lane-type		1	Sites
(7)	Sluice gate				
	Flap gate			5	Sites
(8)	Drain inlet				
	Flap gate			23	Sites
III. Chaffrou River					
(1)	Levee length (Left bank and right bank)				
	CH0 to CH8		0.00 m to 2,000 m	2,000	m

Table 9.1.1 Salient Feature of Proposed Structures (River Improvement Works)(2/3)

No.	Work Item	Sub Item (Type)	Location/Stretches/Length	Dimentsion	Unit
Zone D1					
I. Mejerda River					
(1)	River channel length				
	MD252 to MD1		64,974.36 m to 148,537.42	83,563.06	m
(2)	Scope of construction boundary of levee embankment (Left bank and right bank)				
	MD251 to MD29		67,312.99 m to 139,335.82	72,022.83	m
	MD24 to MD0		14,1007.44 m to 148,537.42	7,529.98	m
			Total	79,552.81	m
		Actual construction length	(Left bank)	36,671	m
			(Right bank)	33,909	m
			Total	70,580	m
(3)	Low water channel excavation				
	MD251 to MD135, B=25 m		67,312.99 m to 105,317.25	38,004	
	MD251 to MD1, B=20 m		105,317.25 m to 148,537.42	43,220	m
			Total	81,224	
(4)	Sluice gate				
	2.00x2.00x2 barrels to 2.50x2.50x3 barrels			11	Nos.
	2.00x2.00x1 barrel to 1.50x1.50x1 barrel			27	Nos.
	1.00x1.00x1barrel			34	Nos.
(5)	Slope protection				
		Concrete frame		1,000	m
		Stone pitching		10,000	m^3
		Fascine mattress		81,000	m^2
(6)	Renewal of existing bridge				
	MD 134		Road bridge, L=140 m	1	LS
(7)	Stop log at Mejez El Bab old bridge			2	Sets
II. Majez El Bab Bypass Channel					
(1)	Bypass channel				
		Length		4512	m
		Channel bottom width		15	m
		Discharge	Mejerda River	Q = 450	m^3/s
			Bypass Channel	Q = 250	m^3/s
			side slope	01:02.0	
(2)	Inlet structure			1	Set
(3)	Outlet structure			1	Set
(4)	Ground sill			3	Sites
(5)	Bridge				
		30m x 2 spans = 60m	Two-lane-type	4	Sites
(6)	Drain inlet			1	Set
(7)	Slope protection				
		Stone pitching	1 location	1,200	m
III. Lahmer River					
(1)	Levee length (Left bank and right bank)				
		LA0 to LA8	0.00 m to 2,000 m	2,000	m
Zone U2					
I. Mejerda River					
(1)	River channel length				
		MU1 to MU164	0.00 m to 63889.42 m	63,889	m
(2)	Scope of construction boundary of levee embankment (Left bank and right bank)				
		MU1 to MU53	0.00 m to 21159.41 m	21,159	
		MU79 to MU172	30,077.29 m to 63,889.42 m	33,812	m
			Total	54,972	
		Actual construction length	(Left bank)	34,833	m
			(Right bank)	32,666	m
			Total	67,499	m
(3)	Low water channel excavation				
		MU53 to MU129, B=50 m	21,159.41 m to 50,385.72 m	29,226	
		MU129 to MU164, B=40 m	50,385.72 m to 63,889.42 m	13,504	
			Total	42,730	
(4)	Sluice gate				
		2.00x2.00x2 barrels to 2.50x2.50x3 barrels		6	Nos.
		2.00x2.00x1 barrel to 1.50x1.50x1 barrel		16	Nos.
		1.00x1.00x1barrel		20	Nos.

Table 9.1.1 Salient Feature of Proposed Structures (River Improvement Works)(3/3)

No.	Work Item	Sub Item (Type)	Location/Stretches/Length	Dimentsion	Unit
(5)	Slope protection				
			Concrete frame	1,000	m
			Stone pitching	10,000	m^3
			Fascine mattress	99,000	m^2
(6)	Renewal of existing aqueduct with foot bridge				
	MD 134	To be improved to Road bridge, L=110 m		1	
II. Bou Salem Bypass Channel					
(1)	Bypass channel				
		Length		7,736	m
		Channel bottom width		25	m
		Discharge	Mejerda River	Q = 1140	m^3/s
			Bypass Channel	Q = 700	m^3/s
			side slope	01:02.0	
(2)	Inlet structure			1	Set
(3)	Outlet structure			1	Set
(4)	Ground sill			8	Sites
(5)	Bridge				
		30m x 2 spans = 60m	Two-lane-type	5	Sites
(6)	Drain inlet			1	Set
(7)	Slope protection				
		Stone pitching	3 locations, total length	1,500	m
III. Bou Heurtma River					
(1)	Levee length (Left bank and right bank)				
		BH0 to BH32	0.00 m to 6,742.34 m	6,742.34	m
IV. Tessa River					
(1)	Levee length (Left bank and right bank)				
		TS0 to TS24	0.00 m to 4,348.24 m	4,348.24	m
V. Kasseb River					
(1)	Levee length (Left bank and right bank)				
		KS0 to KS11	0.00 m to 3,056.98m	3,056.98	m
Zone U1					
I. Mejerda River					
(1)	River length				
		MU164 to MU360	63889.42 m to 158306.49m	94,417.07	m
(2)	Scope of construction boundary of levee embankment (Left bank and right bank)				
		MU164 to MU172	63889.42 m to 67610.96m	3,721.54	m
		Actual construction length	(Left bank)	2,264	m
			(Right bank)	2,860	m
			Total	5,124.00	m
(3)	Low water channel excavation				
		MU164 to MU208, B=10 m	63889.42 m to 79550.78 m	15,661	m
		MU208 to MU248, B=15 m	79550.78 m to 99714.35 m	20,164	m
		MU208 to MU248, No excavation		0	m
		MU305 to MU329, B=10 m	128913.2 m to 141842.33 m	12,929	m
			Total	48,754	m
(4)	Sluice gate				
		1.00x1.00x1barrel		3	Nos.
(5)	Slope protection				
		Stone pitching		5,000	m^3
		Fascine mattress		45,000	m^2
Zone M					
I. Mellegue River					
(1)	River length for study				
		MG1 to MU114	63889.42 m to 158306.49m	158,306.00	m
(2)	Scope of construction boundary of levee embankment (Left bank and right bank)				
		MG1 to MG35	0.00 m to 8895.23m	8,895.23	m
		Actual construction length	(Left bank)		
			(Right bank)		
(3)	Low water channel excavation				
		MG1 to MG52	0.00 m to 12871.42 m	12,871	m
(4)	Sluice gate				
		1.00x1.00x1barrel		3	Nos.

Source: The Study Team

Table 9.1.2 Action Plan of Project on Strengthening Flood Control Function of Reservoirs in Mejerda River Basin

Project Title : Project on Strengthening Flood Control Function of Reservoirs in Mejerda River Basin
Country : Tunisia
Project Area : Mejerda River Basin
Project Type : Technical Cooperation Project
Field : Water Resources-Disaster Management-Flood Disaster
Term of Cooperation : 2.5 Years
Implementing Organization : Ministry of Agriculture and Water Resources

Work Schedule

Main Programs and Activities	First Yeay	Second Year	Third Year	Position in Charge
1. Improvement of simulation model for coordinated operation of dams				E2, E3, E4
2. Drafting improved operation rules of 7 selected reservoirs for flood control				E2
3. Trial applicaton (2 rainy seasons), review and improvement of the draft improved reservoir operation rules for flood control				E2, E4
4. Coordination of institution arrangements relateted to improved reservor operation rules for flood control				E6
5. Strengthening function of collection, storing, analysis and dissemination of data/information				E5, E2
6. Preparing monitoring plan to sustain project effect				All

Staffing Schedule (Expatoriates)

Position	First Yeay	Second Year	Third Year	M/M
E1: Team Leader				21
E2: Reservoir Operation				21
E3: Hydrorogy and Hydraulics				2
E4: Flood Forecasting				6
E5: System Management				5
E6: Institutional Arrangement				5
E7: Coordinator				21
			Total	**81**

Rainy season

Table 9.2.1 Action Plan of Project on Strengthening Function of Flood Forecasting and Warning System (FFWS) in Mejerda River Basin

Project Title : Project on Strengthening Function of Flood Forecasting and Warning System (FFWS) in Mejerda River Basin
Country : Tunisia
Project Area : Mejerda River Basin
Project Type : Technical Cooperation Project
Field : Water Resources-Disaster Management-Flood Disaster
Term of Cooperation : 3 Years
Implementing Organization : Ministry of Agriculture and Water Resources

Work Schedule

Main Programs and Activities	First Yeay	Second Year	Third Year	Position in Charge
1. Scrutiny on additional installation of telemetric rainfall and water-level gauges to existing telemetry system				E3
2. Installation of additional telemetric rainfall and water-level gauges				E3, E4, E6
3. Study on flood forecasting method and model				E2, E3
4. Development of flood forecasting model				E2, E4, E5
5. Installation of measuring device of dam release discharge				E4, E6
6. Improvement of FFWS based on trial application and review of the draft improved reservoir operation rules for flood control				E2, E5
7. Preparing system operation manual				E2, E4, E5
8. Preparing monitoring plan to sustain project effect				All

Staffing Schedule (Expatoriates)

Position	First Yeay	Second Year	Third Year	M/M
E1: Team Leader				16
E2: Flood Forecasting				14
E3: Hydrorogy and Hydraulics				6
E4: System Management				6
E5: Forcasting Model Development				8
E6: Civil works				4
E7: Coordinator				16
			Total	**70**

Rainy season

Table 9.2.2 Action Plan of Project on Strengthening Evacuation and Flood Fighting System in Mejerda River Basin

Project Title	: Project on Strengthening Evacuation and Flood Fighting System in Mejerda River Basin
Country	: Tunisia
Project Area	: Mejerda River Basin
Project Type	: Technical Cooperation Project
Field	: Water Resources-Disaster Management-Flood Disaster
Term of Cooperation	: 1 Years
Implementing Organization	: Ministry of Agriculture and Water Resources

Work Schedule

Main Programs and Activities	First Yeay	Second Year	Third Year	Position in Charge
1. Improvement of information sharing system among official agencies and communities regarding flood disaster management and evacuation plan				E2
2. Study and setting of alert levels at key water-level gauging stations for evacuation/flood fighting activities				E2, E3
3. Formulation of precise criteria to commence evacuation/flood fighting activities				E2
4. Development of understandable evacuation procedures and drilling at pilot areas				E2
5. Preparing monitoring plan to sustain project effect				All

Staffing Schedule (Expatoriates)

Position	First Yeay	Second Year	Third Year	M/M
E1: Team Leader				12
E2: Evacuation/Flood Fighting				12
E3: Hydrologist				4
E4: Coordinator				12
			Total	**40**

Rainy season

Table 9.2.3 Action Plan of Project on Organizational Capacity Development for Mejerda River Basin

Project Title	: Project on Organizational Capacity Development for Mejerda River Basin
Country	: Tunisia
Project Area	: Mejerda River Basin
Project Type	: Technical Cooperation Project
Field	: Water Resources-Disaster Management-Flood Disaster
Term of Cooperation	: 3 Years
Implementing Organization	: Ministry of Agriculture and Water Resources

Work Schedule

Main Programs and Activities	First Stage		(Second Stage)	Third Stage	Position in Charge
	First Yeay	Second Year		Last Year	
First Stage					
1. Scrutiny and establishment of permanent division or direction in charge of Mejerda River basin inside DGBGTH					E1, E4
2. Detailed study on 11 proposed programs for organizational capacity development					E1, E2, E3, E4,E5, E6
3. Initiating the proposed programs					E1, E2, E3, E4,E5, E6
4. Selection of a pilot project to be conducted in the second stage					E1, E4
5. Provision of documented technical guidelines, standards and rules					E1, E2, E3, E4, E6
Second Stage					
Conducting a pilot project under proposed river improvement peoject of the Mejerda River					
Third Stage					
1. Scrutiny and establishment of an agency in charge of O/M of the Majerda River basin, if the pilot project justifies the					E1, E4
2. Preparing monitoring plan to sustain project effect					All

Staffing Schedule (Expatoriates)

Position	First Yeay	Second Year		Last Year	M/M
E1: Team Leader/River Management					30
E2: River Facilities					16
E3: Dam Operation/Maintenance					10
E4: Organization and Institution					18
E5: Economics					2
E6: Environmental and Social Consideration					4
E7: Coordinator					18
				Total	**98**

Rainy season

Table 9.2.4 Action Plan on Strengthening of Flood Plain Regulation/Management (Flood Zoning)

Project Title : Project on Strengthening of Flood Plain Regulation/Management (Flood Zoning)
Country : Tunisia
Project Area : Mejerda River Basin
Project Type : Technical Cooperation Project
Field : Flood Plain Management
Term of Cooperation : 3 Years
Implementing Organization : DGBGTH, Ministry of Agriculture and Water Resources

Position	First Year	Second Year	Third Year	M/M
E1: Team Leader				20
E2: Hydrologist				4
E3: GIS Expert				8
E4: Land Use Planner				10
E5: Agroeconomis				6
E6: Institutional Specialist				6
E7: IT Expert/System Engineer				4
E8: Coordinator				16
			Total	**74**

Main Programs and Activities	First Year	Second Year	Third Year	Position in charge
	Step 1	Step 2	Step 3	
1. Delineation of flood prone area through runoff and inundation analyses of the Mejerda River basin				E1, E2, E3
2. Updating of GIS data base with current cropping information				E1, E3, E4
3. Preparation of flood risk map with zoning by risk level				E1, E2, E4
4. Analysis on improved cropping pattern based on current prevailing land use				E1, E4, E5
5. Preparation of guideline for flood risk mapping				E1, E2, E3
6. Preparation of guideline for enhanced land use control for urabn and rural areas				E1, E3, E4, E5
7. Dissemination, application, evaluation and validation of the guidelines in target CRDAs and local governments				E1, E6, E7
8. Training and seminar				All

Table 11.1.1 List of River Improvement Works Planned for Flood Control (1/3)

Location	No.	Zone/area name	River name	Structural measures	Location[*1]	Target/extent/effect of flood protection	Tentative scale of structural measures (Principal dimensions)		Probable impacts on the environment	Remarks
Upper Area	A	Jendouba and Upstream	Mejerda (Upper reaches)	River improvement (excavation, revetment works, etc.)	63.9 Km - 158.3 Km	Mitigation of flood inundation damage in Jendouba City proper and its upstream	Length of river improvement	48.8 km	Impacts on river environment due to change of river flow regime, land acquisition, securing appropriate spoil disposal areas	
							River channel width after improvement works (between tops of riverbank slopes on the right and left sides)	70 m		
							Planned dike height	2.0 m		
							Planned dike length (total of right and left river banks)	5.1 km		
	B	Mellegue Lower Reaches	Mellegue (Lower reaches)	Dike construction + river improvement (excavation, revetment works, etc.)	0 Km - 12.9 Km	Protection from flood inundation in the areas along the Mellegue lower reaches (cultivated land spreading in the left low land areas of the river reaches)	Length of river improvement	12.9 m	Impacts on river environment due to change of river flow regime, land acquisition, securing appropriate spoil disposal areas	
							River channel width after improvement works (between tops of riverbank slopes on the right and left sides)	75 m		
							Planned dike height	2.0 m		
							Planned dike length (total of right and left river banks)	7.4 km		
	C	Mellegue Confluence to Bou Salem	Mejerda (Upper reaches)	Bypass channel at Bou Salem, incl. bridge construction	30.5 Km - 47.8Km	Mitigation of flood inundation damage in Bou Salem City and its upstream	Total length of bypass channel	7.7 km	Change of river flow regime, securing appropriate spoil disposal areas	It is expected that the land acquisition will not be required because the land along the planned alignment of bypass channel belongs to the government
							Channel width (between tops of side slopes on the right and left sides)	60 m		
							Design discharge (provisional)	700 m^3/s		
							Excavation volume	3.2 $mil.m^3$		
				Dike construction + river improvement (excavation, revetment works, etc.)	30.1 Km - 63.9 Km		Length of river improvement	33.8 km	Impacts on river environment due to change of river flow regime, land acquisition, securing appropriate spoil disposal areas	The stakeholder meeting was held in Bou Salem in September 2007.
							River channel width after improvement works (between tops of riverbank slopes on the right and left sides)	120 m		
							Planned dike height	3.0 m		
							Planned dike length (total of right and left river banks)	31.5 km		
	D	Upstream of Sidi Salem Dam (Up to Bou Salem)	Mejerda (Upper reaches)	River improvement (excavation, revetment works, etc.)	0 Km- 30.1 Km	Protection from flood inundation in the areas along the river reaches suffering from progress of sedimentation adjacently upstream of Sidi Salem Dam (cultivated land along the river reaches)	Length of river improvement	30.1 km	Impacts on river environment due to change of river flow regime, land acquisition, securing appropriate spoil disposal areas	
							River channel width after improvement works (between tops of riverbank slopes on the right and left sides)	200 m		
							Planned dike height	4.0 m		
							Planned dike length (total of right and left river banks)	49.5 km		

Table 11.1.1 List of River Improvement Works Planned for Flood Control (2/3)

Location	No.	Zone/area name	River name	Structural measures	Location[*1]	Target/extent/effect of flood protection	Tentative scale of structural measures (Principal dimensions)		Probable impacts on the environment	Remarks
Middle Area	E	Downstream of Sidi Salem Dam to Larrousia Dam	Mejerda (Lower reaches)	Bypass channel at mejez El Bab, incl. bridge construction	105.3 Km - 110.6 Km	Mitigation of flood inundation damage in the zone including Mejez El Bab City proper, conservation of historical property (old bridge dating from the 17th century) of which the destruction or relocation seems difficult)	Total length of bypass channel	4.5 km	Change of river flow regime, land acquisition, securing appropriate spoil disposal areas	The channel passes through mainly agricultural lands, avoiding dwellings and the risks of resettlement
							Channel width (between tops of side slopes on the right and left sides)	60 m		
							Design discharge (provisional)	200 m^3/s		
							Excavation volume	2.65 $mil.m^3$		
				Dike construction + river improvement (excavation, revetment works, etc.)	67.3 Km - 148.5 Km		Length of river improvement	81.2 km	Impacts on river environment due to change of river flow regime, land acquisition, securing appropriate spoil disposal areas	
							River channel width after improvement works (between tops of riverbank slopes on the right and left sides)	90 m		
							Planned dike height	1.0 m		
							Planned dike length (total of right and left river banks)	70.6 km		
Lower Area	F	El Battane	Mejerda (Lower reaches)	River improvement (excavation, revetment works, etc.)	48.5 Km - 67.3 Km	Mitigation of flood inundation damage in and around El Battane City proper, conservation of historical property (El Battane weir dating from the 17th century) of which the destruction or relocation seems difficult) and its downstream	Length of river improvement	18.8 km	Impacts on river environment due to change of river flow regime, land acquisition, securing appropriate spoil disposal areas	
							River channel width after improvement works (between tops of riverbank slopes on the right and left sides)	95 m		
							Planned dike height	2.0 m		
							Planned dike length (total of right and left river banks)	0.5 km		
	G	Jedeida (up to confluence of Chafrou River)	Mejerda (Lower reaches)	Dike construction + river improvement (excavation, revetment works, etc.)	31.3 Km - 48.6Km	Mitigation of flood inundation damage in and around Jedeida City proper	Length of river improvement	17.3 km	Impacts on river environment due to change of river flow regime, land acquisition, securing appropriate spoil disposal areas	
							River channel width after improvement works (between tops of riverbank slopes on the right and left sides)	110 m		
							Planned dike height	1.0 m		
							Planned dike length (total of right and left river banks)	15.5 km		
	H	El Mabtouh - Estuary of Mejerda River	Mejerda (Lower reaches)	Dike construction + river improvement (excavation, revetment works, etc.)	0 Km - 31.3 Km	Mitigation of flood inundation damage in agricultural land spreading along the Mejerda lowest reaches and conservation of the agricultural land	Length of river improvement	31.3 km	Impacts on river environment due to change of river flow regime, land acquisition, securing appropriate spoil disposal areas	The stakeholder meeting was held in Sidi Thabet in September 2007.
							River channel width after improvement works (between tops of riverbank slopes on the right and left sides)	170 m		
							Planned dike height	2.0 m		
							Planned dike length (total of right and left river banks)	40.3 km		

Table 11.1.1 List of River Improvement Works Planned for Flood Control (3/3)

Location	No.	Zone/area name	River name	Structural measures	Location*1	Target/extent/effect of flood protection	Tentative scale of structural measures (Principal dimensions)		Probable impacts on the environment	Remarks
Lower Area	H	El Mabtouh - Estuary of Mejerda River	Mejerda (Lower reaches)	Retarding basin	11.8 Km - 31.1 Km	Mitigation of flood inundation damage in agricultural land spreading along the Mejerda lowest reaches and conservation of the agricultural land	Total surface area of retarding basin	2230 ha	Impacts on surrounding agricultural land due to flood inundation (during floods)	The candidate area for retarding basin is pasture land (unused land) and unsuitable for agriculture, which is used currently as a natural retarding basin in a rainy season
							Planned inundation depth in retarding basin	3.0 m		
				Modification of existing drainage canal to convey some flood water to the retarding basin	11.8 Km - 31.1 Km		Length of new drainage canal	2.77 km	Securing appropriate spoil disposal areas	
							Length of existing drainage canal to be modified	27.01 km		
				Modification of existing facilities (gates structures, raising bridge)	11.8 Km - 31.1 Km		Sluice at outlet of drainage canal to be modified	23 sites	Land acquisition for raising bridge	Demolition of existing facilities and construction of new ones
							Raising bridge (incl. raising approach road)	6 bridges		

Note: *1 A, C, D: distance from upper end of Sidi Salem Reservoir, E to H: distance from estuary of Mejerda River, B: distance from confluence of Mellegue River with Mejerda River

Table 11.3.1 Impact Matrix for Project Structural Measures Envisaged in the Master Plan (1/3: Pre-construction)

Environment Elements / Project Structural Measures		Physical Environment								Natural Environment			Socio-economic Environment					
		Topography and Geology	Soil Erosion	Waste (Dredged/excavated material)	Groundwater (well water use)	Water quality Mejerda River	Water quality Retarding Basin	Air quality (emission gas, dust)	Noise and vibration	Terrestrial flora and fauna	Aquatic flora and fauna	Protected species and areas	Land acquisition	People 's unrest and conflict / opposition	Change of income/livelihood	Impact on agriculture, forestry and fishery	Impacts on downstream area	Traffic and transportation
1) Measures for the upper area (Jendouba, Le Kef Governorates, west part of Beja Governorate)	Measure A: Jendouba & U/s Improvement Works												-1	-1				
	Measure B: Mellegue Improvement Works												-	-				
	Measure C1: Bou Salem Bypass Channel												-1	-1				
	Measure C2: Bou Salem & U/s Improvement Works												-	-				
	Measure D: Improvement Works D/s of Bou Salem up to Sidi Salem Reservoir												-	-				
2) Measures for the middle area (east part of Beja Governorate)	Measure E1:Mez El Bab Bypass Channel												-2	-2				
	Measure E2: Improvement Works D/s of Sidi Salem Dam up to Larrousia Dam												-1	-1				
3) Measures for the lower area (Ariana, Manouba,and Bizerte Governorates)	Measure F: El Battane Improvement Works												-1	-1				
	Measure G: Jedeida Improvement Works												-1	-1				
	Measure H1: Mabtouh Improvement Works												-1	-1				
	Measure H2:Mabtouh Retarding Basin												-1	-				
4) No Action	No measures applied																	

Note) " -": Negligible negative impact, " -1" : Minor negative impact, " -2": Medium negative impact, " -3": Significant negative impact
" +" Negligible positive impact, " +1" : Minor positive impact, " +2" : Medium positive impact, " +3" : Significant positive impact

Table 11.3.1 Impact Matrix for Project Structural Measures Envisaged in the Master Plan (2/3: Construction)

Project Structural Measures	(Environment Elements)	Physical Environment								Natural Environment			Socio-economic Environment					
		Topography and Geology	Soil Erosion	Waste (Dredged/excavated material)	Groundwater (well water use)	Water quality Mejerda River	Water quality Retarding Basin	Air quality (emission gas, dust)	Noise and vibration	Terrestrial flora and fauna	Aquatic flora and fauna	Protected species and areas	Land acquisition	People 's unrest and conflict / opposition	Change of income/livelihood	Impact on agriculture, forestry and fishery	Impacts on downstream area	Traffic and transportation
1) Measures for the upper area (Jendouba, Le Kef Governorates, west part of Beja Governorate)	Measure A: Jendouba & U/s Improvement Works	-	+1	-1	-	-1		-1	-2	-				-1	+1	-1	-	-1
	Measure B: Mellegue Improvement Works	-	+1	-	-	-1		-1	-1	-				-	+	-	-	-
	Measure C1: Bou Salem Bypass Channel	-1		-2	-	-2		-1	-2		-2			-1	+3	-1	-	-1
	Measure C2: Bou Salem & U/s Improvement Works	-	+1	-2	-	-1		-1	-2	-1				-	+2	-1	-	-1
	Measure D: Improvement Works D/s of Bou Salem up to Sidi Salem Reservoir	-	+1	-2	-	-1		-1	-2	-1				-	+2	-1	-	-1
2) Measures for the middle area (east part of Beja Governorate)	Measure E1:Mez El Bab Bypass Channel	-1		-2	-	-2		-1	-2		-2			-2	+2	-1	-	-1
	Measure E2: Improvement Works D/s of Sidi Salem Dam up to Larrousia Dam	-	+1	-1	-	-1		-1	-2	-				-1	+1	-1	-	-1
3) Measures for the lower area (Ariana, Manouba,and Bizerte Governorates)	Measure F: El Battane Improvement Works	-	+1	-1	-	-1		-1	-2	-				-1	+1	-1	-	-1
	Measure G: Jedeida Improvement Works	-	+1	-1	-	-1		-1	-2	-				-1	+1	-1	-	-1
	Measure H1: Mabtouh Improvement Works	-	+1	-1	-	-1		-1	-1	-				-1	+1	-1	-	-1
	Measure H2:Mabtouh Retarding Basin			-1		-1	-1	-1	-1					-	+1	-1	-	-1
4) No Action	No measures applied		-3			-3				-3	-3				-3	-3	-3	

Note) " -": Negligible negative impact, " -1" : Minor negative impact, " -2": Medium negative impact, " -3": Significant negative impact
" +" Negligible positive impact, " +1" : Minor positive impact, " +2" : Medium positive impact, " +3" : Significant positive impact

Table 11.3.1 Impact Matrix for Project Structural Measures Envisaged in the Master Plan (3/3: Operation)

Project Structural Measures	Environment Elements	Physical Environment								Natural Environment			Socio-economic Environment					
		Topography and Geology	Soil Erosion	Waste (Dredged/excavated material)	Groundwater (well water use)	Water quality Mejerda River	Water quality Retarding Basin	Air quality (emission gas, dust)	Noise and vibration	Terrestrial flora and fauna	Aquatic flora and fauna	Protected species and areas	Land acquisition	People 's unrest and conflict / opposition	Change of income/livelihood	Impact on agriculture, forestry and fishery	Impacts on downstream area	Traffic and transportation
1) Measures for the upper area (Jendouba, Le Kef Governorates, west part of Beja Governorate)	Measure A: Jendouba & U/s Improvement Works		+1												+1			
	Measure B: Mellegue Improvement Works		+1												+			
	Measure C1: Bou Salem Bypass Channel	-1			-						-2				+3	-1	-	-1
	Measure C2: Bou Salem & U/s Improvement Works		+1												+2			
	Measure D: Improvement Works D/s of Bou Salem up to Sidi Salem Reservoir		+1												+2			
2) Measures for the middle area (east part of Beja Governorate)	Measure E1:Mez El Bab Bypass Channel	-1			-						-2				+2	-1	-	-1
	Measure E2: Improvement Works D/s of Sidi Salem Dam up to Larrousia Dam		+1												+1			
3) Measures for the lower area (Ariana, Manouba,and Bizerte Governorates)	Measure F: El Battane Improvement Works		+1												+1			
	Measure G: Jedeida Improvement Works		+1												+1			
	Measure H1: Mabtouh Improvement Works		+1												+1			
	Measure H2:Mabtouh Retarding Basin						-1								+1			
4) No Action	No measures applied		-3							-3	-3					-3	-3	

Note) " -": Negligible negative impact, " -1" : Minor negative impact, " -2": Medium negative impact, " -3": Significant negative impact
" +" Negligible positive impact, " +1" : Minor positive impact, " +2" : Medium positive impact, " +3" : Significant positive impact

Table 11.4.1 Evaluation of Structural Measures in the Master Plan

1) Measures for the upper area

Structural measures	Negative Impact			Positive Impact	Evaluation
	Pre-construction	Construction	Operation	All stages	
Jendouba & U/s Improvement Works	-1	-2		+1	○
Mellegue Improvement Works	-	-1		+	◎
Bou Salem Bypass Channel	-1	-2	-2	+3	○
Bou Salem & U/s Improvement Works	-	-2		+2	○
Improvement Works D/s of Bou Salem up to Sidi Salem Reservoir	-	-2		+2	○

2) Measures for the middle area

Structural measures	Negative Impact			Positive Impact	Evaluation
	Pre-construction	Construction	Operation	All stages	
Mez El Bab Bypass Channel	- 2	-2	-2	+2	○
Improvement Works D/s of Sidi Salem Dam up to Larrousia Dam	-1	-2		+1	○

3) Measures for the lower area

Structural measures	Negative Impact			Positive Impact	Evaluation
	Pre-construction	Construction	Operation	All stages	
El Battane Improvement Works	-1	-2		+1	○
Jedeida Improvement Works	-1	-2		+1	○
Mabtouh Improvement Works	-1	-1		+1	○
Mabtouh Retarding Basin	-1	-1	-1	+1	○

Note) " -": Negligible negative impact, " -1" : Minor negative impact, " -2": Medium negative impact, " -3": Significant negative impact, " +" Negligible positive impact, " +1" : Minor positive impact, " +2" : Medium positive impact, " +3" : Significant positive impact
○: Recommendable, ◎: Recommended

Table 11.4.2 Framework of Environmental Management for Mitigation and Monitoring (1/2)

Project structural measures	Impacts with medium magnitude	Conceivable mitigation measures	Necessary monitoring item
Jendouba and Upstream Improvement Work	Noises and vibrations during construction period	Prohibit transportation of material near localities and sensitive facilities such as school, clinic etc, gear down vehicles, and ban all horn use	Noise and vibration levels along the transportation road and in settlement area.
Bou Salem Bypass Channel	Land acquisition and social problem at pre-construction	Dissemination of necessity of the project. According to relevant regulation and policies, provide adequate compensation fees	Complaint from local people
	People's unrest and conflict/opposition	Dissemination of necessity of bypass channel, including possible impacts and benefits. Compensation for inconvenience of daily life	Comments and complaints from local residents
	Noises and vibrations during construction period	Prohibit transportation of material near localities and sensitive facilities such as school, clinic etc, gear down vehicles, and ban all horn use	Noise and vibration levels along the transportation road and in settlement area.
	Earthwork fill, spoil and oil wastewater will affect the Mejerda water quality during construction	Strengthen environmental management, and reduce disturbance to the water bodies Maintain and clean machinery and vehicles in a fixed area away from the riverbanks. Build simple, seep resistant lavatory and septic tank, and sanitize and clean up refuge. Build an earth bank along the river to prevent wastewater discharge into the river	Water quality in Mejerda River, Impacts on aquatic organisms
	Generation of waste (Dredged/excavated)	Land acquisition with proper method and compensation for procurement of spoil bank area. Proper management for dumped material not to discharge to surrounding area	Condition of spoil bank, Complaint from local residents
Bou Salem and Upstream Improvement Works	Noises and vibrations during construction period	Same as the case of Jendouba Improvement Works	Noise and vibration levels along the transportation road and in settlement area.
	Generation of waste (Dredged/excavated)	Same as the case of Jendouba Improvement Works	Condition of spoil bank, Complaint from local residents

Table 11.4.2 Framework of Environmental Management for Mitigation and Monitoring (2/2)

Project structural measures	Impacts with medium magnitude	Conceivable mitigation measures	Necessary monitoring item
Improvement Works Downstream of Bou Salem up to Sidi Salem Reservoir	Noises and vibrations during construction period	Same as the case of Bou Salem Improvement Works	Noise and vibration levels along the transportation road and in settlement area.
	Generation of waste (Dredged/excavated)	Same as the case of Bou Salem Improvement Works	Condition of spoil bank, Complaint from local residents
Mez El Bab Bypass Channel	Land acquisition and social problem at pre-construction	Same as the case of Bou Salem bypass channel	Complaint from local people
	People's unrest and conflict/opposition	Same as the case of Bou Salem bypass channel	Comments and complaints from local residents
	Noises and vibrations during construction period	Same as the case of Bou Salem bypass channel	Noise and vibration levels along the transportation road and in settlement area.
	Earthwork fill, spoil and oil wastewater will affect the Mejerda water quality during construction	Same as the case of Bou Salem bypass channel	Water quality in Mejerda River, Impacts on aquatic organisms
	Generation of waste (Dredged/excavated)	Same as the case of BouSalem bypass channel	Condition of spoil bank, Complaint from local residents
Improvement Works Downstream of Sidi Salem Dam up to Larrousia Dam	Noises and vibrations during construction period	Same as the case of Bou Salem Improvement Works	Noise and vibration levels along the transportation road and in settlement area.
El Battane Improvement Works	Noises and vibrations during construction period	Same as the case of Mez El Bab Improvement Works	Noise and vibration levels along the transportation road and in settlement area.
Jedeida Improvement Works	Noises and vibrations during construction period	Same as the case of El Battane Improvement Works	Noise and vibration levels along the transportation road and in settlement area.

Source: the Study Team

Table 12.2.1 Project Cost for River Improvement (1/4): Zone D2 (Financial Cost)

D2

Unit:TND1,000

Description	FC	LC	Total Cost			2011		2012		2013		2014		2015		2016		2017	
	TND	TND	TND equiv.	US$ equiv.	Yen 10^3 equiv.	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC
(1) Construction cost (Base cost)	27,428,000	41,142,000	68,570,000	58,557,000	6,253,000	0	0	0	0	2,743	4,114	6,857	10,286	8,228	12,343	6,857	10,286	2,743	4,114
1.1 River Improvement	27,428,000	41,142,000	68,570,000	58,557,000	6,253,000	0	0	0	0	2,743	4,114	6,857	10,286	8,228	12,343	6,857	10,286	2,743	4,114
1.2 FFWS																			
(2) Land Acquisition	0	9,265,000	9,265,000	7,912,000	845,000	0	0	0	1,853	0	2,780	0	2,780	0	1,853	0	0	0	0
(3) Government Administration 3% of (1) + (2)	0	2,335,000	2,335,000	1,994,000	213,000	0	117	0	234	0	350	0	467	0	467	0	467	0	234
(4) Engineering Services 10% of (1)	2,743,000	4,114,000	6,857,000	5,856,000	625,000	411	617	686	1,029	274	411	411	617	411	617	411	617	137	206
(5) Subtotal (1)+(2)+(3)+(4)	30,171,000	56,856,000	87,027,000	74,319,000	7,936,000	411	734	686	3,115	3,017	7,655	7,268	14,149	8,640	15,280	7,268	11,370	2,880	4,553
(6) Physical Contingency 10% of (5)	3,017,000	5,686,000	8,703,000	7,432,000	794,000	41	73	69	312	302	766	727	1,415	864	1,528	727	1,137	288	455
(7) Sub-Total (5)+(6)	33,188,000	62,542,000	95,730,000	81,751,000	8,730,000	453	807	754	3,427	3,319	8,421	7,995	15,564	9,504	16,808	7,995	12,507	3,168	5,009
(8) Price Contingency	5,106,000	14,586,000	19,692,000	16,816,000	1,796,000	29	80	65	460	363	1,436	1,062	3,238	1,488	4,146	1,446	3,584	652	1,642
FC:2.1% and LC:3.2% of (7)						(.064)	(.099)	(.087)	(.134)	(.11)	(.171)	(.133)	(.208)	(.157)	(.247)	(.181)	(.287)	(.206)	(.328)
(9) Sub total (7)+(8)	38,294,000	77,128,000	115,422,000	98,567,000	10,526,000	482	887	820	3,887	3,682	9,857	9,057	18,802	10,992	20,954	9,441	16,091	3,820	6,650
(10) Taxes	0	18,152,000	18,152,000	15,501,000	1,655,000	0	138	0	243	0	1,723	0	4,299	0	5,283	0	4,579	0	1,887
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	16,937,000	16,937,000	14,464,000	1,545,000	0	0	0	0	0	1,589	0	4,100	0	5,078	0	4,367	0	1,803
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	1,215,000	1,215,000	1,038,000	111,000	0	138	0	243	0	133	0	199	0	205	0	212	0	84
R: Rate of price contingency																			
Grand Total	**38,294,000**	**95,280,000**	**133,574,000**	**114,068,000**	**12,181,000**	**482**	**1,026**	**820**	**4,130**	**3,682**	**11,580**	**9,057**	**23,101**	**10,992**	**26,237**	**9,441**	**20,669**	**3,820**	**8,537**

Note: (a) Exchange rates applied to conversion of the currencies are : US$ 1 = TND 1.171 = Yen 106.79 based on prevailing rate in June 2008
(b) Proportion of construction cost is : FC : LC = 40 : 60
(c) Base year for counting of price contingency is June 2008.

Table 12.2.1 Project Cost for River Improvement (2/4): Zone U2 (Financial Cost)

Unit:TND1,000

Description	FC	LC	Total Cost			2017		2018		2019		2020		2021		2022		2023		2024	
	TND	TND	TND equiv.	US$ equiv.	Yen 10^3 equiv.	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC
(1) Construction cost (Base cost)	35,607,000	43,520,000	79,127,000	67,572,000	7,216,000	0	0	0	0	3,561	4,352	7,121	8,704	8,902	10,880	8,902	10,880	7,121	8,704	0	0
1.1 River Improvement	35,607,000	43,520,000	79,127,000	67,572,000	7,216,000	0	0	0	0	3,561	4,352	7,121	8,704	8,902	10,880	8,902	10,880	7,121	8,704	0	0
1.2 FFWS																					
(2) Land Acquisition	0	12,724,000	12,724,000	10,866,000	1,160,000	0	0	0	2,545	0	3,817	0	3,817	0	2,545	0	0	0	0	0	0
(3) Government Administration 3% of (1) + (2)	0	2,756,000	2,756,000	2,354,000	251,000	0	276	0	276	0	276	0	413	0	551	0	551	0	413	0	0
(4) Engineering Services 10% of (1)	3,561,000	4,352,000	7,913,000	6,757,000	722,000	534	653	712	870	356	435	356	435	534	653	534	653	534	653	0	0
(5) Subtotal (1)+(2)+(3)+(4)	39,168,000	63,352,000	102,520,000	87,549,000	9,349,000	534	928	712	3,691	3,917	8,880	7,478	13,370	9,436	14,629	9,436	12,084	7,656	9,770	0	0
(6) Physical Contingency 10% of (5)	3,917,000	6,335,000	10,252,000	8,755,000	935,000	53	93	71	369	392	888	748	1,337	944	1,463	944	1,208	766	977	0	0
(7) Sub-Total (5)+(6)	43,085,000	69,687,000	112,772,000	96,304,000	10,284,000	588	1,021	783	4,060	4,308	9,768	8,225	14,707	10,379	16,092	10,379	13,292	8,421	10,747	0	0
(8) Price Contingency	13,543,000	34,639,000	48,182,000	41,146,000	4,394,000	121	335	181	1,503	1,107	4,045	2,330	6,755	3,220	8,143	3,505	7,367	3,080	6,491	0	0
FC:2.1% and LC:3.2% of (7)						(.206)	(.328)	(.231)	(.37)	(.257)	(.414)	(.283)	(.459)	(.31)	(.506)	(.338)	(.554)	(.366)	(.604)	(.394)	(.655)
(9) Sub total (7)+(8)	56,628,000	104,326,000	160,954,000	137,450,000	14,678,000	708	1,356	964	5,563	5,415	13,813	10,555	21,462	13,599	24,235	13,885	20,659	11,502	17,238	0	0
(10) Taxes	0	25,521,000	25,521,000	21,794,000	2,327,000	0	214	0	280	0	2,381	0	4,766	0	6,187	0	6,385	0	5,308	0	0
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	23,801,000	23,801,000	20,325,000	2,171,000	0	0	0	0	0	2,215	0	4,573	0	5,899	0	6,088	0	5,026	0	0
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	1,721,000	1,721,000	1,470,000	157,000	0	214	0	280	0	166	0	193	0	288	0	297	0	282	0	0
R: Rate of price contingency																					
Grand Total (9) + (10)	**56,628,000**	**129,847,000**	**186,475,000**	**159,244,000**	**17,005,000**	**708**	**1,570**	**964**	**5,843**	**5,415**	**16,194**	**10,555**	**26,228**	**13,599**	**30,421**	**13,885**	**27,044**	**11,502**	**22,546**	**0**	**0**
							2,278		6,807		21,609		36,783		44,021		40,929		34,048		0

Note: (a) Exchange rates applied to conversion of the currencies are : US$ 1 = TND 1.171 = Yen 106.79 based on prevailing rate in June 2008

(b) Proportion of construction cost is : FC : LC = 45 : 55

(c) Base year for counting of price contingency is June 2008.

Table 12.2.1 Project Cost for River Improvement (3/4): Zone D1 (Financial Cost)

D1

Unit:TND1,000

Description	FC	LC	Total Cost			2023		2024		2025		2026		2027		2028	
	TND	TND	TND equiv.	US$ equiv.	Yen 10^3 equiv.	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC
(1) Construction cost (Base cost)	29,682,000	36,278,000	65,960,000	56,328,000	6,015,000	0	0	0	0	4,452	5,442	8,905	10,883	8,905	10,883	7,421	9,070
1.1 River Improvement	29,682,000	36,278,000	65,960,000	56,328,000	6,015,000	0	0	0	0	4452	5442	8905	10883	8905	10883	7421	9070
1.2 FFWS																	
(2) Land Acquisition	0	6,657,000	6,657,000	5,685,000	607,000	0	0	0	1,331	0	1,997	0	1,997	0	1,331	0	0
(3) Government Administration 3% of (1) + (2)	0	2,179,000	2,179,000	1,861,000	199,000	0	218	0	327	0	436	0	436	0	436	0	327
(4) Engineering Services 10% of (1)	2,968,000	3,628,000	6,596,000	5,633,000	602,000	445	544	742	907	297	363	594	726	445	544	445	544
(5) Subtotal (1)+(2)+(3)+(4)	32,650,000	48,742,000	81,392,000	69,507,000	7,423,000	445	762	742	2,565	4,749	8,237	9,498	14,042	9,350	13,195	7,866	9,941
(6) Physical Contingency 10% of (5)	3,265,000	4,874,000	8,139,000	6,950,000	742,000	45	76	74	257	475	824	950	1,404	935	1,319	787	994
(7) Sub-Total (5)+(6)	35,915,000	53,616,000	89,531,000	76,457,000	8,165,000	490	838	816	2,822	5,224	9,061	10,448	15,446	10,285	14,514	8,652	10,935
(8) Price Contingency FC:2.1% and LC:3.2% of (7)	16,893,000	42,045,000	58,938,000	50,331,000	5,375,000	179 (.366)	506 (.604)	322 (.394)	1,849 (.655)	2,214 (.424)	6,418 (.708)	4,740 (.454)	11,784 (.763)	4,980 (.484)	11,892 (.819)	4,459 (.515)	9,596 (.878)
(9) Sub total (7)+(8)	52,808,000	95,661,000	148,469,000	126,788,000	13,540,000	669	1,345	1,138	4,671	7,438	15,479	15,188	27,230	15,265	26,406	13,111	20,530
(10) Taxes	0	25,188,000	25,188,000	21,510,000	2,297,000	0	213	0	360	0	3,552	0	7,248	0	7,413	0	6,402
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	23,512,000	23,512,000	20,079,000	2,144,000	0	0	0	0	0	3,347	0	6,907	0	7,128	0	6,130
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	1,676,000	1,676,000	1,431,000	153,000	0	213	0	360	0	206	0	340	0	285	0	272
R: Rate of price contingency																	
Grand Total (9) + (10)	**52,808,000**	**120,849,000**	**173,657,000**	**148,298,000**	**15,837,000**	**669**	**1,558**	**1,138**	**5,031**	**7,438**	**19,031**	**15,188**	**34,478**	**15,265**	**33,820**	**13,111**	**26,933**
							2,226		6,169		26,469		49,666		49,084		40,044

Note: (a) Exchange rates applied to conversion of the currencies are : US$ 1 = TND 1.171 = Yen 106.79 based on prevailing rate in June 2008
(b) Proportion of construction cost is : FC : LC = 45 : 55
(c) Base year for counting of price contingency is June 2008.

U1+M

Table 12.2.1 Project Cost for River Improvement (4/4): Zone U1 + M (Financial Cost)

Unit:TND1,000

Description	FC TND	LC TND	Total Cost TND equiv.	Total Cost US$ equiv.	Total Cost Yen 10^3 equiv.	2026 FC	2026 LC	2027 FC	2027 LC	2028 FC	2028 LC	2029 FC	2029 LC	2030 FC	2030 LC
(1) Construction cost (Base cost)	10,510,000	10,510,000	21,020,000	17,950,000	1,917,000	0	0	0	0	3,153	3,153	5,255	5,255	2,102	2,102
1.1 River Improvement	10,510,000	10,510,000	21,020,000	17,950,000	1,917,000	0	0	0	0	3,153	3,153	5,255	5,255	2,102	2,102
1.2 FFWS															
(2) Land Acquisition	0	2,790,000	2,790,000	2,383,000	254,000	0	0	0	558	0	1,116	0	1,116	0	0
(3) Government Administration 3% of (1) + (2)	0	714,000	714,000	610,000	65,000	0	0	0	143	0	250	0	214	0	107
(4) Engineering Services 10% of (1)	1,051,000	1,051,000	2,102,000	1,795,000	192,000	0	0	315	315	210	210	315	315	210	210
(5) Subtotal (1)+(2)+(3)+(4)	11,561,000	15,065,000	26,626,000	22,738,000	2,428,000	0	0	315	1,016	3,363	4,729	5,570	6,901	2,312	2,419
(6) Physical Contingency 10% of (5)	1,156,000	1,507,000	2,663,000	2,274,000	243,000	0	0	32	102	336	473	557	690	231	242
(7) Sub-Total (5)+(6)	12,717,000	16,572,000	29,289,000	25,012,000	2,671,000	0	0	347	1,118	3,700	5,202	6,127	7,591	2,543	2,661
(8) Price Contingency	6,902,000	15,258,000	22,160,000	18,924,000	2,021,000	0	0	168	916	1,907	4,565	3,353	7,117	1,474	2,660
FC:2.1% and LC:3.2% of (7)						(.454)	(.763)	(.484)	(.819)	(.515)	(.878)	(.547)	(.938)	(.5797)	(.9996)
(9) Sub total (7)+(8)	19,619,000	31,830,000	51,449,000	43,936,000	4,692,000	0	0	515	2,033	5,606	9,767	9,480	14,708	4,018	5,322
(10) Taxes	0	8,630,000	8,630,000	7,370,000	787,000	0	0	0	155	0	2,483	0	4,212	0	1,781
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	8,041,000	8,041,000	6,867,000	733,000	0	0	0	0	0	2,344	0	4,032	0	1,664
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	589,000	589,000	503,000	54,000	0	0	0	155	0	138	0	180	0	116
R: Rate of price contingency															
Grand Total (9) + (10)	**19,619,000**	**40,460,000**	**60,079,000**	**51,306,000**	**5,479,000**	**0**	**0**	**515**	**2,188**	**5,606**	**12,250**	**9,480**	**18,920**	**4,018**	**7,102**
									2,703		17,856		28,400		11,120

Note: (a) Exchange rates applied to conversion of the currencies are : US$ 1 = TND 1.171 = Yen 106.79 based on prevailing rate in June 2008
(b) Proportion of construction cost is : FC : LC = 50 : 50
(c) Base year for counting of price contingency is June 2008.

Table 12.2.2 Project Cost for Strengthenig Flood Control Function of Reservoirs in Mejerda River Basin

Unit:TND1,000

Description	FC	LC	Total Cost			2010		2011		2012		2013		2014		2015	
	TND	TND	TND equiv.	USD equiv.	Yen equiv.	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC
(1) Engineering Services*	2,842,400	710,600	3,553,000	3,034,000	324,018,000			568	142	1,137	284	1,137	284				
(2) Government Administration 30% of (1)		1,065,900	1,065,900	910,000	97,205,000				213		426		426				
(3) Subtotal (1)+(2)	2,842,400	1,776,500	4,618,900	3,944,000	421,223,000			568	355	1,137	711	1,137	711				
(4) Physical Contingency 10% of (3)	284,240	177,650	461,890	394,000	42,122,000			57	36	114	71	114	71				
(5) Subtotal (3)+(4)	3,126,640	1,954,150	5,080,790	4,339,000	463,345,000			625	391	1,251	782	1,251	782				
(6) Price Contingency FC:2.1% and LC:3.2% of (5)	285,591	277,021	562,612	480,000	51,308,000			40	39	108	105	137	133				
(7) Subtotal (5)+(6)	3,412,231	2,231,171	5,643,402	4,819,000	514,653,000			666	430	1,359	887	1,388	915				
(8) Taxes 10% of (7) for (2)		133,870	133,870	114,000	12,208,000				26		53		55				
Grand Total	3,412,231	2,365,042	**5,777,273**	**4,934,000**	**526,862,000**			666	455	1,359	940	1,388	970				

Notes:

(a) Exchange rates applied to conversion of the currences are: USD 1 = TND 1.171 = Yen 106.79, besed on prevailing rates in June 2008.

(b) Base year for counting price contingerncy is June 2008.

(c) * Including remuneration and direct cost

Table 12.2.3 Project Cost for Strengthenig Flood Forecasting and Warning System (FFWS) in Mejerda River Basin

Unit:TND1,000

Description	FC	LC	Total Cost			2010		2011		2012		2013		2014		2015	
	TND	TND	TND equiv.	USD equiv.	Yen equiv.	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC
(1) Engineering Services*	2,456,000	614,000	3,070,000	2,622,000	279,970,000			1,842	461	246	61	368	92				
(2) Telemeter Station**	274,000	225,000	499,000	426,000	45,507,000			274	225								
(3) Government Administration 30% of (1)		921,000	921,000	787,000	83,991,000				691		92		138				
(4) Subtotal (1)+(2)+(3)	2,730,000	1,760,000	4,490,000	3,834,000	409,468,000			2,116	1,376	246	154	368	230				
(5) Physical Contingency 10% of (4)	273,000	176,000	449,000	383,000	40,947,000			212	138	25	15	37	23				
(6) Subtotal (4)+(5)	3,003,000	1,936,000	4,939,000	4,218,000	450,415,000			2,328	1,514	270	169	405	253				
(7) Price Contingency FC:2.1% and LC:3.2% of (6)	217,533	215,907	433,440	370,000	39,528,000			150	150	23	23	44	43				
(8) Subtotal (6)+(7)	3,220,533	2,151,907	5,372,440	4,588,000	489,943,000			2,477	1,664	294	192	450	296				
(9) Taxes	57,742	161,758	219,500	187,000	20,017,000			58	132	0	11	0	18				
(18% of (8) for (2))	(57,742)	(48,965)	(106,707)	(91,000)	(9,731,000)			(58)	(49)	(0)	(0)	(0)	(0)				
(10% of (8) for (3))	(0)	(112,793)	(112,793)	(96,000)	(10,286,000)				(84)		(11)		(18)				
Grand Total	3,278,276	2,313,664	**5,591,940**	**4,775,000**	**509,960,000**			2,535	1,796	294	203	450	314				

Notes:

(a) Exchange rates applied to conversion of the currences are: USD 1 = TND 1.171 = Yen 106.79, besed on prevailing rates in June 2008.

(b) Base year for counting price contingerncy is June 2008.

(c) * Including remuneration and direct cost

(d) ** Installation of additional rainfall and water level telemeter stations, and measuring device of dam release discharge

Table 12.2.4 Project Cost for Strengthenig Evacuation and Flood Fighting System in Mejerda River Basin

Unit:TND1,000

Description	FC	LC	Total Cost			2010		2011		2012		2013		2014		2015	
	TND	TND	TND equiv.	USD equiv.	Yen equiv.	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC
(1) Engineering Services*	1,403,200	350,800	1,754,000	1,498,000	159,957,000			0	0	0	0	1,403	351				
(2) Government Administration 30% of (1)		526,200	526,200	449,000	47,987,000				0		0		526				
(3) Subtotal (1)+(2)	1,403,200	877,000	2,280,200	1,947,000	207,944,000			0	0	0	0	1,403	877				
(4) Physical Contingency 10% of (3)	140,320	87,700	228,020	195,000	20,794,000			0	0	0	0	140	88				
(5) Subtotal (3)+(4)	1,543,520	964,700	2,508,220	2,142,000	228,739,000			0	0	0	0	1,544	965				
(6) Price Contingency FC:2.1% and LC:3.2% of (5)	169,021	164,552	333,573	285,000	30,420,000			0	0	0	0	169	165				
(7) Subtotal (5)+(6)	1,712,541	1,129,252	2,841,793	2,427,000	259,159,000			0	0	0	0	1,713	1,129				
(8) Taxes 10% of (7) for (2)		67,755	67,755	58,000	6,179,000				0		0		68				
Grand Total	1,712,541	1,197,007	**2,909,548**	**2,485,000**	**265,338,000**			0	0	0	0	1,713	1,197				

Notes:

(a) Exchange rates applied to conversion of the currences are: USD 1 = TND 1.171 = Yen 106.79, besed on prevailing rates in June 2008.

(b) Base year for counting price contingerncy is June 2008.

(c) * Including remuneration and direct cost

Table 12.2.5 Project Cost for Organizational Capacity Development for Mejerda River Basin

Unit:TND1,000

Description	FC	LC	Total Cost			First Stage						Second Stage				Third Stage	
						2010		2011		2012		▪▪▪▪▪▪▪▪▪				2019	
	TND	TND	TND equiv.	USD equiv.	Yen equiv.	FC	LC	FC	LC	FC	LC					FC	LC
(1) Engineering Services*	3,438,400	859,600	4,298,000	3,670,000	391,959,000			1,719	430	1,032	258					688	172
(2) Government Administration 30% of (1)		1,289,400	1,289,400	1,101,000	117,588,000				645		387						258
(3) Subtotal (1)+(2)	3,438,400	2,149,000	5,587,400	4,771,000	509,546,000			1,719	1,075	1,032	645					688	430
(4) Physical Contingency 10% of (3)	343,840	214,900	558,740	477,000	50,955,000			172	107	103	64					69	43
(5) Subtotal (3)+(4)	3,782,240	2,363,900	6,146,140	5,249,000	560,501,000			1,891	1,182	1,135	709					756	473
(6) Price Contingency FC:2.1% and LC:3.2% of (5)	414,310	408,134	822,444	702,000	75,003,000			122	117	98	95					194	196
(7) Subtotal (5)+(6)	4,196,550	2,772,034	6,968,584	5,951,000	635,504,000			2,013	1,299	1,233	804					951	669
(8) Taxes 10% of (7) for (2)		166,322	166,322	142,000	15,168,000				78		48						40
Grand Total	4,196,550	2,938,356	**7,134,907**	**6,093,000**	**650,672,000**			2,013	1,377	1,233	853					951	709

Notes:
(a) Exchange rates applied to conversion of the currences are: USD 1 = TND 1.171 = Yen 106.79, besed on prevailing rates in June 2008.
(b) Base year for counting price contingerncy is June 2008.
(c) * Including remuneration and direct cost

Table 5.5.1 Calculation of Denudation Rate

1	Name of Dam	Sidi Salem					
	Capacity at Normal Water Level (Mm^3)	814.0	Date of Measure	Jun-87	Aug-89	Mar-91	Oct-98
	Catchment Area As(km^2)	18191	Period of Time t(year)	6.0	8.0	10.0	17.0
	Date of Service Start	1981	Sediment Volume (Mm^3)	30.6	47.0	52.0	87.5
			Annual Sediment Volume Md'(Mm^3/yr)	5.1	5.9	5.2	5.1
			Annual Net Swdiment Volume Md(Mm^3/yr)	3.3	3.8	3.4	3.3
	Data Source	① ②	Denudation Rate (mm/yr)	0.2	0.2	0.2	0.2
2	Name of Dam	Mellegue					
	Capacity at Normal Water Level (Mm^3)	270.0	Date of Measure	Jun-75	May-80	Dec-91	Jun-00
	Catchment Area As(km^2)	10309	Period of Time t(year)	21.0	26.0	37.5	46.0
	Date of Service Start	1954	Sediment Volume (Mm^3)	54.5	90.0	142.0	179.0
			Annual Sediment Volume Md'(Mm^3/yr)	2.6	3.5	3.8	3.9
			Annual Net Swdiment Volume Md(Mm^3/yr)	1.7	2.3	2.5	2.5
	Data Source	① ②	Denudation Rate (mm/yr)	0.2	0.2	0.2	0.2
3	Name of Dam	Bou Heurtma					
	Capacity at Normal Water Level (Mm^3)	117.5	Date of Measure	Mar-93			
	Catchment Area As(km^2)	390	Period of Time t(year)	16.0			
	Date of Service Start	1976	Sediment Volume (Mm^3)	2.0			
			Annual Sediment Volume Md'(Mm^3/yr)	0.1			
			Annual Net Swdiment Volume Md(Mm^3/yr)	0.1			
	Data Source	① ②	Denudation Rate (mm/yr)	0.2			
4	Name of Dam	Ben Metir					
	Capacity at Normal Water Level (Mm^3)	62.0	Date of Measure	1986			
	Catchment Area As(km^2)	103	Period of Time t(year)	32.0			
	Date of Service Start	1954	Sediment Volume (Mm^3)	4.0			
			Annual Sediment Volume Md'(Mm^3/yr)	0.1			
			Annual Net Swdiment Volume Md(Mm^3/yr)	0.1			
	Data Source	① ②	Denudation Rate (mm/yr)	0.8			
5	Name of Dam	Kasseb					
	Capacity at Normal Water Level (Mm^3)	82.0	Date of Measure	1986			
	Catchment Area As(km^2)	101	Period of Time t(year)	18.0			
	Date of Service Start	1968	Sediment Volume (Mm^3)	2.8			
			Annual Sediment Volume Md'(Mm^3/yr)	0.2			
			Annual Net Swdiment Volume Md(Mm^3/yr)	0.1			
	Data Source	① ②	Denudation Rate (mm/yr)	1.0			
6	Name of Dam	Lakhmes					
	Capacity at Normal Water Level (Mm^3)	8	Date of Measure	1975	1991	Jun-00	
	Catchment Area As(km^2)	127	Period of Time t(year)	9.0	25.0	34.0	
	Date of Service Start	Apr-66	Sediment Volume (Mm^3)	2.0	1.2	1.0	
			Annual Sediment Volume Md'(Mm^3/yr)	0.2	0.0	0.0	
			Annual Net Swdiment Volume Md(Mm^3/yr)	0.1	0.0	0.0	
	Data Source	① ②	Denudation Rate (mm/yr)	1.1	0.2	0.2	
7	Name of Dam	Siliana					
	Capacity at Normal Water Level (Mm^3)	70.0	Date of Measure	May-94			
	Catchment Area As(km^2)	1,040	Period of Time t(year)	7.0			
	Date of Service Start	Dec-87	Sediment Volume (Mm^3)	4.1			
			Annual Sediment Volume Md'(Mm^3/yr)	0.6			
			Annual Net Swdiment Volume Md(Mm^3/yr)	0.4			
	Data Source	① ②	Denudation Rate (mm/yr)	0.4			

Data Source
①Le Transport Solide des Oueds en Tunisie, Apr 2001 (The Strong Transportation of the Wadis in Tunisia, Apr 2001)
②Monthly data of dams
(grey shading) : The original data are questionable.

Table 12.2.6 Project Cost for Strengthenig of Flood Plain Regulation/Management

Unit:TND1,000

Description	FC	LC	Total Cost			2010		2011		2012		2013		2014		2015	
	TND	TND	TND equiv.	USD equiv.	Yen equiv.	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC
(1) Engineering Services*	2,596,800	649,200	3,246,000	2,772,000	296,021,000			909	227	1,039	260	649	162				
(2) Government Administration 30% of (1)		973,800	973,800	832,000	88,806,000				341		390		243				
(3) Subtotal (1)+(2)	2,596,800	1,623,000	4,219,800	3,604,000	384,827,000			909	568	1,039	649	649	406				
(4) Physical Contingency 10% of (3)	259,680	162,300	421,980	360,000	38,483,000			91	57	104	65	65	41				
(5) Subtotal (3)+(4)	2,856,480	1,785,300	4,641,780	3,964,000	423,310,000			1,000	625	1,143	714	714	446				
(6) Price Contingency FC:2.1% and LC:3.2% of (5)	241,560	233,946	475,506	406,000	43,364,000			64	62	99	96	78	76				
(7) Subtotal (5)+(6)	3,098,040	2,019,246	5,117,286	4,370,000	466,674,000			1,064	687	1,242	810	792	522				
(8) Taxes	0	121,155	121,155	103,000	11,049,000			0	41	0	49	0	31				
(10% of (7) for (2))	(0)	(121,155)	(121,155)	(103,000)	(11,049,000)				(41)		(49)		(31)				
Grand Total	3,098,040	2,140,401	**5,238,441**	**4,473,000**	**477,723,000**			1,064	728	1,242	859	792	554				

Notes:

(a) Exchange rates applied to conversion of the currences are: USD 1 = TND 1.171 = Yen 106.79, besed on prevailing rates in June 2008.

(b) Base year for counting price contingerncy is June 2008.

(c) * Including remuneration and direct cost (including software for hydraulic analysis and GIS)

Table 12.3.1 Assistant Strategy and Priority Sectors of Major Donor Agencies (Multilateral Development Agencies)

	Priority Sectors
World Bank	1) Strengthen the business environment, to support the development of a more competitive, internationally integrated private sector, and improve competitiveness of the Tunisian economy. 2) Enhance skills and employment potential of graduates, and the labor force in a knowledge economy. 3) Improve the quality of social services, through enhanced efficiency of public expenditures. Source: Country Assistance Strategy (CAS) for Tunisia, World Bank, June 2004
EU	1) Creation of the right conditions for private investment, the development of competitive SMEs (small and medium enterprises), growth, a reduction in unemployment and sustainable rural development; 2) Developing education and training, higher education and scientific research as vital building blocks of the knowledge-based society; 3) Facilitating trade in goods and services, approximation of technical regulations and conformity assessment procedures and standards; 4) Developing transport based on safety and security, reinforcing national and regional infrastructures and their inter-connection with the Trans-European Transport Network; developing the energy and information society sectors. Source: Country Strategy Paper 2007-13, EU
African Development Bank	1) The reinforcement of macroeconomic policies and acceleration of reforms addresses the need to improve the business environment and is geared towards consolidating the reform programs. 2) The modernization of infrastructure and consolidation of the productive sector is a strategic option for speeding up growth. 3) The consolidation of human capital focuses on creating employment, in particular by consolidating the linkages between training, research and production; supporting the development of technological centers that give concrete form to such linkages; and ensuring balanced regional development. Source: Country Strategy Paper 2007-11, African Development Bank
Islamic Development Bank	Assistance strategy and priority areas for Tunisia are not clear. Islamic development bank has been providing assistance for industrialization, capacity building for public sector, rural development, agricultural sector, and financial sector.

Table 13.1.1 Calculation of Economic Internal Rate of Return (Whole Project)

(unit: 1,000 TND)

	Cost					Benefit					Net
	D1	D2	U1+M	U2	Total	D1	D2	U1+M	U2	Total	Benefit
2008	0	0	309	206	516	0	0	0	0	0	-516
2009	0	0	1,160	1,774	2,935	0	0	0	0	0	-2,935
2010	0	0	2,033	2,353	4,386	0	0	0	0	0	-4,386
2011	1,239	7,248	2,020	2,359	12,866	0	0	0	0	0	-12,866
2012	801	7,702	7,117	5,387	21,007	0	0	0	0	0	-21,007
2013	835	14,856	8,721	6,476	30,888	0	0	0	0	0	-30,888
2014	14	21,840	8,181	5,449	35,484	0	0	0	0	0	-35,484
2015	14	24,552	5,568	7,655	37,789	0	0	0	0	0	-37,789
2016	14	19,380	173	5,491	25,058	0	0	4,211	9,172	13,383	-11,675
2017	14	8,049	173	9,507	17,744	0	0	4,401	9,584	13,985	-3,758
2018	14	647	173	10,237	11,072	0	76,046	4,599	10,016	90,660	79,589
2019	14	647	173	18,565	19,399	0	79,468	4,806	10,466	94,740	75,341
2020	14	647	173	25,167	26,001	0	83,044	5,022	10,937	99,003	73,002
2021	14	647	173	25,036	25,870	0	86,781	5,248	11,430	103,458	77,589
2022	14	750	173	22,695	23,632	0	89,384	5,406	11,772	106,562	82,930
2023	1,242	647	173	18,607	20,669	0	92,066	5,568	12,126	109,759	89,090
2024	3,320	647	173	1,057	5,196	0	94,828	5,735	23,319	123,882	118,685
2025	13,235	647	173	1,057	15,111	0	97,673	5,907	24,019	127,598	112,487
2026	24,144	647	173	1,057	26,020	0	100,603	6,084	24,740	131,426	105,406
2027	23,280	750	1,510	1,057	26,598	0	103,621	6,266	25,482	135,369	108,771
2028	18,613	647	8,498	1,239	28,997	0	106,729	6,454	26,246	139,430	110,433
2029	578	647	13,092	1,057	15,374	31,067	109,931	6,648	27,034	174,680	159,306
2030	578	647	5,182	1,057	7,464	31,999	113,229	6,848	27,845	179,920	172,457
2031	578	647	321	1,057	2,603	32,959	116,626	9,200	28,680	187,465	184,862
2032	578	750	321	1,057	2,706	33,948	120,125	9,476	29,540	193,089	190,383
2033	691	647	321	1,239	2,898	34,966	123,729	9,760	30,427	198,882	195,984
2034	578	647	321	1,057	2,603	36,015	127,440	10,053	31,339	204,848	202,245
2035	578	647	330	1,057	2,612	37,096	131,264	10,355	32,279	210,993	208,382
2036	578	647	321	1,057	2,603	38,208	135,202	10,665	33,248	217,323	214,721
2037	578	750	321	1,057	2,706	39,355	139,258	10,985	34,245	223,843	221,137
2038	691	647	321	1,239	2,898	40,535	143,435	11,315	35,273	230,558	227,660
2039	578	647	321	1,057	2,603	41,751	147,738	11,654	36,331	237,475	234,872
2040	578	647	330	1,057	2,612	43,004	152,171	12,004	37,421	244,599	241,988
2041	578	647	321	1,057	2,603	44,294	156,736	12,364	38,543	251,937	249,335
2042	578	750	321	1,057	2,706	45,623	161,438	12,735	39,700	259,495	256,789
2043	691	647	321	1,239	2,898	46,992	166,281	13,117	40,891	267,280	264,382
2044	578	647	321	1,057	2,603	48,401	171,269	13,511	42,117	275,299	272,696
2045	578	647	330	1,057	2,612	49,853	176,407	13,916	43,381	283,558	280,946
2046	578	647	321	1,057	2,603	51,349	181,700	14,333	44,682	292,064	289,462
2047	578	750	321	1,057	2,706	52,889	187,151	14,763	46,023	300,826	298,120
2048	691	647	321	1,239	2,898	54,476	192,765	15,206	47,404	309,851	306,953
2049	578	647	321	1,057	2,603	56,110	198,548	15,663	48,826	319,147	316,544
2050	578	647	330	1,057	2,612	57,794	204,505	16,132	50,290	328,721	326,109
2051	578	647	321	1,057	2,603	59,527	210,640	16,616	51,799	338,583	335,980
2052	578	750	321	1,057	2,706	61,313	216,959	17,115	53,353	348,740	346,034
2053	691	647	321	1,239	2,898	63,153	223,468	17,628	54,954	359,202	356,304
2054	578	647	321	1,057	2,603	65,047	230,172	18,157	56,602	369,978	367,376
2055	578	647	330	1,057	2,612	66,999	237,077	18,702	58,300	381,078	378,466
2056	578	647	321	1,057	2,603	69,009	244,189	19,263	60,049	392,510	389,907
2057	578	750	321	1,057	2,706	71,079	251,515	19,841	61,851	404,285	401,579
2058	691	647	321	1,239	2,898	73,211	259,060	20,436	63,706	416,414	413,516
2059	578	647	321	1,057	2,603	75,408	266,832	21,049	65,618	428,906	426,304
2060	578	647	330	1,057	2,612	77,670	274,837	21,681	67,586	441,774	439,162
2061	578	647	321	1,057	2,603	80,000	283,082	22,331	69,614	455,027	452,424
2062	578	750	321	1,057	2,706	82,400	291,575	23,001	71,702	468,678	465,971
2063	691	647	321	1,239	2,898	84,872	300,322	23,691	73,853	482,738	479,840
2064	578	647	321	1,057	2,603	87,418	309,332	24,402	76,069	497,220	494,617
2065	578	647	330	1,057	2,612	90,041	318,611	25,134	78,351	512,137	509,525
2066	578	647	321	1,057	2,603	92,742	328,170	25,888	80,701	527,501	524,898
2067	578	750	321	1,057	2,706	95,524	338,015	26,664	83,122	543,326	540,620
2068	691	0	321	1,239	2,251	98,390	0	27,464	85,616	211,470	209,219
2069	578	0	321	1,057	1,956	101,342	0	28,288	88,184	217,814	215,859
2070	578	0	330	1,057	1,965	104,382	0	29,137	90,830	224,349	222,384
2071	578	0	321	1,057	1,956	107,513	0	30,011	93,555	231,079	229,123
2072	578	0	321	1,057	1,956	110,739	0	30,911	96,362	238,012	236,056
2073	691	0	321	1,239	2,251	114,061	0	31,839	99,252	245,152	242,901
2074	578	0	321	0	899	117,483	0	32,794	0	150,276	149,378
2075	578	0	330	0	908	121,007	0	33,778	0	154,785	153,877
2076	578	0	321	0	899	124,637	0	34,791	0	159,428	158,529
2077	578	0	321	0	899	128,376	0	35,835	0	164,211	163,312
2078	691	0	321	0	1,012	132,228	0	36,910	0	169,137	168,126
2079	0	0	321	0	321	0	0	38,017	0	38,017	37,696
2080	0	0	330	0	330	0	0	39,158	0	39,158	38,828

EIRR = 25.0%