Figure 12.1 Implementation Schedule, First Stage

Descriptions	1st Year 1994	2nd Year 1995	3rd Year 1996	4th Year 1997	5th Year 1998	Remarks
I. Preconstruction Activities						
(1) Feasibility Study						
(2) Financial Arrangement	(8 mths)					w/Selection of consultant
(3) Detailed Design w/add. Survey		(12 mths)				w/ tender documents &
(4) Tender and Contract			(6 mths)			P/Q for tenderer
(5) Land Acquisition		(12 mths)				
II. Construction						
(1) Oued Ennkhilet/Sebkhet Ariana				(30 mths)		
(2) Oued Hammam				(30 mths)		

Figure 12.2 Implementation Organization

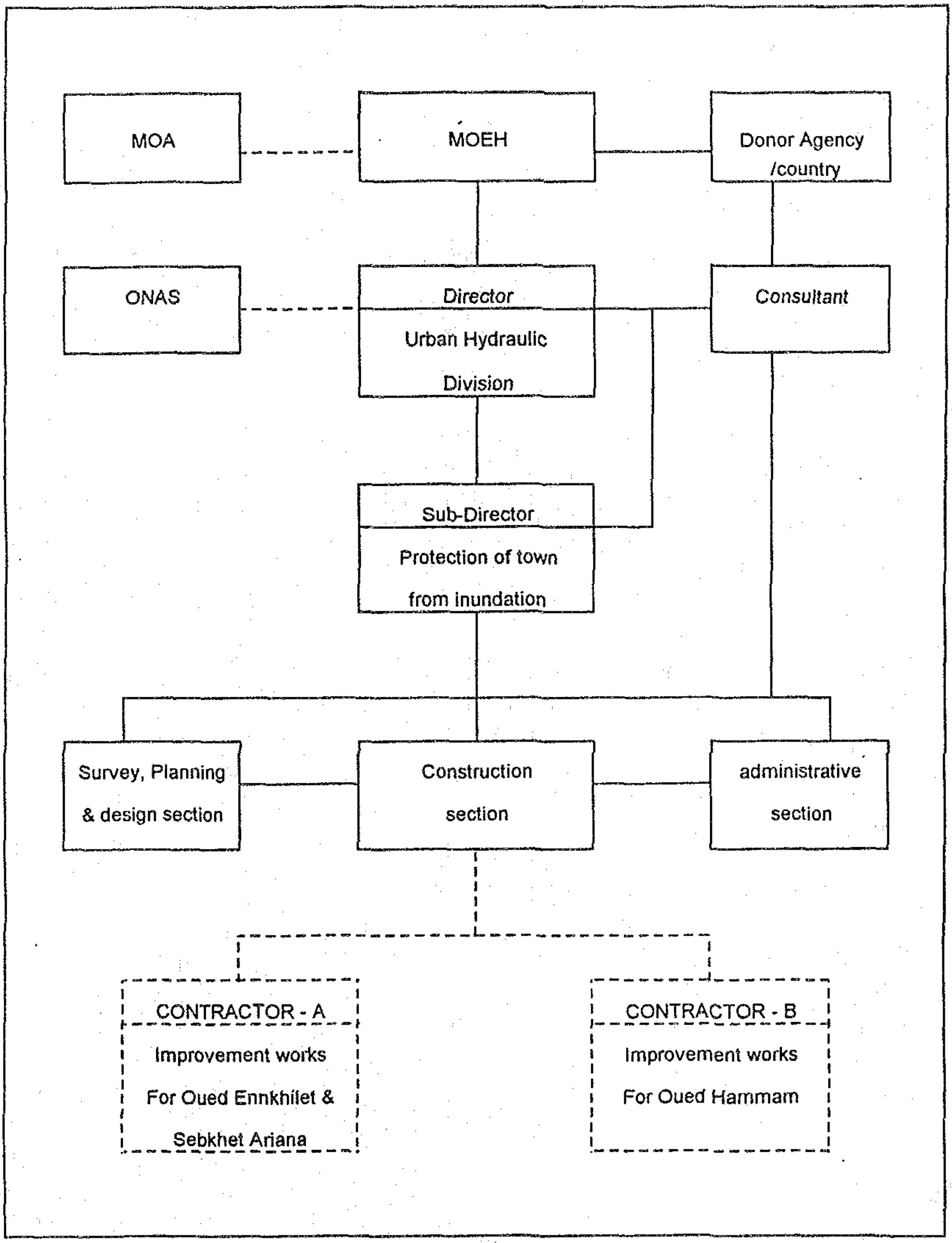
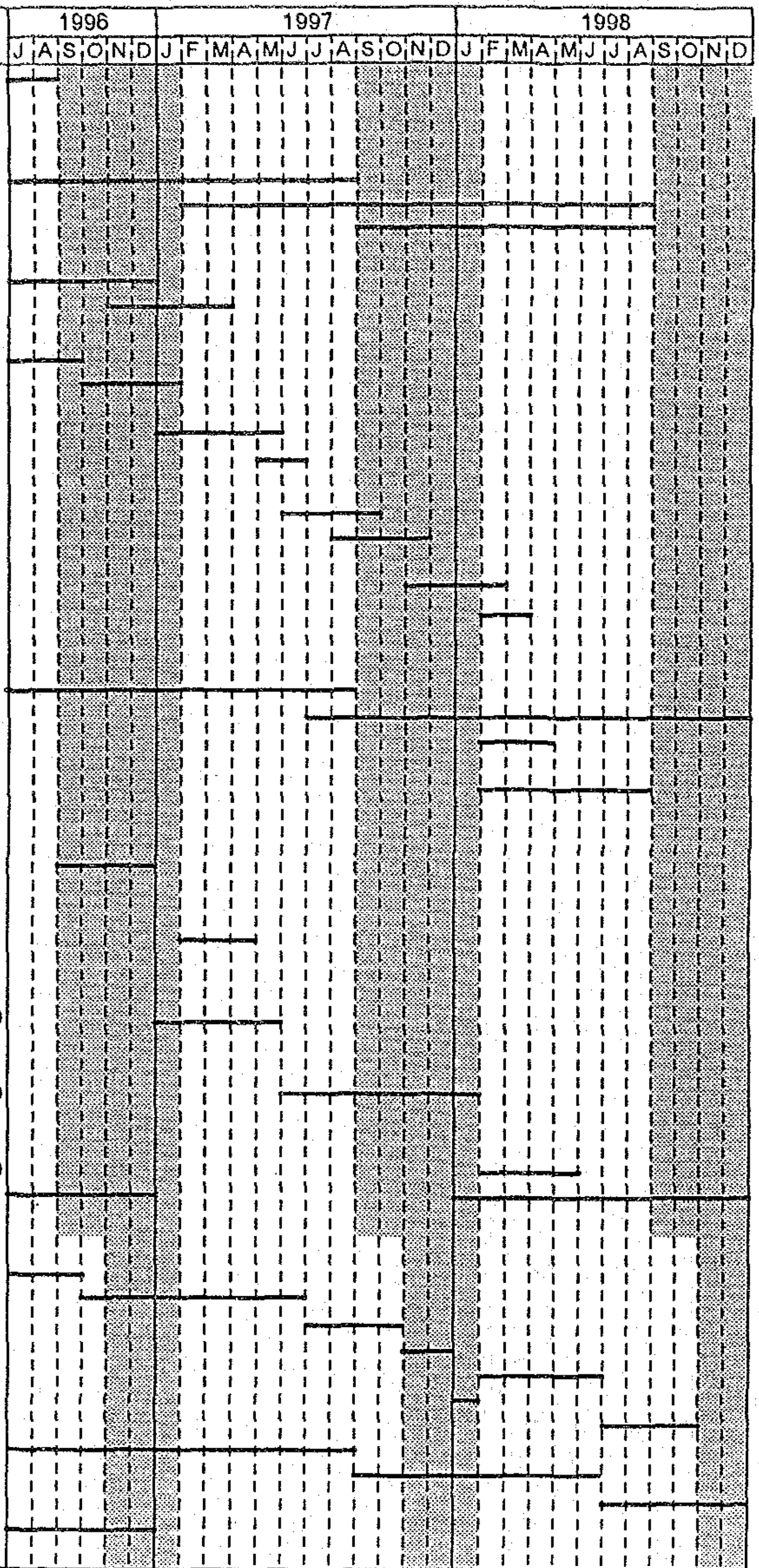


Figure 12.3 Construction Time Schedule, First Stage

Construction Work Items	Unit	Q'ty
1. Preparatory Works		
2. Oued Ennkhilet		
2.1 Oued Ennkhilet Main		
- River Improvement	lin.m	2695
- Bridge, RVE-543 & 533	nos	2
- Drainage Sluice	nos	5
2.2 Canal, C1		
- Canal Improvement	lin.m	1573
- Drainage Sluice	nos	5
2.3 Canal, R2		
- Canal Improvement	lin.m	918
- Bridge (Culvert)	nos	5
2.4 Canal, G1		
- Canal Improvement	lin.m	1113
- Bridge (Culvert)	nos	2
2.5 Canal, G2		
- Canal Improvement	lin.m	1255
- Bridge (Culvert)	nos	3
2.6 Canal, G1'		
- Canal Improvement	lin.m	299
- Bridge (Culvert)	nos	1
2.7 Flood Diversion N°.3 (trapezoidal earth lining)		
- Diversion construction	lin.m	3800
- Bridge, RVE-543,533, Others	nos	5
- ONAS Sewage Facilities reroute	L.S	-
- Drainage Sluice	nos	6
2.8 Flood Diversion N°.4 (Box culvert)		
- Diversion construction	lin.m	288
2.9 Retarding Basin A (Concrete Wall Dam)		
- Concrete	cu.m	260
2.10 Retarding Basin G (Pond Type)		
- Excavation	cu.m	25600
2.11 Retarding Basin I (Pond Type)		
- Excavation	cu.m	42700
2.12 Retarding Basin J1 (Pond Type)		
- Excavation	cu.m	24100
2.13 Other Crossing Facilities	L.s	-
3. Oued Hammam		
3.1 Oued Hammam, Stretch H-1	lin.m	572
3.1 Oued Hammam, Stretch H-2	lin.m	560
3.1 Oued Hammam, Stretch H-3	lin.m	565
3.2 Oued Laya, Stretch H-4	lin.m	250
3.3 Oued Kebir, Stretch K-1	lin.m	884
3.3 Oued Kebir, Stretch K-4	lin.m	84
3.3 Oued Kebir, Stretch K-5	lin.m	1532
3.4 Bridge, touristic road	set	1
3.5 Bridge, GP-1	set	1
3.6 Bridge, MC-48	set	2
3.7 Other Crossing Facilities	L.s	



Legend: [shaded box] : rainy season

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF EQUIPMENT AND HOUSING
THE REPUBLIC OF TUNISIA

THE STUDY ON FLOOD PROTECTION PROGRAM FOR GREATER TUNIS AND SOUSSE

PART II

FEASIBILITY STUDY ON OUED HAMMAM

THE STUDY
ON
FLOOD PROTECTION PROGRAM
FOR
GREATER TUNIS AND SOUSSE

PART II FEASIBILITY STUDY

II-2 Oued Hammam

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CHAPTER 1 SOCIO-ECONOMIC BACKGROUND

1.1 Introduction

The major trends of significance indicated by the base socio-economic data for the Governorate of Sousse (see Master Plan Study - Part 1, Chapter 1) are as follows:

* The structure of the Regional economy shows that Industry and Tourism are the major economic sectors in the Governorate.

*Agriculture, which represented 35.6% of employment in 1966, is now a mere 16.7%. This trend is expected to continue, with large moves into the services sector.

*There has been rapid urbanization, which can be expected to continue in the future, particularly in the "satellite" towns of Kalaa Kebira and Kalaa Seghira, as Sousse Town, and Hammam Sousse reach high density and saturation levels.

*Tourism will continue to be a major activity in the Governorate.

1.2 Population

The population of the Governorate is in excess of 400,000. The Oued Hammam passes through major populated areas in the Governorate of Sousse including Hammam Sousse, Akouda, Kalaa Kebira and Kalaa Seghira. These towns represented 25% (102,000) of the total population of the Governorate in 1992. All these Communes have high rates of urbanization - Akouda 81.6%, Kalaa Kebira 87.17% and Hammam Sousse effectively 100%. Density is high, with 275 persons per ha in Sousse town, and 5.48 persons per household in Hammam Sousse.

According to the Urban Master Plan for the Sousse-Monastir area, these towns will continue to be important centers of urban expansion in the future. By the year 2020 population in these towns is expected to increase to 250,000 (85,000 for Hammam Sousse, 38,000 for Akouda, 90,000 for Kalaa Kebira, and 37,000 for Kalaa Seghira).

Spontaneous housing is a major problem, particularly in the Oued Laia ,and especially in the area of Kalaa Kebira.

1.3 Infrastructure

The Oued Hammam is crossed by four important roads - the GP 1 , the GP 1 By-pass, and the Tourist road (RVE-835) and the MC 48 which runs from Hammam Sousse to Akouda. *The recent opening of the Autoroute has diverted much traffic and current* estimates are for nearly 6,000 movements per day on the GP 1 By-pass, and 9,300 for the GP 1. Daily flows are estimated at 12,225 for the MC 48, and 13,300 for the RVE-845.

The zone also has the ONAS sewage treatment plant (Sousse Nord SE5) with an average daily discharge of 8,700m3 per day, and treatment of 2,700 kg per day. Expansion plans are underway, and capacity is expected to rise in the near future to 17,430 m3 and 4,750 kg respectively. The plant serves an estimated 66,500 inhabitants and 19,200 hotel residents.

1.4 Economic Activities

The Oued Hammam is located in important tourist, industrial and agricultural areas.

1.4.1 Tourism

The Governorate of Sousse is one of the major tourist areas in the country, accounting for 25% of the total hotel and beds. Oued Hammam lies between the development at El Kantaoui and Sousse town. The former has a large number of important hotels, with an estimated 9,000 beds at present, and 20,000 in the future. New developments are proposed at Hergla. Total existing beds in Sousse are estimated to be 23,000.

1.4.2 Industry

Industry in Sousse is largely concentrated in the Industrial Estate of Sidi Abdelhamid in Sousse town. Where the Oued Hammam is concerned, major industrial development is in Akouda, which according the latest Census from the industrial Promotion Agency had 85 enterprises employing 4,100 persons. The relevant figures for Kalaa Kebira were 48 and 1,400, and for Hammam Sousse, 40 and 1,150 respectively. According to the 1984 Census, the sector accounted for 33% of employment in Sousse, 32% in Kalaa Seghira, 29% in Akouda, and 27% in Kalaa Kebira. Industries are mainly light textile, leather and agro-industries. There are 9 olive oil processing plants located in the oued, which contribute to pollution.

1.4.3 Agriculture

Arboriculture is a major activity in the Governorate of Sousse, contributing 34 % to the value of agricultural production. Olives are predominant, covering an estimated 57,000 ha. and 3.4 million trees. 20% of olive production is in the Commune of Kalaa Kebira. However many of the trees are old, and productivity is generally low. Fruit trees cover 1,535 ha of which grenadines (9,504 ha), peach trees (459 ha), and almonds (402 ha) are the most important.

There has been an increase in the production of vegetables and market produce in recent years. In 1989 these crops represented 17% of agricultural production in terms of value There are an estimated 4,500 ha of irrigated land in the Governorate.

There has been much encroachment of agricultural crops on the public lands (DPH - Domaine Public Hydraulique) in the Oued Hammam.

Livestock is important in the Governorate representing 40% of value in the sector.

Future development of the sector is constrained by a number of factors including the break-up of land holdings, water shortages, and improper techniques and inadequate use of the soils.

CHAPTER 2 TOPOGRAPHY AND GEOLOGY

2.1 General

The Master Plan study on seven oueds in the Greater Sousse area was carried out during end-Feb. and end-Aug.1993 (Phases 1 and 2) at both the site in Tunis and also in Tokyo Japan. As a result, the case of Oued Hammam was finally determined as the most recommendable one on which the feasibility study be made as Phase 3 work at the site during the period of end-Sept. 1993 to beg-Feb. 1994.

For the Oued Hammam, only the levee embankment was planned, and geotechnical investigation was made to clarify the quality of embankment materials. The location of investigated spots in the Oued Hammam basin is shown on Fig.2.1.

2.2 Topography and Geology

The topography of the study area is a flat alluvial plain developed between the Quaternary fluvial low hills undulated very gently. The comparatively high hills are developed in the right bank area near the river mouth. The geology of study area consists of the alluvial deposits of alternation of sand and clay layers of 10 - 15 m thick and the fluvial deposits below and on the both side hills. In the hills near the river-mouth, some soft rock outcrops of the marl are found.

2.3 Investigation Works

The study area was reconnoitered and four (4) sampling sites for the levee embankment material of SL1 to SL4 were selected. SL3 is situated on the fluvial hill and the others are situated on the alluvial deposits of river course. The location of those sites is shown on Fig.2.1. Geotechnical investigation works were sublet to the local contractor "Geotechnique Tunisie", and the field works were carried out by the contractor during October and November 1993 under the supervision of an Expert of the JICA Study Team.

From the four (4) sites, the disturbed samples were taken from the ground surface to 3 m deep and tested at the laboratory of the contractor on the following six (6) items:

- Natural moisture content
- Specific gravity
- Gradation

- Liquid and plastic limits
- Compaction
- Permeability

The stratification at the sampling spots are shown Fig. 2.2. SL1 consists of the layer of medium sand with small gravels to 1 m deep and the sandy clay layer below it. SL2 consists of the medium sand layer to 1.25 m and the clayey sand layer below it. SL3 consists of the top soil layer to 0.5 m deep and the fine sand layer below it. SL4 consists of the layer of medium sand with small gravel to 0.8 m deep and the clayey sand layer below it.

The laboratory soil test result is shown in Table 2.1. The soil materials of SL1 and the SL2 lower layer are classified into CL, those of SL2 upper layer and SL4 into SM and SL3 into SP. The natural moisture content of SL3 is 2 % which is 6 % lower than its optimum moisture content and those of the others range from 20 % to 24 % which are 7 - 13 % higher than their respective optimum moisture contents.

Other than the above investigation work, the following geotechnical investigation results were collected from ONAS and MOEH, and data were reviewed for the foundation of bridges to be planned in the study of this time.

- Boring record with pressio-meter test and Dutch-cone penetration test in the sewage treatment plant lot adjacent to the Touristic road near the river-mouth.
- Boring record with/without standard penetration test and Dutch-cone penetration test at the crossing area of the Oued Hammam and the Touristic road.
- Boring record with pressio-meter test and Dutch-cone penetration test at the bridge of new GP-1 road crossing the Oued Hammam.

2.4 Interpretation of Investigation Result

1) Embankment material

The soil of alluvial deposit layer in the river course is recommended for the levee embankment material because they are essentially suitable for the embankment material though their moisture contents shall be required to be decreased by 3 to 8 % for the embankment materials. This moisture content reduction can be attained by combination of the lowering of ground water level by trench excavation and dewatering and the airing. The material in the fluvial deposit is classified into SP of very fine gradation and accordingly very erodible. In case that the sand is used for levee embankment material, clay or other materials lining shall be required. Slope of 1v : 2h is recommended for the both sides of levee embankment.

2) Bridge foundation

Accompanying to the levee construction, new bridges should be required at the Touristic road, old GP-1 road and/or the site near to AQOUDA. According to the previous investigation result in the sewage treatment plant and at the bridge of the new GP-1 road, it was revealed that the alluvial deposits of alternation of sand and clay layers is developed to 10 - 15 m depth. Their cone penetration resistance ranges from 3 to 40 kg/cm2 and the elastic moduli by the pressio-meter range from 10 to 60 kg/cm2. These values correspond to N-values of 5 - 10, which are judged to be insufficient to attain the bearing capacity of a direct foundation for a bridge. Below the alluvial deposits, the fluvial deposit layer is developed showing its elastic moduli not less than 130 kg/cm2 which correspond to the N-value of about 30. Accordingly a pile foundations to be founded on the fluvial deposit layer is recommendable. The driving depth of piles is recommended to be 15 m from the present ground surface though this is too conservative for the bridge of the old GP-1 road where the width of alluvial plain becomes narrow.

CHAPTER 3 HYDROLOGY

3.1 Runoff Analysis

3.1.1 Methodology

Basically, the same method applied for the M/P stage is considered in the runoff analysis in Oued Hammam basin to this F/S stage. The rational method is utilized for the determination of basic flood runoff in consideration of the basin scale and availability of hydrological data. Basic conditions on the rational formula is described as below.

(1) Runoff coefficient

The classification of runoff coefficient in Oued Hammam basin is reviewed in accordance with the detail future land use plan. Following runoff coefficients for various land use types are determined taking account of the M/P study, standard of Japan and USA, available topographic map and present and future land use map.

Land Use Type	Present Land Use Condition	Future Land Use Condition
Urban center, Commercial, Residential areas :	0.6	0.8
Industrial areas :	0.6	0.6
Agricultural lands, Open spaces :	0.2	0.2
Water surface :	1.0	1.0

(2) Time of concentration

The time of concentration is defined as total of inlet time and flow time. The travel time of surface flow (overland flow and/or undefined channel) in the uppermost basin on each branch is calculated as the inlet time and the Kirpich formula is utilized to estimate the inlet time. The flow time is calculated from assumed average flow velocity in the channel taking account of channel condition, bed slope, carrying capacity, etc.

(3) Rainfall intensity

Average rainfall intensity in time of concentration is obtained from IDF (Intensity-Duration-Frequency) curve formula that was studied by "Institut National De La

Meteorologie" based on the rainfall record in 10 years (1981 to 1990) at the station of Monastir. Basic conditions of rational formula mentioned above is summarized in Table 3.1. The other hand, the unit hydrograph method with rational formula's peak discharge is used to develop runoff hydrographs for evaluation of flood damages. In this method, a runoff coefficient is defined to be the ratio of runoff to rainfall over a given time period and the same values mentioned above are adopted for runoff coefficient.

3.1.2 Runoff Simulation Model

(1) Drainage basin

Oued Hammam basin has a catchment area of 222.30 km2 and this basin is divided into 23 sub-basins (Basin No.1 to 23) to examine into the details of flood runoff on secondary and tertiary channels.

(2) Land use

Present and future land use condition is reviewed on each sub-basin with newest land use information and areas in the each sub-basin are classified into 4 zones according to the hydrological viewpoints. The weighted runoff coefficient for the rational formula under the present and future land use condition is calculated on each sub-basin.

The drainage area and its weighted runoff coefficient of each sub-basin are shown in Table 3.2.

(3) River system model

The river system model is made for runoff analysis taking account of the present river system and alternative plans and calculation points are also determined at the point of interest on the river system model. River system model and calculation points of Oued Hammam basin is shown in Fig. 3.1.

3.1.3 Rainfall Analysis

(1) Hydrologic design scale

Following basic condition are used for the design rainfall.

- Design scale for basic flood runoff : 100-year return period
- Design scale for 1st stage development : 10-year return period
- Evaluation of flood damage : 1.05, 2, 5, 10, 25, 50, 100-year return period

(2) Design hyetograph

Design hyetograph is utilized to obtain runoff hydrographs by the unit hydrograph method with rational formula's peak discharge.

The alternating block method is applied for the design hyetograph that is developed as center density distribution from an IDF curve with time interval equal to the time of concentration.

(3) Duration of design rainfall

Duration of design rainfall is adopted as 48 hours considering the longest time of concentration in Oued Hammam basin.

3.1.4 Flood Runoff Analysis

(1) Basic flood runoff

The Basic flood runoff for 1.05, 2, 5, 10, 25, 50, 100-year return period and present and future land use condition is calculated without any existing flood control facilities. Results of calculated basic flood runoff in Oued Hammam basin at each calculation point are shown in Table 3.3. The design basic flood runoff distribution is determined based on these calculated results.

(2) Existing flood control facilities

There is no existing flood control facility such as regulation ponds or reservoirs in Oued Hammam basin so that the basic flood runoff is the same as the condition with existing flood control facilities.

The runoff hydrographs from each sub-basin at each calculation point are also calculated by the unit hydrograph method with rational formula's peak discharge. Fig. 3.2 shows the same sample results of the calculated synthetic hydrograph at a certain calculation point. These runoff hydrograph is used for the estimation of flood damages.

3.2 Riverbed Material Investigation

3.2.1 General

Riverbed material investigation in Oued Hammam basin was carried out for the purpose of clarifying a characteristic of riverbed material in the basin. Samples of riverbed material were taken at 6 spots in Oued Hammam basin as shown in Fig 3.3.

3.2.2 Riverbed Material

Specific gravity of each sample is about 2.66 and grain size d50 (grain size that passing percentage is 50%) ranges from 0.027 mm to 0.21 mm. Results of riverbed material investigation are summarized below and results of gradation test are plotted in Fig. 3.4 on each sampling spot.

Sampling spot	Specific gravity (g/cm3)	d50 (mm)
S 1 (+ 2.0 km)	2.66	0.0350
S 2 (+ 7.5 km)	2.61	0.1200
S 3 (+ 5.8 km)	2.66	0.1000
S 4 (+ 8.3 km)	2.63	0.2100
S 5 (+ 13.0 km)	2.68	0.0270
S 6 (+ 14.5 km)	2.67	0.0360

CHAPTER 4 LAND USE PLAN

4.1 Introduction

It deals with a feasibility study focusing on present land use plan in the study area of four towns in the region of Metropolitan Sousse. The towns of the study area incorporate Hammam Sousse, Akouda, Kalaa Kebira and Kalaa Sghira within the Governorate of Sousse. The geological situation near the Metropolitan Sousse has encouraged urban development of these towns. Under the present land use of this region, several phenomena are observed in these towns such as predominance of spontaneous settlements (illegal settlements) and expansion of urbanization in the agricultural zones and flood inundated zones. Many habitants have suffered damages from flood inundation by constructing their houses inside inundated zones and agricultural zones in the form of illegal way. In this aspect, the delimitation of the study area was determined by a catchment area basis against flood inundation. The presentation of this proposed land use plan was approached to regional concept, considering rapidly changing urbanization in the context of conurbation in the Regional Sousse as illustrated in Figs.4.1 and 4.2. In addition, Table 4.1 and Table4.2 shows the land use proportion of urbanized areas. This chapter herewith aims to study present and future land use plan with a target year of 2000 in a short term and 2020 in a long term.

4.2 General

The towns of Hammam Sousse, Akouda, Kalaa Kebira and Kalaa Sghira are located approximately 10km away in the north and northwest of Metropolitan Sousse as shown in Fig.4.3. Although the towns have different natural conditions, the characteristics of the region have maintained mainly agricultural activities. These towns have developed on the Sehloul plain between the Mediterranean Sea and the hills of Kalaa Kebira, composing of gentle slopes and undulated lands. All of this region is under the catchment of Oued Hammam. Also, the GP1 in the east and Auto route in the west of this region provides linkage to main urban centers as illustrated in Fig.4.3.

4.3 Hammam Sousse

4.3.1 Urbanization

Hammam Sousse has evolved from an agricultural village to an urban agglomeration. The town had developed in the form of a comprehensive spatial expansion from 1973-

1988. In this period, the urbanized area doubled from 98ha to 211ha. The urban growth was directed toward the southeast in continuity with the Sehloul plain. Also, development is witnessed along the GP1 in the North as shown in Fig.4.4. The most spectacular growth is in the Bir Moussa and zone of touristic road (RVE 845) in the East of GP1 as shown in Fig.4.4.

4.3.2 Present Land Use

Residential Zone

The residential area covers in an area of 250 ha including housing, public and activities. This zone has evolved both sides of the GP 1 from an old central area toward the southeast in the zone of Sahloul. The residential zones are characterized three patterns. The upper-class residential zone is situated in the East of the GP1 (sea front), while the modest inhabitants occupy in the West of the GP1. The other zone of middle-class is located between these zones in the area of Sehloul and Medina. In addition, anarchic housing areas have created by migration from the old central area and industrial development in the surrounding urban zones and agricultural zones, where are prone to flood inundation.

Agricultural Zone

Agricultural zone covers in an area of 620 ha, of which 170 ha is distributed for irrigated cultivation and the rest of 450 ha is occupied by dry cultivation. The agricultural sector produces mainly olive fruits (dry arboriculture) and vegetables. For recent years, there has been a tendency that agricultural sector has decreased for the benefit of the tourism and industry in Hammam Sousse. The encroachment of agricultural zone by spontaneous settlements is observed in the area of Ghrabi in the West of GP1 By-pass, El Bhaier, El H'mada and El K'bira.

Public Facilities

The road infrastructure has developed with the touristic boom such as GP1, GP1 By-pass and RVE 845 (Touristic road). Nevertheless, the socio-cultural facilities do not correspond to the image of the town.

Flood Inundation Zone

Hammam Sousse is a catchment area of the Oued Hammam. The oued crosses in the northern part of urbanized area in the town. Because of this geological situation of the town, many areas are exposed to inundation by run-off river basin along the Oued Hammam. The urbanized zones in low area where are prone to flood inundation are situated in the East of the GP1 and alongside the Oued Hammam.

4.3.3 Future Land Use

1) The high-density old town center has been deteriorated with insufficiency of public facilities. Along with this, the high price of land in the old central town led to the increase of spontaneous settlements in surrounding urban zones. In this aspect, the redevelopment plan of the old town is proposed in accordance with urban expansion.

2) The anarchic housing areas that increased in the zones of No.144, Oued El Ksila, El Ghrabi and El Bhaier have constructed in agricultural zones. Moreover, these zones are prone to inundation and have poor road infrastructure. The strict controls of spontaneous settlements are required to protect the agricultural zones and reserved land for public facilities. In addition, public housing program is proposed as a countermeasure of eliminating spontaneous housing habitats.

3) Hammam Sousse lacks sufficient public spaces because of mainly high price of the land and lack of space in the central town. Moreover, the transformation of public facilities into residential area is witnessed. With the urban expansion, socio-cultural, institutional facilities that could not secure the space in the central area are located far from the residential zones. In this perspective, it is required to provide balanced spatial distribution with the development.

4) The existing industrial zone occupies only 30% in the town because the industrial units prefer to be established on the major trunk roads such as GP1. In this view, the allocation of future industrial zone should be distributed in the easily accessible area from the major road.

5) A provision of rehabilitation of infrastructure facilities against flood controls is imperative. The improvement should involve drainage, sewage systems and retention ponds. The retention ponds can be utilized for parks and sports grounds in dry season as an alternative purpose.

7) The development scheme of Center-East areas in Hammam Sousse should be carried out in the context of region that is under the influence of the Metropolitan Sousse.

4.4 Akouda

4.4.1 Urbanization

The urbanization of Akouda has taken place in all the direction around the old town. The development has consolidated the linear growth along the RVE 815 during 1980-1988. However, the most spectacular growth was occurred in the East and in the North of MC 48 as depicted in Fig.4.5. The additional housing development is represented by grouped-type in continuity with existing constructions and occupation of the area of the Oued Larouk. Many groups of residential areas were developed along the GP 1 By-pass. The expansion of housing areas is noticeable in the West, while the growth is confined to only some plots in the South. The space consumed during this period was biggest and the urbanization doubled from 93ha to 202ha in 1980-1988.

4.4.2 Present Land Use

Residential zones

The residential zone covers in an area of 180ha. This zone has evolved from an old town center and become an origin of the formation of the urban fabric . The residential zones in Akouda are represented four types. The old town has a traditional housing type while the extension residential zone in southeast involves isolated residential areas. Moreover, mixed-type of housing that consists of grouped, row and isolated housing types exists both sides of the RVE 815 in the North and under the M 48 in the South. Like other surrounding towns, spontaneous housing problem is observed in this town. These spontaneous settlements are mainly located in agricultural zones and flood inundation zones such as the Oued El Arouk, Oued El Halem, Oued Djenen and Oued Errommane.

Agricultural zone

The agricultural zone covers in an area of 4,460 ha, of which 1,020 ha is irrigated and the other 3,440 ha is dry cultivated agriculture. The principal agricultural products are olive and grenadine. Nevertheless, this town also shows the decrease of agricultural sector due to the low-income from agricultural work and industrialization.

Public facilities

In this town, insufficiency of public facilities is observed that include social, sports, cultural, green area, administrational and institutional purpose.

Industrial zone

New industrial zone has created such as firms and companies in the agricultural zone in a form of anarchic way. Moreover, the industrial service facilities are not accompanied with the expansion of industrial zone.

Road infrastructure

Akouda is linked with principal roads that involve the GP 1 By-pass in the East and Auto route in the South-West. Also, the MC 48 and the RVE 815 are running in the South and North, respectively. Also, the RVE 815 is merging into GP 1 as shown in Fig.4.3.

Flood Inundation Zone

The major reason of inundation in this town is overflow of water along the Oued Kebir in the southern urbanized area. Moreover, run-off from the catchment basins in the North of the town flows on the roads. The water is gathered on the MC 48 and causes flood inundation up to the GP 1 By-pass. Also, the town has ill-defined oued bed in the urban zones and lack of water evacuation facilities from rainwater.

4.4.3 Future Land Use

1) The old town center has deteriorated with the absence of social facilities and social houses for low-income people. Also, the high land price and lack of space in the old central town led to the increase of spontaneous settlements in surrounding urban areas. In this aspect, the redevelopment plan of the old town is necessary in accordance with urban expansion.

2) The expansion of anarchic housing led to some constructions under high-electric cables as well as agricultural zones. In order to avoid this danger, the creation of underground network of electric cable should be provided. Also, the spontaneous habitats should be eliminated in the agricultural zone by offering public housing program and administrative control in consideration of agricultural protection.

3) Although this industrialization created much employment in this town, the transport infrastructure does not correspond with the scale of industry. In addition, the lack of industrial service facilities in the industrial zone is observed. This has led to the establish some firms in the residential or agricultural zones. In this view, future land use plan should incorporate necessary infrastructure and industrial service facilities in consideration of agricultural protection. Moreover, the industrial zone should be allocated on the main road to reduce traffic congestion.

4) The qualitative and quantitative shortage of public facilities is witnessed, particularly in the old urban center. This is mainly resulted from the high land price and lack of space. In this regard, provision of well-balanced socio-collective facilities should be provided in this town in consideration of approaching socio-economic aspect as well as physical spatial distribution for the benefit of all the residents.

5) The inundation of the main roads blocks traffic after heavy rain. The program of infrastructure improvement against flood inundation should be implemented such as drainage, sewage systems and retention ponds. Moreover, water pollution along the oueds should be prevented because the deposits of rubbish on the riverbed lead to elevate water level and impede the flow of water toward the outlet.

6) The road infrastructure among Akouda and the nearby agglomerations such as Sousse, Hammam Sousse, Kalaa Kebira and Kalaa Sghira should be improved. This road rehabilitation involves the MC 48, RVE 815, GP 1, GP 1 By-pass and the RVE 819 as shown in Fig.4.3.

4.5 Kalaa Kebira

4.5.1 Urbanization

Kalaa Kebira has transformed from an agricultural village to an urban town. The town is mainly directed to agriculture and the urban area has expanded since recent few years that concerns primarily residential development. The urbanization of the town has taken place based on two successive land use plans. The first plan was made by an Italian city planner to improve and restructure the old city during 1965~1975. During this plan, the town was characterized as rural life with traditional urban fabric of predominance of narrow roads. Moreover, the existence of two oueds (Oued El Kebir and Oued Seghir) surrounded the town influenced the choice of urban expansion. To solve these constraints, the plan was directed to the two points. One is not to disorganize the old urban fabric by any development and the other is not to block the oueds that is spillway and rainwater for security and health problems. This plan involved the division of two major zonings, socio-cultural and residential. The second land use plan was elaborated by a group of the Study Team of Center that was approved by decree in 1976 and intended to be achieved the plan during 1975-1985. Nevertheless, this land use plan was not respected because it lacks severity of controls. The town evolved during this decade according to the land use plan by the Study Team of Center is represented as follows ;

- The form of zoning division with different allocations constitute constraints and restrictions for the residents.
- Unequal distribution of land use facilities
- Distribution pattern of zoning on total planned area such as residential zone and road (409.5 ha), industrial zone (50.5 ha) and facility zone (40 ha)

4.5.2 Present Land Use

Residential zone

The residential area includes housings, public and activity facilities with a size of 571 ha. The old city is composed of solely grouped traditional houses. The types of housing are characterized by zoning regulation such as isolated, pair, continued and grouped for the expansion of urbanization. At the same time, Kalaa Kebira shows the highest spontaneous housing rate of 70% in the total residential area in Sahel .

Agricultural zone

This town is mainly rely on agriculture for its rich fields. The major agricultural product is olive in Kalaa Kebira. However, the urban expansion has taken place in many agricultural properties in an anarchic way.

Public zone

This zone involves service, education and sports with an area of 27.8 ha. Parcels of land for public facilities have reserved in accordance to the zoning regulation. The green zone covers a total area of about 113 ha, of which 11ha is reserved for the oueds and protection zones. This zone also includes 14 ha that is allocated for municipal park.

Industrial zone

Industrial zone covers in an area of 9 ha, located on the road of "Ghdir El Ajla". The activities in this zone are not developed and concerns light industry. Along with this, there is an industrial activity zone with an area of 3.2 ha.

Flood Inundation Zone

The inundation zones are located along the downstream flows of oueds. As the spontaneous settlements and traversing roads in this area obstruct the natural flow of the oueds, this becomes one of the reasons of the flood inundation in this town. Moreover, two oueds of the Oued Kebir and the Oued Seghir surround the town completely that are running from Hammam Sousse beach. This causes a serious risk of flood inundation by overflow of the oueds and pollution due to stagnation of water.

4.5.3 Future Land Use

1) Among the total area of 500 ha by the Kalaa Kebira land use plan, 442 ha (88.4%) is already occupied and only 58 ha (11.6%) is available. Apart from the illegal constructions, some constructions are situated in non-urbanized zone by the land use plan. The constructions are scattered all around the area, amounting to 500 houses in the size of 60 ha. Moreover, the saturation of space in the areas of East Zaarna, West Zaarna, Oued M'hamed and Jeradaa is witnessed. From the phenomena above, the land use was disorganized and initial allocations of zoning were changed by constructions in non-urbanized zone and spontaneous settlements. In this view, the future land use proposed by the town involves integration of the development plan of 4 zones ; the residential zone of "Ghdir El Ajla", the zone of El Mansoura, the zone behind a station and industrial zone of A.F.I. In addition, the improvement for expansion in the eastern side of the railroad is included.

2) Most of the inhabitants live in house with large ground surface. This type of housing requires a big space at the expanse of agricultural lands. Therefore, it is required to intensify the land occupation of less space for the housing that leads to harmonious qualitative development.

3) The evolution of town was quantitative rather than qualitative one. The existing public facilities in Kalaa Kebira are insufficient and unequally distributed. The future land use should be planned to contribute in the development of the town on the basis of these aspects. Providing more public facilities, green spaces and development of constructions on both sides of main road will give an urban amenity to this town.

4) This town is mainly rely on agriculture for its rich fields. For this, the agriculture zone must be protected on the basis of foodstuff from urbanization because many agricultural properties have urbanized in an anarchic way. In addition, public housing program should be implemented to halt the spontaneous housing problem.

5) The inundation of the main roads blocks traffic after heavy rain. The program of infrastructure improvement against flood inundation should be implemented such as drainage, sewage systems and retention ponds. Moreover, water pollution along the oueds should be prevented because the deposits of rubbish on the river bed lead to elevate water level and impede the flow of water toward the outlet.

6) Industry sector is a significant factor to encourage job employment. As the region is concerned with mainly agriculture, it is desirable to develop food industrial zone in this

town to vitalize economic life and provide job opportunities for local residents. Moreover, the industrial zone should be located in the main road to reduce traffic congestion and inconvenience for the residents.

7) The road system should be organized into hierarchy. Also, traffic in the town should be improved by widening of the following roads : Rue 1 Juin, Rue Ali Bel Houane, Rue Hedi Chaker and Rue Beater Ben Aicha. Other roads will be widened to reinforce traffic system, as well.

4.6 Kalaa Sghira

4.6.1 Urbanization

Since independence of the country, the urbanization of Kalaa Sghira has occurred in the North and East towards Sousse, Hammam Sousse, Akouda and Ennaguer. After the town became a county town of the delegation of Kalaa Sghira in 1982, the population has moved to the surrounding areas of the town. After the creation of industrial sector, the expansion was occurred in a form of urban sprawl by spontaneous settlements because of the lack of control. In addition, as this expansion had not accompanied with sufficient infrastructure, majority of this town remains as a small-medium size town.

4.6.2 Present Land Use

Residential

The residential area covers in an area of 220 ha with the relevant public facilities. The most of urban evolution is accompanied with residential development. However, much of urban expansion along the RVE 819 has taken place without any prior divisions. The type of existing house is traditional grouped in the old center and isolated flat houses in all around center. At the same time, spontaneous habitats have appeared in the El Harik and along the Oued Aoun.

Agricultural

The agricultural sector remains important activity in this town. The agricultural fields cover 3,500 ha for olive trees and 7,000 ha is reserved for main cultivation and breeding of sheep and cattle.

Public facilities

The town of Kalaa Sghira has a certain number of administrative, socio-collective and cultural facilities at present. Nevertheless, they are still insufficient state for the development of the town.

Flood Inundation Zone

The inundation zones are mainly in the South and in the center of the town. The causeway with 3 m high that supports the railway and surrounds the town in the South is a constraint of run-off. While this causeway plays an efficient protection role for the town, it leads to the inundation of built-up low areas in the upstream. This town has also uncertain oued bed that can be overflowed after heavy rain in the urban zones and lacks of water evacuation facilities from rainwater.

4.6.3 Future Land Use

1) The revision of old land use plan of Kalaa Sghira is necessary because the situations are modified in certain zone. This is because of the constructions in non-urbanized zones. Also, the new auto route is linked to GP 1 By-pass while crossing upper residential area of Kalla Sghira from the west to east. The new land use plan should concern the integration of new industrial zone and modification of the open space and green zone of Ejjorf by the zoning regulations into residential area.

2) The future land use plan of Kalaa Sghira should ensure the protection of rich agricultural fields. In this regard, the urban expansion will be reached to the field of pomegranate trees and irrigated areas of Sabbaghine and Echeragui. Moreover, the urbanization should be occurred by equilibrated distribution of public facilities and organized road hierarchy to intensify urban fabric.

3) The inundation of the main roads blocks traffic after heavy rain. The program of infrastructure improvement against flood inundation should be implemented such as drainage, sewage systems and retention ponds. The retention pond can be utilized for parks and sports grounds in dry season as an alternative way.

4) The future land use plan by the Town of Kalaa Sghira will incorporates as follows to meet the needs of the town ;

- The industrial zone will be developed in an area of 25 ha in the Northeast.
- The residential zone will be created with schools and public facilities in an area of 48 ha.
- The agricultural zone of "Saint le Roi" in the North will be transformed into a residential zone, covering an area of 55 ha.

- The agricultural zone of "Ras el oued" in the West will be classified by residential zone in an area of 50ha.

4.7 Conclusion

Land use plan is very important because it provides the future vision of the region in the context of socio-economic aspects as well as physical development. Although the towns have different natural conditions, the characteristics of the region have maintained agricultural activities. Nevertheless, the geological situation near the Metropolitan Sousse has encouraged urban development of these towns. The most conspicuous urban expansion is accompanied with residential development from the old town centers. However, the disparity between this old town and new urban area are one of the problems in the development of the towns and it also creates the phenomenon of spontaneous settlement in surrounding urban areas. In this sense, the rehabilitation of these old towns is necessary along with improvement of anarchic housing problems.

Much of this rapid expansion has led to disordered development in the agricultural protection zones and flood inundation zones in a form of anarchic way by spontaneous habitats. Also, much land use distribution was carried out without previous divisions of land such as the construction along the RVE 819 in the town of Kalaa Sghira. In this perspective, the reclassification of existing land use plan is necessary that is not appropriate for present situation. In terms of spontaneous settlements, a provision of public housing program should be made.

In addition, the region is prone to flood inundation zone, situated in all the catchment areas of the Oued Hammam. Moreover, it is observed that the existing public facilities and infrastructure in this region are insufficient and unequally distributed. In this regard, the future development should be accomplished by well-balanced spatial distribution of public facilities and basic infrastructure in order to be self-sufficient towns in the region.

CHAPTER 5 URBAN DRAINAGE

5.1 General

Urban drainage systems consist of storm water drainage system and sewerage system. The major purpose of the study is to check whether domestic and industrial waste water becomes a base flow of the Oued Hammam before flood occurs. If this flow is very minimal, then the flow will be neglected in determining design flood.

Reviewing data and information on storm water drainage system and sewerage system in study area, and also through field reconnaissance and interview, it has been revealed that the inundation of the low-lying area along the river course is the critical since before. It is judged that it comes from poor existing storm water drainage system. On the other hand, domestic water is partly treated at sewer treatment plant locating at the left bank near the Touritic road, and treated water is discharged directly into the sea.

5.2 Existing Urban Drainage System

Data Collected:

Besides the data and information on urban drainage collected by S/W Mission, the JICA Study Team continued to collect additional data/information from various sources. As a result, it was found that the studies and succeeding implementations of storm water drainage and sewerage systems in the Greater Sousse area had mainly been made to date in several steps by National Sanitation Agency (ONAS). The Oued Hammam basin is locating at the northern end of the entire system. There exist several data and information relating to storm water drainage and sewerage systems which had been published in the past. However data and information collected during Phases 1 and 3 at the site were rather old one. Members of the JICA Study Team visited several times ONAS offices in Sousse, and visited a local consultant who is well acquainted with the present conditions and future implementation plan of ONAS's projects. The JICA Study Team could obtain general information about it, but not the detailed one.

To grasp the relation between water supply and urban drainage system, data concerning water supply were also collected from Water Authority (SONEDE). Water supply to urban and rural areas in the country is autonomously operated and managed by SONEDE since before. Stage-wise development of water supply system has been carried out to date, and now SONEDE is implementing the Eighth Plan which covers five years starting from 1992 and ending 1996. Data that show the nation-wide rehabilitation and extension program in this Eighth Plan was obtained, however, area-wide program was not available.

Review of Data Collected:

Data collected and information obtained through interviews to staff concerned of ONAS, SONEDE and MOEH, and some local consultants were examined. It was understood that storm water drainage and sewerage systems in urban areas in the Greater Sousse area have been operated and managed, and rehabilitated by MOEH and ONAS since before. Every five year, the review of Master Plan had been made, and now is in the Fourth Stage. Storm water drainage and sewerage systems are being planned, operated and maintained by ONAS, reviewing the previous Master Plan. Modified Master Plan and the Feasibility Study on priority projects are now under finalization, and the final reports will be issued by ONAS soon. The JICA Study Team requested ONAS to avail the latest data and information studied in the recent study, however it has not been released to date.

As for water supply for both Greater Tunis and Sousse areas, the details of existing facility, supply capacity, served population, etc. are not available. Data obtained from SONEDE show only nation-wide water supply features

Field Reconnaissance and Findings:

Field reconnaissance was continued to grasp the actual situation of storm water drainage system and sewerage systems at the site which are being operated by ONAS. As a result, it was found the following:

(1) In Greater Sousse area, there exist two sewer treatment plants now. The Sousse South Plant (WWTP South) is discharging treated water into the Oued Hallouf through pipe culvert. The Souse North Plant (WWTP North) locating at the right bank near Touristic road is overloaded, and untreated sewer water is being spilled out to the Mediterranean Sea at the river mouth of Oued Hammam. Moreover, at many places it was observed waste water is discharged into oueds, and it emits bad odor to the surrounding areas. The quantity of this sewer water is not known yet, but it would be not so significant from the viewpoint of flooding.

(2) As most parts of storm water drainage systems consist of underground structures such as pipes, concrete culvert, manhole, etc., it is rather difficult to grasp the actual situation without referring to detailed drawings of the systems. The staff concerned of ONAS Sousse explained the JICA Study Team that the Oued Maouar basin is the most problem area, causing inundation of the area due to poor drainage system.

5.3 Present Condition at the Site

(1) Existing drainage system and facility

Details of the existing drainage system and facility at the site are not known yet, as inventory in the Greater Sousse area operated and maintained by ONAS and MOEH has not been released to the JICA Study team.

(2) Urban drainage development plan

Grand Sousse Master Plan for urban drainage had been reviewed by ONAS in 1991/92, and the following storm water drainage network is projected to improve the existing system. The projected storm water drainage network is divided into four parts, and the Oued Hammam basin belongs to the northern part.

- For northern part: four (4) interceptor sewers 6,200 m in total, (one) interceptor by MOEH.
- For the western part: three (3) interceptor sewers, and coastal interceptor sewers.
- The eastern part draining the area of the road to Manastir.
- The southern part for Sousse integrated in the basin of the Oued Hallouf: six(6) interceptor sewers, 9,500 m in total.

(3) Institution relating to drainage and water supply

Institution relating to drainage and water supply is just the same to that of Greater Tunis area, as described in the Master Plan.

5.4 Preliminary Design of Urban Drainage System

In the urbanized area of the Oued Hammam basin, it has been observed that some urban roads were inundated during storm rainfall due to poor urban drainage system. It mainly comes from insufficient surface drainage system. To minimize the inundation of those urban roads, it is recommended such urban drainage system should be planned and implemented by ONAS in collaboration with MOEH. Due to limited and insufficient data and information, the preliminary deign of urban drainage system in the study area was not carried out if the frame of feasibility study.

CHAPTER 6 ENVIRONMENTAL IMPACT ASSESSMENT

6.1 Background

The existing environmental conditions in the Oued Hammam basin in terms of the economic development, problem of flooding and causes, environmental problems and water quality in the river stretches are summarized in Table 6.2 of the Master Plan Report (Part I). Additional detailed information is presented in the present chapter as part of the EIA of flood control measures for the Oued Hammam in Sousse. These supplement the information and results already presented for the Oued Hammam basin in the IEE conducted as part of the master plan study.

6.2 Existing Conditions

6.2.1 Physical Environment

(a) General Site Characteristics

The Oued Hammam is collecting the flood waters from various tributaries including Oued Laya, Oued M'Derraj, and Oued Guemgame before flowing into the downstream urban areas of Hammam Sousse city. It has a very large catchment area of 222 km2. Very flat plain is spreading in the upstream reaches and river courses are not clear in these areas. Lower reach of the Oued Hammam, south of GP1 in the touristic zone, is provided with dikes on both banks. Length of the improved section is approximately 350 m with a bottom width of 56 m. Large sized rocks have been placed on the river to cover exposed polluted stagnating water in the river. These river improvement works was carried out by the Ministry of Tourism under the guidance of MOEH. Upstream of this section, the river has been left in the natural condition where flooding risk is very high. Riverine landscaping in this area is very poor.

(b) Erosion Problems

Erosion problems like river bank erosion, erosion by wearing, layer erosion, and claw erosions in the agricultural fields are seen in the upstream areas due to the characteristics of the flooding phenomena and due to the cultivation practiced. The absence of a defined drainage system of rainwater due to undulating and gentle slope as well as soil characteristics results in rupture or birth of new ravine heads of variable dimensions following strong floods. This kind of erosion by wearing out is observed in the sloping basins of the Oued El Kebir, and the Oued Kharroub near Kalaa Kebira.

(c) Eutrophication

River eutrophication is extensive with very dense vegetation growth. Some river sections upstream are very dry due to the arid climate and are being used as pathways. River water quality is very poor especially near urban agglomerations due to discharge of untreated domestic and industrial waste water.

6.2.2 Human Use and Living Environment

In addition to natural causes, significant flooding and environmental problems in the Oued Hammam basin are due to human activities. A discussion of these problems is given below:

(a) Rapid urban growth and concurrence of city-countryside

The population distribution in Oued Hammam basin is characterized by a big concentration in the coastal urban towns. Hammam Sousse, Akouda, Kalaa Kebira, and K. Sghira, all have a population density greater than 3,000 persons per km2. The rural backside area of Hammam Sousse is almost empty. The countryside of Kalaa Kebira and Kalaa Sghira have a very low population. The outlying rural areas are progressively becoming depopulated to the advantage of the nearest urban agglomerations. This situation is not only disrupting rural life but also causing significant environmental problems in the urban areas. Rampant urbanization, often uncontrolled at certain sites, has resulted in excessive consumption of space and saturation of infrastructure, and caused pollution problems to aggravate. Some of these ill effects have resulted directly as a result of very rapid tourism development in the coastal region.

(b) Inadequate sanitation network and treatment facilities, and lack of drainage network

Hammam Sousse is equipped with a sanitation network of 34 km length and five pumping stations. The used water is collected and drained into the Sousse North Treatment Plant (only primary treatment) and then discharged into the sea. This plan has an average daily discharge of 8,700 m3 and treatment of 2,700 kg per day. With further expansion the plan will reach 17,430 m3 and 4,750 kg. It serves 66,500 inhabitants and a capacity 19,200 hotel residents.

Kalaa Kebira is equipped with a sanitary network of 35 km length and a pumping station for serving 19,000 persons covering about 40 % of the population of the area. This collected waste water is drained to the North Sousse Treatment Plant. The domestic waste water not linked to this sanitary network is discharged into the Oued El Kebir which is a tributary of the Oued Hammam at four points. The total average discharge corresponds to 4 m3/h.

Kalaa Sghira is equipped with a sanitation network of 17 km length covering 70 % of the population of the area. The collected water is discharged into the Oued Laya. A purification station is now under construction.

Akouda has a sanitation network of 20 km length with a pumping station serving about 64 % of the population of the area. A part of this collected water is drained towards the North Sousse Treatment Plant, while the rest is discharged directly into the Oued Hammam. This rate of flow is about 0.1 m3/h.

The localities of Kalaa Kebira, Kalaa Seghira, Akouda and Hammam Sousse are not equipped with storm water drainage systems. The storm water discharges artificially along the pathways towards the different rivers which cross the towns.

(c) Industrial Pollution and Garbage Disposal Problems

An inventory of the sources of pollution carried out in Sept. 1991 by the DPH showed that the pollution is essentially of an organic type due to discharged domestic waste water as described above into the river, due to garbage disposal and existence of rubbish deposits in the river bed, and discharge of 'Marjine' from olive processing into the river.

Garbage disposal into the river has resulted in many crossing structures on the rivers such as water bar, or bridges to be completely blocked allowing no flow of water. Rubbish and filth deposits exist in the basin of the Oued Laya near the cities of Hammam Sousse, Akouda, Kalaa Kebira and K. Seghira. The rubbish deposit of Hammam Sousse is very near the riverbed.

Nine factories use the riverbed of the Oued Laya for the discharge of 'Margine' and its oil in the city of Kalla Sghira. Olive extraction is done between Nov. and March and pollution is seen during winter. This discharge is reported to cause pollution of the ground water. The discharge of waste water has resulted in very significant eutrophication of the riverbed further aggravating the flooding problem.

(d) Encroachment of riverbeds

The encroachment of the riverbeds, especially in the upstream agricultural areas, has begun since decades. It is seen that well planted olive trees, pomegranate trees as well as market garden culture exist.

In the urban zone, the encroachment is in the form of illicit constructions very near or on the riverbed. This phenomenon is well developed in the Oued Laya basin and in the city of Kalaa Kebira.

6.3 Without Project Impacts

Most of the downstream and upstream stretches of the Oued Hammam have sufficient flow capacity for 100-year flood. However, in the middle reach around the confluence to the Oued Kebir, the flow capacity is only equivalent to 1- to 5-year flood. Inundation occurs at around the confluence of the Oued Hammam and the Oued Kebir and flood water flows downstream of this basin since inland slope is slightly steep. The potential flood inundation area is extensive and is increasing year by year. It is estimated that the flood inundation area is around 288 ha under present land use conditions and about 309 ha under future (year 2010) land use conditions for a flood of 100-year return period. For a 10 year retention period, these figures are 128 ha and 157 ha respectively. Estimated flood damages as seen in Chapter 9 of Part I are of the order of 36 million Tunisian Dinars (DT) under present land use condition and about 47 million DT under future land use condition for a flood of 100-year flood return period. Major part of these damages estimated are due to income losses from traffic delays (80 to 82 %), damage to property (10 to 11 %) and road damage (3 to 4 %) under present or future land use conditions.

Without the proposed structural measures for flood protection, the risk to flood damage would be very high. When flooding occurs, it would cause considerable economic disruption and losses. In addition to direct losses due damage to properties and roads, the indirect losses due to traffic delays would be very high as seen above. In the absence of the project (and thus the non-structural measures as well), the risk of communities to water related communicable diseases would also be high as there is significant discharge of domestic and industrial waste water and garbage disposal into the river basin.

6.4 With Project Impacts

Table 6.1 presents the EIA matrix.

6.4.1 Proposed Structural Measures

The proposed structural measures for flood protection of the Oued Hammam basin is only river improvement works. Enhancement of riverine landscape would become a very important component, especially in the downstream areas towards the sea where is prime touristic area. In the downstream reaches as well as in the reaches near and in the various urban conglomerations in dense residential or commercial areas, pedestrian ways and resting plazas with focal gardening need to be considered to rehabilitate the river zone.

For industrial areas, selected greenery and green buffer zones are very effective to protect and ameliorate the river environment. In the recreational areas, the river reserves could be used for diversified recreational uses. Jogging and cycling courses may be incorporated. In the agricultural area and buffer zone, some recreational trails with grass covered land and some potential riverine ecological conservation areas need to be considered.

In general, improvement of riverine landscape shall be done by improvement of river revetments, clearing of river reserve, improvement of river reserve, provision of observation plazas and resting areas, provision of walkways on bridge brink, conservation of natural vegetation, riverside walkway improvement in conjunction with the development of nearby touristic, business and/or residential areas and by harmonized design of riverine facilities and structures.

6.4.2 Negative Impacts

Negative impacts of the proposed river improvement works are not perceived. Resettlement or relocation of a few scattered families may need to be done since they are occupying and living on the riverbed itself in the upstream reaches. During the construction period, possible negative impacts could be temporary erosion and siltation problems due to the river improvement works. To minimize this negative effect, appropriate construction methods should be undertaken with due environmental considerations. Possible negative impacts during construction period and recommended mitigation measures are the same as for the Oued Ennkhilet area.

6.4.3 Positive Impacts

Project impacts are very positive as they will not only protect the population and infrastructure from floods, but they will also result in significant improvement of the riverine landscape and thus improve the quality of life of people living near the river. Appropriate riverine landscaping if undertaken as enumerated above would also improve the use of river reserve area for recreational purposes. Good landscaping is very important in residential and commercial areas as well as in the coastal touristic zone. River improvement works would also decrease the problem of erosion and river eutrophication to some extent.

Thus, from the above it is clear that compared with the wholly negative nature of the without project alternative, the social and natural environmental impacts of the proposed project structural measures are very beneficial. From an environmental point of view, the project is determined sound with no negative impacts. However, several environmental problems discussed in detail earlier will continue to persist until and unless suitable environmental mitigation and monitoring measures are also formulated and implemented along with the proposed structural measures. This is discussed in the next section.

6.5 Environmental Mitigation and Monitoring Measures

Environmental mitigation and monitoring measures are necessary in the post-construction period in addition to the proposed structural measures for reducing and controlling floods. These need to address the following issues:

(a) Formulation and implementation of land use plans. This is for preservation of green areas, agricultural areas, touristic areas, and protected areas, preventing new spontaneous housing in flood prone areas and rehabilitation of existing spontaneous settlements. Appropriate land use planning and effective implementation of policies is necessary. Plans for housing zone development catering to low income communities need to be formulated.

(b) Prevention of water pollution due to garbage disposal and domestic and industrial waste water discharges into the drainage system, streets and the river. Improved and regular monitoring as well as strict enforcement of pollution control laws is necessary. Garbage and solid waste collection system needs to be improved. Appropriate screening facilities need to be provided at strategic locations along the river.

(c) Watershed management activities and planting of vegetation along river banks should be undertaken in order to delay runoff and increase infiltration, thereby reducing the risk of flood.

(d) Prohibiting and preventing certain types of structures from being built on the flood way and flood plain to reduce risk. This can be done through formulation and implementation of zoning ordinances.

(e) Development of a flood warning system and an evacuation cum management plan for settlements or population in vulnerable flood prone areas.

(f) Formulating plans for provision of appropriate drainage systems and sanitation facilities for all of the study area.

(g) Environmental education and public awareness program for conservation of river and sebkhet environment should be formulated and implemented by making maximum use of mass communication media.

CHAPTER 7 RIVER AND FLOOD

7.1 General

Major floods recorded in Sousse in recent years are those in 1969, 1973, 1986 and 1989. The 1969 flood was particularly severe and many people were affected. In order to protect the residential properties and public facilities from these severe floods, some flood control structural and non-structural measurements are urgently required.

Flood inundation problems in the Oued Hammam become a serious social problem especially in the lower reaches year by year. One of the major causes is judged to be an urbanization in the Oued Kebir basin. Eventually this would bring about flooding problem in the downstream reaches. It is therefore urgently required to solve this flood problem by some effective means. In this chapter, present river basin conditions, river improvement progress, flood conditions and characteristic are described.

7.2 Oued Hammam River Basin

The Oued Hammam basin is located at the northwestern and western region of the Greater Sousse with a catchment area of 222 km2. The feather-shaped Oued Hammam basin is bounded by the Chabet el Menndra hills in the northwest and indistinct hills between the Oued Hamdoun in the southeast as shown in Fig. 7.1.

River basin is widely used as agricultural lands and main product is olive as described in Chapter 4. Urban area is spreading in northern area of this basin. Those major towns are Kalaa Srira, Kalaa Kebira, Akouda and Hammam Sousse, and are located along the Oued Hammam as shown in Fig.7.1, and those towns are being suffered from recurrent flood inundation.

There are major roads such as Touristic road, GP-1 road, and By-pass road of GP-1 are crossing in the lower urbanized zone of the project area. In addition to these major roads, first crass highway named A-1 road, that is crossing in the middle reach of the Oued Hammam. was completed during the Study period. This A-1 road is scheduled to be connected with the Greater Tunis near future. Touristic road and GP-1 road are often stopped by the flood water because there are no proper bridge now.

The Oued Laia, a main tributary of the Oued Hammam, is originated in Hennchie Chinchou area and travels some 30 km from southwest to northeast direction. Very flat plain is spreading in the upper areas and river courses are not identified clearly. The

Oued Hammam is collecting the flood water from the tributaries on the left bank and finally discharges into the Mediterranean Sea. Those major tributaries are the Oued Laia, the Oued Zebs, the Oued Kharroub, the Oued Kebir, the Oued Seghir, the Oued M'Darrej, the Oued Guemgame and the Oued Ghedir Ajila. These catchment areas are as follows;

Name of River	Catchment Area (km2)
Oued Laia (at Jct.with Zebs)	99.8
Oued Zebs	14.9
Oued Kharroub	12.4
Oued Laia (at Jct.with Kebir)	163.7
Oued Guemgame	12.6
Oued M'darrej	9.8
Oued Seghir	4.4
Oued Ghedir Ajila	11.0
Oued Kebir	40.3
Oued Hammam	222.3

River slopes of the main stream are approximately 1/400 in the upper reach, 1/550 in the middle reach and 1/750 in the lower reach respectively. There are rather deep valleys with a height of 10 to 20 m in the upstream from Kalaa Srira. Almost all stretches are under the natural conditions except lower reaches from GP-1 road where confining dikes have been constructed.

7.3 Flood Runoff Distribution

To grasp the scale of inundation area and the flood discharge capacities of the existing river, the flood runoff distribution at each return period is firstly prepared under the existing river conditions. The Oued Hammam basin is divided into sub-basins considering the topographical conditions, future flood control plans and existing flood control facilities. Fig.7.1 shows the divided sub-basins of Oued Hammam.

The flood runoff discharges are studied based on the divided sub-basins and river system models, which is described in Chapter 3, with due consideration of the present and future land use conditions, which are obtained from present and future land use plans.

The flood runoff distribution for the Oued Hammam basin is shown in Fig.7.2. Flood peak discharges for 10-yr and 100-yr floods from major tributaries are obtained as follows;

Name of River	Catchment Area (km^2)	Present land use 100-yr	Present land use 10-yr	Future land use 100-yr	Future land use 10-yr
Laia (at Jct.with Zebs)	99.8	100 m^3/s	50m^3/s	100 m^3/s	50 m^3/s
Zebs	14.9	40	18	40	18
Kharroub	12.4	26	12	26	12
Laia (at Jct.with Kebir)	163.7	130	60	140	65
Guemgame	12.6	35	16	40	18
M'darrej	9.8	30	14	40	18
Seghir	4.4	30	14	45	20
Ghedir Ajila	11.0	30	14	35	18
Kebir	40.3	95	45	130	60
Hammam	222.3	180	80	200	90

The peak discharges from the Oueds M'darrej, Seghir and Kebir are conceived to be increased up to approximately 1.4 times in future due to a rapid urbanization. On the other hand, the peak discharges from the Oued Laia basin will not increase so much because the changing of the land use in this area is assumed negligibly small.

7.4 Flood Discharge Capacity

To formulate the future river improvement plan, estimation of the existing river capacity is necessary. Flow capacity of the existing Oued Hammam is estimated by using uniform and non-uniform flow calculation based on the above flood runoff distribution.

Their results are illustrated in Figs.7.3 and 7.4. It is obvious that the lower end of the Oued Hammam where there is the confining dike has a sufficient discharge capacity to convey the flood runoff of 100-yr flood under the future land use conditions. The Oued Laia also has a sufficient discharge capacity against 10-yr flood. On the other hand, other stretches have only the flow capacity equivalent to 1- to 5-yr flood. This means some river improvement works are urgently required.

7.5 Floods and Inundation

The intensive interview surveys were conducted in order to identify the flooding areas in the Oued Hammam basin for the 1969 flood mainly. The interview survey results were checked up with the topographical maps and flood marks. Finally the boundary of flooded area by 1969 flood is delineated as shown in Fig.7.5. The figure shows that flood water spread from the junction of the Oued Laia and the Oued Kebir to downstream. The inundated area is estimated to be 3.5 km2 for 1969 flood.

Through the interview surveys, the following important information was obtained.

1) There was an agricultural intake structure constructed in 1936 between GP-1 road and Touristc road. This structure choked the flow area of the Oued Hammam and caused the big flood inundation in the upstream areas in 1969. During the 1969 flood, these main facilities were washed away by the flood water. There are remains on the right bank.

2) There is a bottle necked portion at just downstream of junction of the Oued Kebir and the Oued Laia. This section was narrower than present width. Right bank approximately 10 to 15 m were eroded by the flood water in 1969.

3) No river improvement works had been executed before 1969 flood along the Oued Hammam.

Judging from this information, it is obvious that the old Oued Hammam was much dangerous river than the existing Oued Hammam.

Flood inundation areas for each return period are assumed based on the above 1969 flood information, hydraulic analysis and topographical conditions. Fig 7.6 shows the assumed flood prone areas for 2-yr, 10-yr and 100-yr floods under the future land use condition. The figure shows big flood prone area is spread in the lower reach. Estimated flood inundation areas and duration are shown in Table 7.1 and summarized as follows;

Return Period	Flood Inundation Areas (ha)	
	Present Land Use	Future Land Use
2-yr	52	59
10-yr	128	157
100-yr	288	309

The potential inundation area is extensive and it is increasing year by year. It is desirable to carry out some flood control works as soon as possible.

7.6 Present River Facilities

River improvement works with the confining dikes have been carried out by the Ministry of Tourism under the guidance of MOEH from river mouth to GP-1 road except Touristic road site. Its total length is about 1,860 m. River bottom has been metalled by excessively large-sized rocks to cover exposed polluted stagnating water in river channel between the river mouth and the Touristic road. That length is approximately 350 m and a bottom width is 56 m. Upstream of this improved section has been left under natural condition in which flooding might occur easily.

MOEH prepared a flood control plan for the Oued Hammam in 1990. Flood control structures against 100-yr flood are recommended. Location and typical sections of these facilities are shown in Fig.7.7. Three small dams i.e., Laia Dam, M'Darrej Dam and Guemgame Dam located on each tributary are studied by the MOEH for flood control purposes. These dams were reviewed during the Master Plan stage and discarded for the further study because these dams were judged to be uneconomical.

CHAPTER 8 COMPARATIVE STUDY ON ALTERNATIVE PLANS

8.1 General

In the Master Plan Study, seven (7) flood control alternative plans with prospective retarding basins were studied and river improvement plan only was finally selected through a comparative study. This is because that the Oued Hammam basin spreads widely and the duration of flood peak time is rather long. It is clear that the construction of the retarding basin is not so effective for flood control in the lower reaches of the Oued Hammam basin. Then, river improvement plan only was studied for comparative study in the feasibility study stage.

Based on the flood damage studied in the feasibility study level in Chapter 10, flood damage along some river stretch is not so serious. There are not so important properties in the flood inundation area from the river stretch of the Oued Kebir between the MC-48 road and the railway crossing at the upstream, and the river stretch of the Oued Hammam between the By-pass road of the GP-1 and a confluence of the Oueds Kebir and Laia.

Then, flood control alternative plan for the Oued Hammam is formulated by selecting the river stretch to be improved. For comparative study of the alternative plan, as all the alternative plans have different benefit, not only river improvement cost but produced benefit are estimated. These plans are compared in terms of 10-yr flood. Some minor tributaries or tributaries where only some spots are required to be improved are discarded in the feasibility study.

8.2 Design Criteria of Flood Control Measures

For the formulation of river improvement plan and design of river facilities, the following basic design criteria are applied.

(1) River Improvement Plan

i) Designed river profile follows present river or ground profile, basically.
ii) Present river course are remained not to improve as much as possible.
iii) Deepening of riverbed is basically introduced not to cause the inner water, so that the flood water level is kept lower or almost the same with the ground level.
iv) River cross section is decided considering the land use condition along river course, existing structures, design flow velocity, etc.
v) In case the flood water level is higher than the ground level, following freeboard is principally applied :

50 m3/s > Design Discharge ... 0.6 m
50 m3/s ≤ Design Discharge ... 0.3 m.

vi) Non-uniform flow analysis is applied for designed channel flow calculation. The following roughness coefficient of Manning's formula is adopted. :
n = 0.035 .... for natural or earth lined river
n = 0.025 .... for concrete lined river
n = 0.023 .... for concrete lined pipe.

vii) For channel flow calculation, sea level is set at EL.0.4 m.

(2) Design of River Facilities

i) Total five (5) kinds of open channel and a box culvert are applied for design section of river stretch. These typical cross sections are shown in Fig. 8.1.
ii) Riverbed width of earth-lining section is at least 2.0 m.
iii) The site inspection road is basically applied for both sides of the river, of which width is 3.0 m.
iv) Bridge (Refer to Fig. 8.1)
Freeboard to soffit level .... Same as river improvement plan
Length of one span .... At most 20 - 25 m

8.3 Formulation of Alternative Plan

To formulate flood control plan, the river course consisting of the Oueds Hammam, Laia and Kebir is divided into nine (9) river stretches from H-1 to K-5. These river stretches are shown in Fig.8.2. The flood control work for each river stretch is planned based on the flood runoff distribution (Ref.: Fig.7.2). Their major improvement works are shown below.

<u>Oued Hammam</u>

The river stretch H-1 extends to just downstream of the GP-1 road from the river mouth. As this stretch was already improved and has an enough capacity for 100-yr flood, then improvement works are limited to the construction of a bridge over the Touristic road and deepening of riverbed near the GP-1. The river stretch H-2 covers from the GP-1 to the By-pass road of the GP-1, and improvement works are construction of the GP-1 bridge and forming of the proper river channel. The river stretch H-3 extends from the By-pass road to a confluence of the Oueds Laia and Kebir, of which lower stretch is a swamp area. The improvement for bottle neck section just upstream of the swamp is the major work in this river stretch. Also, construction of proper river channel for the swamp area can be one of alternative.

<u>Oued Laia</u>

The river stretch H-4 extends along the Oued Laia. Most of this stretch has an enough capacity for 10-yr flood except 250 m stretch upstream from the confluence. The improvement work on the stretch H-4 is construction of proper river channel for this short stretch in first stage, and deepening and widening for all the stretch are in the second stage.

Oued Kebir

The river stretch K-1 covers from the confluence to the MC-48 road, of which improvement work is rehabilitation of the existing bridge over the MC-48 road and construction of proper river channel. The river stretch K-2 & K-3 extends to a railway bridge. Most of this stretch has an enough capacity for 100-yr flood, but there is no proper river channel. To make channel can be one of the alternative plan. The river stretches K-4 & K-5 extend to a confluence to the Oued M'darrej and some bridges were already improved. The major improvement work for this stretch is deepening, widening and rehabilitation of the existing bridges.

Based on the aforementioned river improvement work, the improvement cost including direct construction cost and land acquisition cost, and flood damage are estimated for each river stretch. These are summarized below. Here, the bridge is assumed to be constructed or rehabilitated for 100-yr flood and the land required is also to be acquired in the first stage.

(Unit : DT1,000)

River Stretch	River Improvement Cost		Flood Damage (10-yr)	
	1st Stage	2nd Stage	Present	Future
H-1	2,448	0	2,030	4,993
H-2	1,137	42	459	771
H-3	487	104	66	261
H-4	136	232	5	7
K-1	795	127	20	72
K-2&K-3	590	118	10	13
K-4&K-5	706	275	46	127

It appears from the above table that flood damage from the river stretches H-4 and K-2 & K-3 is slight because of the elevated topographical condition along the present river course. And improvement of K-1, K-4 and K-5 are also not so economical by itself but it is necessary to improve these stretches because there are some bridges and these should be protected. On the other hand, flood damage from the river stretches of H-1 and H-2 is very serious, so that urgent river improvement work is required for those river stretches. Then, the following flood control alternative plans are formulated.

Alternative 1: This is a plan of river improvement work for all the river stretches from H-1 to K-5. This plan includes construction of proper river channel for the stretches K-2 & K-3 and swamp area of the H-3.

Alternative 2: This is a plan of river improvement work for river stretches H-1, H-2, H-3 excepting swamp area, H-4, K-1 and K-4 & K-5. In this plan, the construction of proper river channel for the stretches K-2 & K-3 and swamp area of the H-3 is not included.

Alternative 3 This is a plan of river improvement work for river stretches H-1, H-2, H-3 excepting swamp area, H-4, K-1 and K-4 & K-5. In the stretch H-4, river improvement work is carried out only for the short stretch near the confluence with the Oued Kebir.

The schematic diagrams for the above three (3) flood control alternative plans are illustrated in Fig.8.3.

8.4 Selection of Alternative Plan

Three flood control alternative plans are compared each other for the selection of most recommendable plan, by economic internal rate of return (EIRR) as one of the economic index for a public undertaking. For the calculation of the EIRR, the economic project cost and produced benefit by implementation of the project are required.

The project cost is estimated for each alternative plan, which includes direct construction cost, land acquisition cost, government administration cost, engineering service cost and contingency. Among these costs, the last three non-direct costs are estimated from the direct cost as described in Chapter 11. This project cost is converted to the economic cost in the way explained in Chapter 13 to be compared with the benefit.

Then, cash and benefit flow is prepared based on the assumed construction schedule, and the EIRR is estimated. The EIRR thus calculated is shown below.

Alternative Plan	EIIR
1	15.3%
2	17.0%
3	17.4%

According to the above, Alternative 3 is selected as the most recommendable plan. This plan is presented in Figs.8.4 and 8-5. The remained river stretches (H-3, K-2 and K-3) not to be improved in this plan are forming a natural retarding basin, then it will not cause social problem.

CHAPTER 9 SELECTED FLOOD CONTROL PLAN

9.1 General

Through the comparative studies in the previous chapter, river improvement works between the Touristic road and Bypass road of GP-1 on the Oued Hammam, on the lower reach of the Oued Kebir and the upper most stretches of the Oued Kebir are recommended to include the flood control plan for the Oued Hammam Basin. Considering the land use conditions and topographical conditions, further preliminary design for flood control plan is executed.

Following basic design conditions and criterion are applied for the preparation of the flood control plan.

1) Basic design flood is to be taken at 100-yr flood for the all rivers and those secondary channels.

2) 10-yr flood is to be adopted for the tertiary or drainage channels.

3) Stage-wise development

    i) First step development is to be considered on the basis of 10-yr flood for river improvement.

    ii) River or channel width should be kept sufficient for 100-yr flood for future development.

    iii) Determination of the priority river stretches is based on that not to cause the adverse effect in the downstream reaches.

9.2 Preliminary Design

For designing the river facilities, the basic design criterion that is described in the pervious chapter is applied. In addition to that design criteria, following criteria and conditions are introduced;

1) Crossing facilities such as bridge are to be considered on the basis of 100-yr flood principally even in the first stage development.

2) Land acquisition and compensation are to be considered on the basis of 100-yr flood even in the first stage development.

3) Location of embankment dike, if required, is to be considered on the basis of 100-yr flood even in the first stage development.

By applying the design criteria as described before and flood runoff distribution, preliminary design and the construction volume estimate are executed for each canal. There is a possibility to cause inner water problem along the riverain areas where embankment dikes are proposed. This problem will be almost solved by introducing the flap gate at the drainage sluiceway. Figs.9.1, 9.2 and 9.3 show the general plan, longitudinal profile and typical cross sections of the selected river improvement plan respectively. Dimensions of new bridges are illustrated in Figs.9.4 and 9.5.

9.3 Principal Features of Selected Plan

9.3.1 Stretch H-1

River improvement works between the river mouth and GP-1 road have almost been completed by the Tunisian Government. Major river improvement works in the first stage are the construction of the bridge for the Touristic road with river bank protection of 300 m long in the upstream, and shaping up of the river bottom at the downstream of the GP-1 road.

No river improvement is required for the second stage because river discharge capacity is sufficient for 100-yr flood after completion of the first stage work. Principal features are as follows;

Stretch H-1 (Oued Hammam from river mouth to GP-1 Road)

First Stage

(1)	River improvement	Design discharge : 200 m^3/s Bottom width : 36 m Length : 572 m Excavation : 15,100 m^3 Bank protection : 300 m on both bank
(2)	Bridge for Touristic Road	Width : 26 m Length : 84 m

9.3.2 Stretch H-2

The Oued Hammam is widely meandering at just the upstream of the GP-1 road. In addition to this, this section is very narrow and causes the flood inundation problems around there. A short cutting of the river is introduced at this stretch to solve those problems. New bridge for the GP-1 road with a length of 48 m is also urgently required because there is no bridge there at this moment.

Trapezoidal earth-lined section is applied because an enough space is available at the site. Excavation volume of 37,800 m3 and embankment volume of 2,500 m3 are required for constructing the new river channel in the first stage river improvement. In the second stage, heightening of the dike constructed in the first stage is proposed at this stretch.

Principal features are as follows;

Stretch H-2 (Oued Hammam from GP-1 Road to Bypass Road of GP-1 Road)

First Stage

(1)	River improvement	Design discharge : 90 m^3/s Bottom width : 33 m Length : 560 m Excavation : 37,800 m^3 Embankment of dike : 2,500 m^3 Bank protection : 60 m on both bank
(2)	Bridge for GP-1 Road	Width : 12 m Length : 48 m
(3)	Drainage Sluice way	2 nos.

Second Stage

(1)	River improvement	Design discharge : 200 m^3/s Length : 560 m Embankment of dike : 4,600 m^3

9.3.3 Stretch H-3

Characteristic of this stretch is divided into two categories. Lower half stretch is a low laying area and the bottle necked section continues in the upper half stretch. From economic and environmental points of view, river improvement works in the lower swampy area are discarded as described in the previous chapter. On the other hand, widening and deepening are essential at the bottle necked portion not only for the Oued Hammam but also for the Oued Kebir.

Trapezoidal earth-lined section is applied at the site. Excavation volume of 18,700 m3 and embankment volume of 2,600 m3 are required for widening and deepening at the bottle necked section in the first stage river improvement. In the second stage, heightening of the dike constructed in the first stage is proposed at this stretch. This embankment volume is estimated to be 3,800 m3.

Principal features are as follows;

Stretch H-3 (Oued Hammam from Bypass Road of GP-1 to Junction with Oued Kebir)

First Stage

(1)	River improvement	Design discharge : 90 m^3/s Bottom width : 33 m Length : 565 m Excavation : 18,700 m^3 Embankment of dike : 2,600 m^3 Bank protection : 50 m on both bank
(2)	Drainage Sluice way	2 nos.

Second Stage

(1)	River improvement	Design discharge : 200 m^3/s Length : 565 m Embankment of dike : 3,800 m^3

9.3.4 Stretch H-4

Since the river improvement works is discarded for this stretch from the economical point of view in the previous chapter, small river improvement works are required to convey the flood water smoothly at the junction with the Oued Kebir. River stretch of approximately 250 m is proposed to be improved. Principal features are as follows;

Stretch H-4 (Oued Laia from Junction with Oued Kebir to Upstream)

First Stage

(1)	River improvement	Design discharge : 65 m^3/s Bottom width : 8 m Length : 250 m Excavation : 1,900 m^3 Embankment of dike : 2,600 m^3 Bank protection : 30 m on both bank
(2)	Drainage Sluice way	2 nos.

Second Stage

(1)	River improvement	Design discharge : 140 m^3/s Bottom width : 20 m Length : 250 m Excavation : 2,700 m^3

9.3.5 Stretch K-1

The Oued Kebir is going down from the crossing point with the MC-48 road to the junction with the Oued Laia. There is no proper river course in the lower stretch and eventually this condition causes the flood inundation problem around there. New bridge for the MC-48 road with a length of 30 m is also urgently required because there is no bridge there.

Trapezoidal earth-lined section is also applied at this stretch. Excavation volume of 23,300 m3 and embankment volume of 8,100 m3 are required for constructing the proper river channel in the first stage river improvement. In the second stage, widening of the river channel from 7 m to 18 m is proposed. That excavation amount is estimated to be approximately 22,300 m3.

Principal features are as follows;

Stretch K-1 (Oued Kebir from Junction with Oued Hammam to MC-48 Road)

First Stage

(1)	River improvement	Design discharge : 60 m^3/s Bottom width : 7 m Length : 884 m Excavation : 23,300 m^3 Embankment of dike : 8,100 m^3 Bank protection : 60 m on both bank
(2)	Bridge for MC-48 Road	Width : 15 m Length : 30 m
(3)	Drainage Sluice way	2 nos.

Second Stage

(1)	River improvement	Design discharge : 130 m^3/s Bottom width : 18 m Length : 884 m Excavation : 22,300 m^3

9.3.6 Stretch K-4

Stretch K-4 is a very short stretch from the railway to the junction with the Oued Seghir. Existing railway bridge has a sufficient flood discharge capacity, however corrugate pipes under the MC-48 road locating at just upstream of the railway bridge is too small to convey the design flood. Then new bridge with a length of 27 m is proposed at the MC-48 road.

Principal features are as follows;

Stretch K-4 (Oued Kebir from Railway to Junction with Oued Seghir)

First Stage

(1)	River improvement	Design discharge : 45 m^3/s Bottom width : 6.5 m Length : 84 m Excavation : 1,600 m^3 Embankment of dike : 700 m^3 Bank protection : 60 m on both bank
(2)	Bridge for MC-48 Road	Width : 12 m Length : 27 m

Second Stage

(1)	River improvement	Design discharge : 100 m^3/s Bottom width : 17 m Length : 84 m Excavation : 600 m^3

9.3.7 Stretch K-5

River is going down the narrow valley along the outside of the Kalaa Kebira. Since three culvert type bridges have been constructed recently along this stretch by MOEH, there are two more small bridges to be replaced. Widening and deepening are required for the existing river channel for the first stage.

Trapezoidal earth-lined section is applied at this stretch. Excavation volume of 14,900 m3 and embankment volume of 10,300 m3 are required in the first stage river improvement. In the second stage, widening of the river channel from 4.5 m to 12 m is proposed. That excavation volume is estimated to be approximately 21,300 m3. Additional box culverts are required at each small bridge in the second stage.

Principal features are as follows;

Stretch K-5 (Oued Kebir from Junction with Oued Seghir to Upstream)

First Stage

(1)	River improvement	Design discharge : 35 m^3/s Bottom width : 4.5 m Length : 1,532 m Excavation : 14,900 m^3 Embankment of dike : 10,300 m^3 Bank protection : 130 m on both bank
(2)	Culvert for Small Road	Twin type, width : 4 m & height : 2.6 m Length : 8 m 2 site
(3)	Drainage Sluice way	2 nos.

Second Stage

(1)	River improvement	Design discharge : 75 m^3/s Bottom width : 12 m Length : 1,532 m Excavation : 21,300 m^3 Bank protection : 100 m on both bank
(2)	Culvert for Small Road to add existing culverts	Single type, width : 4 m & height : 2.6 m Length : 8 m Number : 10 nos. (5 site on both banks)

CHAPTER 10 ESTIMATION OF POTENTIAL FLOOD DAMAGES

10.1 Introduction

10.1.1 General Background

The areas affected by flooding in the Oued Hammam lie within the Communes of Hammam Sousse, Akouda, and Kalaa Kebira. The impact of flooding will be felt in residential, agricultural, and industrial and commercial areas. In addition to the specific impact, a general impact will be felt on population residing within the vicinity of the Oued and on transport flows within and between some of these areas.

The assessment of damages is estimated for different sections of the Oued in order to enable separate evaluations to be made for the alternative works proposed and to enable proper phasing so as to optimize expenditure. The evaluation is based on the extent and duration of potential flooding estimated by the Consultants, and on interviews with Officials and local residents concerning their judgments on the impact of previous floods. These are only considered as indications, since the last major floods occurred in 1969. No specific damage assessments of previous floods have been made in the past for Oued Hammam.

10.1.2 Population Affected

The zone of influence of potential flooding will extend beyond the flood-prone areas since it will indirectly affect the populations in the Communes located in the vicinity. All these Communes have high rates of urbanization - Akouda 81.6%, Kalaa Kebira 87.17% and Hammam Sousse effectively 100%. According to the Urban Master Plan for the Sousse-Monastir area, these towns will continue to be important centers of urban expansion in the future. Projections of population are made on the basis of growth rates to the year 2002 from the latest Urban Development Plans for Akouda and Hammam Sousse (Plan d'Amenagement Urbain de la Commune de Hammam Sousse, et Plan d'Amenagement Urbain de la Commune d'Akouda, 1991), and those for Kalaa Kebira based on forecasts of the Urban Master Plan for Sousse-Monastir (Plan de Developpement Urbain pour la Conurbation de Sousse- Monastir, 1993).

The rate of growth for Hammam Sousse is estimated in the Plan at 5.97%. However, such a rate cannot be expected to be maintained over the long term, since high saturation rates will be reached, and there is limited space for expansion. Accordingly, future growth rates beyond 2002 are reduced to 4% p.a. for Hammam Sousse and 3% for the other two Communes. On these assumptions the population of the three Communes is expected to exceed 200,000 by the year 2020.

10.1.3 Impact on Transport

One of the major consequences will be the disruption to traffic, in terms of delays through the flooding of roads. This will apply both to local and to through traffic. The Oued Hammam is traversed by three important roads - the GP-1, the by-pass to the GP-1, and the RVE 845 (the touristic road). Serious flooding in the past has caused considerable problems through the closure of the GP-1 and the RVE 845, and considerable delays on the GP-1 by-pass, as well as the MC-48 road which runs from Hammam Sousse to Akouda. However the problem has been alleviated to a large extent by the opening in 1993 of the Autoroute which bypasses the town, the result of which has been to divert a significant part of through traffic from the GP-1. Despite this, traffic on these roads still remains considerable and can be expected to increase rapidly as urbanization and tourist development proceeds.

Table 10.1 shows the results of a 1992 traffic census on the GP-1 and GP-1 Bypass. Since the full impact of the Autoroute on this traffic needs to be evaluated some assumptions are made on the traffic diverted from the GP-1 to the Autoroute. Informal assessments by the local Authorities indicate that perhaps 50% of 1992 traffic has been diverted. Table 10.2 shows the present estimated levels of traffic on the GP-1 and the GP-1 By-pass. These are estimated at nearly 6,000 movements per day on the GP-1 bypass, and 9,300 for the GP-1. Table 10.3 shows the results of the traffic census on the MC 48 and RVE 835. Traffic on the RVE 845 is not expected to have been affected by the Autoroute, while that on the MC 48 could even have increased due to traffic using it to access the Autoroute. Daily flows are estimated at 12,322 for the MC 48, and 13,319 for the RVE 845.

Traffic is expected to grow in line with GDP forecasts to the year 2000 i.e. 6% p.a. However in view of the probable saturation of the roads thereafter, lower growth rates can be expected, and rates of 4% p.a. (between 2000 and 2010) and 2% p.a. (between 2010 and 2020) are used to estimate flows. Estimates of the number of passengers are based on typical occupancy rates in Tunisia (as used in the Transport Master Plan for Tunis).

Tables 10.4 and 10.5 show traffic and passenger estimates for the GP-1 By-pass and for the GP-1 for 1993 and the year 2020. Tables 10.6 and 10.7 show the forecasts for the

MC 48 and the RVE 835. These estimates of future traffic flows are used below for the calculations of the benefits for the various sections of the flooded areas of the Oued Hammam.

10.2 Methodology

10.2.1 Introduction

An assessment of the direct and indirect costs associated with flooding will depend on the extent, depth and expected duration of the floods. An analysis of flood damage is made on two base cases : impact under present land use conditions, and impact under future land use conditions. Damage assessment has been made for 1-yr, 10-yr and 100-yr return periods. Flood damage has been assessed in categories related to residential, industrial and commercial and, agricultural areas; the analysis also considers the effect of flooding on roads and transport movements.

10.2.2 Damage and Losses in Residential Areas

(1) Introduction

Some residential areas affected particularly in the immediate vicinity of the oueds include spontaneous housing. It is clear that damage to spontaneous housing will need to be taken into account, since there appear to be no moves by the Authorities to resettle residents to officially designated areas. Land use estimates have been made of the potentially flooded areas; housing densities and the number of houses affected are based on site visits.

The main damage categories attributable to the flood, will be physical damage caused to buildings and to household effects, and potential loss of income to residents through disruption.

(2) Damage to Buildings

(a) Methodological Approach
In broad terms, indicative flood damage particularly in residential areas is generally obtained through a comparison of land values for similar property in flooded and non flooded zones. In normal circumstances, flooding should have an impact on property prices. However, in the Oued Hammam, exposure to flooding does not seem to be a contributory factor in determining land and house prices. The range of land prices quoted

in Sousse and within potentially floodable areas is wide, and cases even exist where similar neighboring properties in the same area have a considerable price differential.

It is evident that factors other than potential flooding have a greater influence in determining prices, such as, proximity to Sousse Center and Tourist areas. It should be noted that in present circumstances, flooding is regarded by occupiers to be a temporary phenomenon. Spontaneous housing is a phenomenon observed along the Oued Hammam, and in some cases these are located in areas which are easily prone to flooding.

Another approach to estimation of flood damage - the contingent valuation approach ("assessment of the willingness to accept compensation for the inconveniences caused by flooding") is considered invalid, in view of the infrequency, and little damage actually experienced since 1969. Difficulties are likely to be encountered in arriving at unbiased and undistorted opinions about the "willingness to pay" of the different respondents. Actual market behavior relating to, for example, property values in flooded as against non-flooded areas has been distorted by the pressure on accommodation within most of the urban area, and it would be extremely difficult to assign realistic values to any hypothetical environmental improvements.

A separate approach to evaluation of the likely benefits of the projects is to use the hedonic method as applied to property prices, between flooded areas and similar homogeneous areas. In principle, the difference in values is taken as an indicator of the likely premium paid to avoid the inconveniences and damage caused by flooding. However, an investigation of the municipal rates shows that these reflect neither the true value of properties nor the environment in which they are located, but are set rather on an basis which does not reflect economic factors. Property values are therefore not considered to be a valid basis for estimating flood damage in the Oued Hammam. It is therefore proposed to use rehabilitation and building construction costs as a proxy to assess the impact of flooding.

(b) Assumptions

Land use has been estimated for the potentially flooded areas, and an analysis and survey of existing housing and construction within these areas been carried out. Increasing urbanization is a phenomenon which is likely to carry on in the potentially floodable areas. Estimates are therefore made for built-up areas under present and under future land use conditions.

The impact of flooding on buildings will be felt on the deterioration of foundations and rehabilitation required in repairing walls and plaster work and other physical damage.

Since it is impossible to carry out surveys on all individual buildings likely to be flooded, some general criteria is used.

Estimation of typical construction costs is notoriously difficult in view of physical factors relative to specific sites. An analysis of data provided by SNIT (Etude des couts de production des logements dans le District de Tunis), indicates that foundation costs for a building vary between 5% and 12% for SNIT buildings, and are generally around 8% in the private sector. The cost of interior decoration and glass used is between 5% to 6%. These costs are generally therefore between 10% and 18%. For the purposes of the analysis, flood damage is estimated at 10% of construction costs.

While these are naturally variable depending upon the nature of terrain and type of construction and finish, two categories of housing are considered. In general, social class housing is estimated to have a unit cost of around DT150/m2 to DT200/m2, and medium standard housing of DT250/m2 to DT300/m2. Costs of spontaneous housing are estimated at the same level as social class housing. Unit cost of DT15/m2 and DT25/m2 are used to calculate flood damage for the two categories.

Housing Density is based on site visits. Where this has not been possible, data from other studies (ONAS) have been used. For spontaneous and popular housing, average typical constructed areas of 60m2 are assumed, and for medium standard housing coefficients of 100m2.

(3) Losses of Household Articles

The value of typical items of household articles in a middle class house, is estimated at around DT3,500. This includes refrigerators, cookers, furniture, carpets, mattresses, clothes and food items. Experience in other countries indicates that flooding of up to 1 meter results in damage of around 10% to household articles. This climbs significantly to nearly 70% at a height of more than 3 meters. Although there are certain areas in Oued Hammam where the height of the water surpassed 1 meter in the great flood of 1969, it is unlikely that this will be exceeded. It is therefore proposed to use 10% of the value of goods as indicative of the likely flood damage (i.e. DT350 per house).

(4) Losses of Income to Residents

It is assumed that disruption caused by flooding will result in loss of income to residents and households. Population density is based on socio-economic data collected for the areas, or if not available, data for neighboring areas has been used. In Oued Hammam this is estimated to be 200 persons per ha. In Sousse the general criteria used for Planning is assumed at 5 persons per household.

The number of workers per household will vary according to the active population and the level of unemployment in different areas. Official figures are likely to be misleading since they do not take into account the informal sector. For example, a survey carried out in 1984, showed that in the Sousse area, unemployment rates ranged from 4.3% in Hammam Sousse to 19.2 % in M'Saken. Employment data for the towns concerned for 1984 is shown in Table 10.8. This indicates that generally employment was around 1.6 workers per household. For the purposes of estimating damages, it is assumed that there will be 2 workers in each household affected.

Projections of wages have been made till the year 2020 based on increasing incomes in line with expected growth of GDP (6% p.a. till the year 2000, 5.5% between 2000 and 2010 and 5% between 2010 and 2020). On this basis the estimates for skilled labor are DT16 per day at present and DT67 per day in 2020, and for unskilled labor DT5 and DT22 respectively.

10.2.3 Losses to Industry and Commercial Enterprises

Losses can be measured in this sector in terms of loss of income for workers, actual damage to the physical assets of a company and disruption to factories resulting in higher costs for the delivery of raw materials and transport of finished products. In order to account for periods of starting up after flood, additional days of inconvenience will be felt beyond the period of flooding.

It is assumed that damage to industrial buildings will be less than to residential buildings, in view of their more basic construction and simpler decoration. Since most of the industry is of a light or commercial nature, actual physical damage will not be significant, and damage is assumed at 5% of construction cost, estimated at DT300/m2 i.e. DT15/m2. The loss of income for workers for the duration of the flooding is based on the estimated wages, as calculated above.

10.2.4 Losses to Agriculture

Flooding will result in damage to crops. It is, however, considered that there will be no loss of further agricultural land through erosion. Agricultural areas prone to flooding are estimated below on present and future land uses.

Major crops grown in the Oued Hammam include vegetables, market produce, and olives. Productivity of the land varies enormously as do prices. It is expected that the flood damage will be serious enough to cause a loss of one harvest. In order to arrive at general estimates of damage, it is assumed that production is shared equally between olives and vegetable products. The range of olive production in areas adjacent to the Oued Hammam varies from 27 kg/tree to 150 kg/tree. Assuming a density of 200 trees per hectare, and an average productivity of 50 kg per tree, total production is estimated at 10,000 kg, which at current prices (DT0.160/kg), puts a value of the crop at around DT1,600 per hectare.

With regard to vegetables, typically, potatoes are grown in the area at a productivity of 12 Tons/ha. on the basis of two crops per year. Current market prices range between DT0.150 and DT0.300. Assuming a medium price level of DT0.200/kg, losses are estimated at DT1,200 per ha per crop. For agricultural areas in general, the loss is therefore assumed at an average of these crops of DT1,400 per ha.

10.2.5 Losses to Transport

(1) Road Damage

It is assumed that in both present land use conditions and expected future land use, roads flooded will need rehabilitation. Construction costs for a new two way road are estimated at around DT240,000 (excluding taxes). Rehabilitation costs are estimated at 50% of the construction cost, and are assumed at DT120,000 per km for primary roads and DT80,000/km for secondary roads, based on a general estimate provided by the Department of Bridges and Roads. The construction costs for basic agricultural roads (pistes) are estimated at DT25,000 per km. However in order to avoid such damage in the future, and to improve the general environment for tourism, it is proposed that a bridge replace the crossing of the Oued Hammam on the RVE 845 Tourist road. This is costed at DT2.1 million.

(2) Traffic Delays and Value of Time

For the purposes of the evaluation, it is assumed that the roads will be cut off for the duration of the floods in a 100-yr probable flood. This will entail delays and diversions to other roads, and will result in loss of income. The number of passengers affected is based on the vehicle occupancy rates from the latest surveys, and on traffic projections based on the latest traffic data available, as estimated in Section 10.3. The value of time of passengers is calculated on forecasts of wages to the year 2020 (see Paragraph

10.2.2). In transport studies generally, the loss of leisure time is calculated at 20% of salary levels, and that of business time at 33% of hourly income. Due to lack of sufficient data in the traffic surveys on purpose of journeys it is proposed to apply an average factor to all journeys. The value of time is therefore taken at 25% of earnings.

At current rates the appropriate value is estimated to be DT0.5 per hour for skilled labor and DT 0.16 per hour for unskilled labor at present. These are assumed to increase in line with expected GDP growth and to be DT2.1/hour and DT0.7/hour respectively in the year 2020. It is further assumed that passengers in private cars and taxis will be in the skilled labor bracket and all others (using buses, trucks and passengers on two wheels) will be unskilled. Tourist traffic will be affected and, it is proposed to use the additional taxi fares concerned as a proxy for the inconvenience caused.

(3) Increased Vehicle Operating Costs

There are two elements of costs involved here. Additional operating costs due to the diversion, and increased vehicle costs due to travel on damaged roads. While it is assumed that the level of flooding will be sufficient to halt traffic completely during the period of inundation, a further impact will be felt in the increased operating costs experienced by vehicles both as a result of more difficult operating conditions and following the degradation in the road surface. This additional cost should be included in the damage assessment. For the purposes of the evaluation it is assumed that the increased operating costs apply for the duration until the road is repaired, and that it will take 30 days to repair the damaged roads. The costs of increased vehicle operation are based on assumptions from the World Bank HDM III model, assuming different degrees of roughness of surfaces in a "with" and "without" situation.

On the basis of the HDM III model, it is assumed that in the "without project case" the section of road affected by flooding is in poor shape, with visible irregularities and shape defects, (this represents a "roughness " level of 71.5 to 91 m/km). In the "with project case" i.e. without flooding, the state of the road is considered as high quality asphalt road (i.e. with a specification of 21-33 m/km). The difference in vehicle operating costs between these categories of road are shown in Table 10.9. These rates are applied to the existing and forecast traffic flows. It is assumed that damage to road surfaces will be the same in cases of present and future land use conditions, but duration of flooding will be different.

10.2.6 Other Factors

The major unquantifiable factor here is the impact on health. This is difficult to assess due to lack of sufficient data, and the problem of attributing diseases to local flooding problems, rather than other causes which may lie outside the study area. Interviews with the Health Authorities indicate that flooding and stagnant water has not hitherto caused the contraction of any serious water-borne diseases among residential populations. This is a potential problem for which concern has been expressed. An analysis of present flooding shows that overflows from the oueds are only one of several causes creating unhealthy environments.

The following are contributory factors for which solutions will need to be found:
-the overloading of networks due to encumbrance from solids - erosion of hills, as well as waste from housing and other works
-the malfunctioning of the secondary networks particularly in housing areas
-Increased flows due to high rates of urbanization in previously agricultural areas
-Construction of numerous obstacles and the infilling of the Oueds, particularly in zones of spontaneous housing
-Insufficient maintenance works

Another major unquantifiable factor of flooding in Hammam Sousse is the impact of adverse publicity on tourism. A further potential hazard is the damage and disruption likely to be caused to the ONAS treatment plant located at the side of the oued.

10.2.7 *Summary of Coefficients used in Estimating Flood Damages*

The various factors and coefficients used for estimating flood damage are summarized as follows; It is difficult to estimate future inflation rates for property and commodities; wages are assumed to rise in line with GDP. For other factors, present rates are maintained. Future damage estimates can therefore be considered to be conservative, and these items can be subject to sensitivity studies.

Summary of Coefficients Used to Estimate Flood Damage (DT)

Category	Coefficient	
	Present (1993)	Future (2020)
1. Residential Areas		
(i) Damage to Buildings		
*Popular/Spontaneous Housing	$15/m^2$	$15/m^2$
*Medium Standard	$25/m^2$	$25/m^2$

(ii) Damage to Household Articles (per household)	350	350
(iii) Loss of Income to Households (DT per day)		
*Skilled	16	67
*Unskilled	5	22
2. Industrial Sector		
(i) Damage to Buildings	$15/m^2$	$15/m^2$
(ii)Loss of Income to workers		(as per households)
3. Agricultural Sector (per hectare)		
(i) Value of Olive Crops	1,600	1,600
(ii)Value of vegetable crops	1,200	1,200
4. Transport		
(i) Rehabilitation of Roads (per km)		
*Primary120,000	120,000	
*Secondary	80,000	80,000
*Agricultural Roads	25,000	25,000
(ii) Traffic Delays/Value of Time (DT per hour)		
*Skilled Labor	0.5	2.1
* Unskilled Labor	0.16	0.7
*Tourists	1.0	4.0
(iii) Additional Vehicle Operating Costs (DT per 1,000 km)		
*Private Cars/taxis	28.79	28.79
*Buses	51.60	51.60
*Light/Medium trucks	86.11	86.11
*Heavy trucks	236.73	236.73

10.3 Evaluation of Flood Damages

10.3.1 Introduction

Given the different socio-economic mix of parts of the Oued Hammam, it is convenient to analyze the damage attributable to potential flooding in several distinct areas, as indicated in Figure 10.1. For each case assessments are made on the basis of present and future land use conditions and in the context of a 100-year flood. Potential damages in 1-yr and 10-yr probable floods are summarized in Sub-section 10.4.2.

10.3.2 Estimation of Flood Damages - Zone A

(1) Characteristics of the Zone

This area is located on the coast, from the River mouth to GP-1 road. Land utilization is mixed, consisting of tourist, residential, industrial, agricultural areas. Experience of the major flood in 1969 shows that in some places water remained generally for one to three days, but in low lying areas it persisted for up to 20 days. Depth varied between 0.2 and 1.5 meters. The tourist road was closed for at least two days. Maximum flood duration will be 36 to 39 hours. A breakdown of the different categories of land affected under present and future land use are as follows;

Land Use Characteristics of Flooded Areas in Zone A (Ha)

	Conditions	
	Present Land Use	Future Land Use
Agricultural	107	74
Urban	30	70
Open	16	16
TOTAL	153	160

Although there is no tourist development directly affected by the flooding in the oued, there will be an impact on neighboring Hotels in terms of unpleasantness, as well as considerable inconvenience to movement from and to El Kantaoui, and other future tourist developments such as Hergla.

The zone also has the ONAS sewage treatment plant (Sousse Nord SE5) with an average daily discharge of 8,700m3 per day, and treatment of 2,700 kg per day. Expansion plans are underway, and capacity is expected to rise in the near future to 17,430m3 and 4,750 kg respectively. The plant serves an estimated 66,500 inhabitants and 19,200 hotel residents. The plant is a primary treatment plant only, and there is likely to be some effect in overflow of sewage from the network. The closure of operations of the plant from the network will have a major effect on hygiene and health conditions in the north of Sousse. There will also be adverse publicity through the pollution of the coastal area. However, this element of potential damage is not costed.

(2) Loss of Income to Residents

The main area where residents will be affected is Hammam Sousse. The built up areas affected are estimated at 30 ha under the present land use conditions, and 70 ha in future land use conditions. Within Zone A, some of these areas are commercial and light industrial, particularly in the area near ONAS, and on the GP-1. It is estimated that 75% of the built-up area will consist of residential property, i.e. 22.5 ha and 52.5 ha respectively.

In order to calculate the number of households affected, socio-economic criteria from planning documents from Hammam Sousse and Sousse town are used. Density in Sousse town is estimated on average at 275 persons per ha. Site visits, however indicate that at present housing is more scattered. It is therefore proposed to use a lower density of 200 persons per ha., for the area likely to be affected. This represents a population affected of 4,500 under present land use conditions. Given the rapid rate of urbanization expected density can be expected to increase and it is proposed to use a density of 275 for the year 2020. On this basis future population affected will be in the region of 14,500 persons.

According to the population census there were 5.48 persons per household in Hammam Sousse. On this basis the total number of households affected at present will be 820. The Master Plan for Sousse estimates future household size at 5 persons per household, and on this basis one can expect there to be 2,900 households in the flood prone areas.

On the basis of 2 workers per household, and average salaries of DT67 per day in the year 2020, income losses will amount to DT330,000 on the basis of 3 days loss of work, (under present land use conditions), and DT1,554,000 (assuming 4 days loss of work, under future land use conditions).

(3) Damage to Residential Buildings

In order to estimate the amount of constructed areas, it is assumed that 50% of the households inhabit popular or standard housing (average areas 60m2), and the rest in medium type housing (100m2). Residential areas are therefore estimated at 65,600m2 under present land use conditions and 232,000m2 under future conditions. On the basis of damages at DT15/m2, DT 25/m2 respectively, total flood damage to residential building is estimated at DT1,394,000 and DT4,930,000 respectively.

(4) Damage to Household Articles

Although there are certain areas in the zone where the height of the water surpassed 1 meter in the great flood of 1969, it is unlikely that this will be exceeded. Under present land use conditions with 820 households affected damage is estimated at DT287,000, and in future land use conditions 2,900 households at DT1,015,000.

(5) Damage to the Industrial Sector

Losses can be measured in this sector in terms of disruption to factories resulting in higher costs for the delivery of raw materials and transport of finished products, loss of income for workers and actual damage to the physical assets of a company. Sufficient data is not available on individual companies in terms of output and revenue. Costs of flooding are based on the loss of income to workers.

In estimating the number of employees in the floodable areas, it is proposed to use the average employment per factory in Hammam Sousse. Table 10.10 gives data on employment in the Industrial Sector in the area. The average number of employees per factory in the area is estimated at 29.

A survey of the area shows that apart from ONAS, most of the buildings are used for light industry and commercial enterprises. Several of these are under construction at present and it is understood that more are proposed. Under the present land use situation, it is assumed that there will be 25 units affected and that these will double in the future to 50, representing 725 and 1,450 employees respectively.

During the flood period, the industries will be unable to work, and that there will be supplementary delays in order to restart production and repair damages. Under present land use conditions, it is estimated that 5 days losses will be incurred, and under future conditions, 6 days. In terms of income loss, this represents DT243,000 and DT583,000 respectively.

Structural damage to industrial and commercial buildings will be far less than to residential buildings. These areas are estimated at 8 ha under present land use conditions and 18 ha. under future conditions. Assuming 50% of the area will be occupied with built-up areas, these are estimated at 4,000m2 and 18,000m2 . On a basis of flood damage at 5% of construction costs of DT300/m2, the damage to buildings is estimated at DT60,000 and DT270,000.

There will also be damage to stock and assets. This element is difficult to estimate in view of the lack of data, and the fact that most of these light industrial and commercial activities are still under construction. A notional amount of DT100,000 is proposed for the present land use condition, and this is increased pro-rata to DT450,000.

(6) Losses in the Agricultural Sector

Although there are an estimated 107 ha in the zone which are likely to be flooded, this number is expected to reduce significantly due to increased urbanization to 74 ha by 2020. At present the zone grows olive trees, vegetables and market produce, such as potatoes. It is assumed that 50% of the area (37 ha) is cultivated with olives and the remainder with potatoes. Value of production has been estimated at DT1,600 per ha. for olives, resulting in a loss of DT59,200. It is assumed that vegetable crops are grown in the other half of the area affected (37 ha). Typically, potatoes are grown in the area. On the basis of a loss of DT1,200/ha per crop, losses are estimated at DT44,000. Total losses in agricultural production will therefore be around DT103,000 under future land use conditions. On a pro-rata basis losses under present land use (107 ha) will amount to DT149,000.

(7) Transport and Traffic Losses

(a) Loss of Income to Passengers
It is assumed that the tourist road (RVE 845) and local roads bordering the oued including the road in the industrial estate and local agricultural roads, will be cut off for the duration of the flooding. According to the experience of the 1969 flood, the main road was closed for up to 3 days. It is probable that this could be a longer period due to clearing up operations, but for the purposes of the evaluation it is assumed that the roads will be cut off for 3 days in present land use conditions and 4 days in future land use conditions. Traffic will divert to using the by-pass of the GP-1 which will remain unaffected by the flood - a diversion of nearly 5 km. This will entail increased Vehicle Operating Costs (VOCs), as well as longer journey times. The diversion of traffic will as a result of congestion add one extra hour's journey time to passengers.

The estimates of the number of passengers affected is 52,700 at present rising to 143,000 in the year 2020 (see Table 10.7). Passengers can be divided into three categories: tourists, skilled labor and unskilled labor. A significant part of this traffic will be related to tourism. Latest figures show that Sousse received 634,000 tourists in 1992. Since the Oued Hammam effectively divides the tourist areas, movements in both directions will be affected. The El Kantaoui area has a large number of important hotels (Hannibal, Bulla Regia, Hasdrubal, Kantaoui, Marhaba etc.), with an estimated 9,000 beds at present. Two further hotels are under construction - the Club Tergui, and the Club Mediterranee. In the Master Plan for Sousse it is proposed to intensify the density of tourist development from 110 beds/ha to 170 beds/ha. The total number of hotel beds in El Kantaoui is expected to reach 20,000 in the future. With an average occupation rate of 60% over the year, it is therefore likely that an average number of tourists in Kantaoui will be 5,400 at present and 12,000 in the future. This figure can be considered to be conservative since future tourist developments along the coast (e.g. Hergla) are not taken into account. In addition, there is considerable movement of traffic from Sousse to Kantaoui of other tourists staying in Sousse. Total existing beds in Sousse are estimated to be 23,000. At an occupancy rate of 60%, this will amount to an average of around 14,000 tourists in Sousse town. Future development will be limited due to space restrictions. Assuming higher rates of occupancy, the number of tourists in Sousse is assumed to be 20,000 by the year 2020.

In order to arrive at approximate estimates of the number of tourists wishing to move between El Kantaoui and Sousse on any one day, it is assumed that one third will wish to make the journey in both directions. On this basis out of nearly 20,000 tourists at present, 6000 will want to travel (12,000 movements); in the future this figure will be 10,000 tourists (20,000 movements).

It is difficult to impute a value to the time of tourists since their leisure time cannot be costed at their own domestic earnings. For the purposes of the analysis, taxi fares for the additional journeys via the deviation are used as a proxy. These are estimated at DT1.0 at present and DT4.0 in the future.

It is assumed that other passengers using private cars and taxis will be at skilled labor rates and those in buses and trucks at unskilled rates. Table 10.11 shows the breakdown by different categories of passenger and estimates of the value of time lost over 3 days (present land use conditions) and 4 days (future land use conditions). Estimated loss of income in this category is DT317,000 under present land use conditions, and DT1,053,000 under Future land use conditions.

(b) Increased Vehicle Operating Costs

These costs will be related to additional running costs on damaged roads, and, for the period of flooding, costs of diversion. It is assumed that 1 km of the RVE 835 will be affected by the flooding, and that traffic will face increased costs for a period of 30 days. In applying the rates for operating costs between the assumed conditions of non flooded and flooded roads, according to the World Bank HDM model, the increased vehicle operating costs are shown in Table 10.12 for existing and future traffic, as forecast above. These costs are estimated at DT16,200 at present, and DT44,200 in the year 2020.

With regard to diversion costs it is assumed that traffic will be diverted for a period of 4 days (under present land use conditions), and 5 days (under future land use conditions). The diversion is estimated at 5 km. These costs are shown in Table 10.13, and are estimated at DT8,400 under present and DT27,750 under future land use conditions. In total, additional vehicle operating costs due to flooding are estimated at DT24,600 for present traffic and DT72,000 for future traffic.

(c) Damage to Roads

Approximately 1 km of the main roads will be damaged. It is proposed that a bridge be constructed in order to avoid future problems. This is estimated at a cost of DT2.1 million. In addition, secondary and agricultural roads alongside the oued will be affected. These are estimated at 5 km. With a rehabilitation cost of DT80,000 per km, the costs are estimated at DT400,000. Total road rehabilitation costs and the cost of the bridge are therefore estimated at DT2.5 million.

(8) Summary of Flood Damages - Zone A

The estimation of potential flood damage in Zone A in a 100-yr probable flood is summarized as follows:

Oued Hammam - Zone A : Estimated Potential Flood Damage (DT1,000)

Category	Present Land Use Conditions	Future Land Use Conditions
Losses to Residents		
Loss of Income to Residents	330.0	1,554.0
Damage to Residential Buildings	1,394.0	4,930.0
Damages to Household Articles	287.0	1,015.0
Losses to Industrial Sector		
Loss of Income	243.0	583.0
Damage to Buildings	60.0	270.0
Damage to equipment/Assets	100.0	450.0
Losses to Agricultural Sector	149.0	103.0
Losses in the Transport Sector		
Passenger Delays	317.0	1,053.0
Increased VOCs	25.0	72.0
Road Rehabilitation	2,500.0	2,500.0
TOTAL	5,405.0	12,530.0

NOTE: Other unquantifiable damages include the health hazards resulting from damage to and stoppage of the ONAS plant during the flood period, and the adverse impact on the tourism.

10.3.3 Estimation of Flood Damages - ZONES B to G

Estimation of flood damages for Zones B to G is made in a similar manner as those of Zone A. Detail of the estimation is shown in a separate volume in the Supporting Report.

(1) Summary of Flood Damages to Zone B

Oued Hammam - Zone B - Estimated Flood Damage (DT1,000)

Category	Land Use Conditions	
	Present	Future
Losses to Residents		
Loss of Income to Residents	112.5	236.0
Damages to Household Articles	38.5	63.0
Damage to Residential Buildings	175.0	275.0
Losses to Industrial Sector		
Loss of Income	145.7	291.4
Damage to Buildings	36.0	60.0
Losses to Agricultural Sector	53.0	46.0
Losses in the Transport Sector		
Loss of Income	5.0	45.0
Road Rehabilitation	280.0	280.0
TOTAL	845.7	1,296.4

(2) Summary of Flood Damages to Zone C

Oued Hammam - Zone C - Estimated Flood Damage (DT1,000)

Category	Land Use Conditions	
	Present	Future
Losses to Residents		
Loss of Income to Residents	12.0	24.0
Damages to Household Articles	10.5	21.0
Damage to Residential Buildings	75.0	150.0
Losses to Agricultural Sector	57.5	57.5
Losses in the Transport Sector		
Road Rehabilitation	40.0	40.0
Loss of Income	28.7	342.5
Increased VOCs	9.6	25.7
Diversion costs (VOCs)	31.3	84.8
TOTAL	264.6	745.5

(3) Summary of Flood Damages to Zone D

The only damages in this zone will be to agricultural crops estimated at DT30,000 under present land use conditions and DT34,500 under future conditions.

(4) Summary of Flood Damages to Zone E

Oued Hammam - Zone E - Estimated Flood Damage (DT1,000)

Category	Land Use Conditions	
	Present	Future
Losses to Residents		
Loss of Income to Residents	2.5	32.0
Damages to Household Articles	14.0	42.0
Damage to Residential Buildings	68.0	204.0
Losses to Agricultural Sector	7.0	10.0
Losses in the Transport Sector		
Road Rehabilitation	10.0	10.0
Loss of Income	9.5	111.0
TOTAL	111.0	409.0

(5) Summary of Flood Damages to Zone F

Oued Hammam - Zone F - Estimated Flood Damage (DT1,000)

Category	Land Use Conditions	
	Present	Future
Losses to Residents		
Loss of Income to Residents	2.5	5.0
Damages to Household Articles	14.0	14.0
Damage to Residential Buildings	36.0	36.0
Losses to Agricultural Sector	17.0	18.0
Losses in the Transport Sector	nil	nil
TOTAL	69.5	73.0

(6) Summary of Flood Damages to Zone G

Oued Hammam - Zone G - Estimated Flood Damage (DT1,000)

Category	Land Use Conditions	
	Present	Future
Losses to Residents		
Loss of Income to Residents	2.5	10.0
Damages to Household Articles	14.0	8.0
Damage to Residential Buildings	36.0	72.0
Losses to Agricultural Sector	7.0	7.0
Losses in the Transport Sector		
Loss of Income	9.5	111.0
Damage to Roads	10.0	10.0
TOTAL	79.0	218.0

10.4 Summary of Flood Damages in the Oued Hammam

10.4.1 Potential Damages in a 100-yr Probable Flood

The overall potential damage likely to be caused in the Oued Hammam under a 100 year flood is estimated at DT6,804,800 under present land use conditions, and DT15,306,400 under future land use conditions. Details by zone are summarized below.

Evaluation of Flood Damage in the Flood Prone Areas Oued Hammam (DT1,000)

Zone	Present Land Use Conditions	Future Land Use Conditions
A	5,405.0	12,530.0
B	845.7	1,296.4
C	264.6	745.5
D	30.0	34.5
E	111.0	409.0
F	69.5	73.0
G	79.0	218.0
TOTAL	6,804.8	15,306.4

10.4.2 Potential Damages in 1-yr and 10-yr Probable Floods

The estimates of flood damage shown below are based on potential flooded areas and flooding duration. Details are to be found in the Supporting Report.

Evaluation of Flood Damage in Flood Prone Areas, Oued Hammam
(1-yr, and 10-yr Floods, Unit:DT1,000)

Areas	Present Land Use		Future Land Use	
	1-yr	10-yr	1-yr	10-yr
A	261	2,030	498	4,993
B	75	459	84	771
C	57	66	250	261
D	0	5	0	7
E	10	20	40	72
F	5	10	5	13
G	23	46	75	127
Total:	431	2,636	952	6,244

CHAPTER 11 COST ESTIMATE

11.1 Project Cost

The project cost for the Oued Hammam scheme has worked out as tabulated in Tables 11.1, and 11.2 and are summarized below excluding price and phisical contingencies:

First Stage	: DT7,950,000
Second Stage	: DT 787,000
Total:	: DT8,737,000

11.2 Conditions for Cost Estimate

(1) Price level : January 1994

(2) Exchange rate : US$1.0 = DT1.0 = ¥110.0

(3) The project cost was estimated divided into foreign and local currency portions assuming certain percent of it taking into accounts following factors:

- availability of skilled, semi-skilled and common laborers in Tunisia,
- productivity and availability of construction materials in Tunisia, and
- productivity and availability of construction plant and equipment.

Major work items of foreign currency portion (F.C.) and local currency portion (L.C.) are as follows.

Excavation by equipment	: F.C. 70 %,	L.C. 30 %
Embankment	: F.C. 70 %,	L.C. 30 %
Concrete	: F.C. 60 %,	L.C. 40 %

(4) implementation period is 57 months for the first stage work including pre-construction procedures starting from April 1994, and construction period is 30 months from the middle of 1996.

(5) Tunisian value added tax was accounted and incorporated in the local currency portion.

(6) No interest during construction was accounted.

(7) The project cost is composed of the followings:

- Direct construction cost
- Land acquisition and compensation costs
- Government administration expenses
- Engineering services expenses
- Price and physical contingencies

11.3 Cost Estimate

Direct construction cost and land acquisition cost are estimated by unit cost and work quantities which are worked out from the feasibility design of this stage. Administration and engineering expenses are estimated in proportion to direct construction cost. Price contingency is estimated applied the following rates which are assumed by consumer price index in Tunisia and Japan.

Local portion	: 6.2 % per annum
Foreign portion	: 2.3 % per annum

Physical contingency is estimated at 15 % of the total cost.

11.4 Disbursement Schedule

An annual disbursement schedule was provided following the proposed implementation and construction schedule as shown in Table 11.3 for the first stage of the Hammam scheme and is summarized below excluding price and physical contingencies.

Year	F.C.(DT1,000)	L.C.(DT1,000)	Total
1994	0	16	16
1995	228	482	710
1996	881	669	1,550
1997	2,012	1,450	3,462
1998	1,282	930	2,212
Total:	4,403	3,547	7,950

11.5 Operation and Maintenance Costs

Annual operation and maintenance costs are estimated at 2.0 % and or DT127,000 of direct construction cost for the first stage of Hammam scheme.

CHAPTER 12 CONSTRUCTION PLAN AND SCHEDULE

12.1 Implementation Plan

12.1.1 Implementation Schedule

The structure measures for flood protection has been proposed by stage-wise construction of river structures for the Oued Hammam, and be completed by the year 2000 and 2020 for 10-year and 100-year probable floods respectively. An implementation schedule for the first stage is provided on the basis of such basic strategy and importance of the project as shown in Fig.12.1, and summarized below:

Stage/Activity	Timing	Duration (month)
First stage		
* Financial arrangement	1994	8
* Detailed design, add. survey and P/Q	1995	12
* Tender and contract	1996	6
* Construction of Oued Hammam scheme	1996-1998	30

12.1.2 Financial Source

Required fund for the project implementation would mainly be financed by the national budget of the Tunisian Government, and some part by supporting loan from donor country or agency.

12.1.3 Mode of Construction

The construction works will be conducted by selected contractor(s) by an international competitive bidding with pre-qualification of bidders.

12.1.4 Implementation Organization

Urban Hydraulic Division of MOEH would be the core agency of the project implementation as shown in Fig 12.2. Major role of MOEH is ;

- Financial arrangement,
- Administration to conduct detailed design by consultant/s,
- To perform international tender and selection of contractor, and

- To administrate and supervise the construction works.

12.2 Construction Plan

12.2.1 Basic Policy for Construction Execution

Following basic policy or approach are proposed to be applied to conduct the various kind of construction works since the project situates in the urbanized or semi-urbanized area.

- to ensure urban environment,
- to avoid adverse effect to tourists,
- to eliminate traffic congestion,
- to use excavated soil effectively, and
- to perform the construction works throughout the year.

12.2.2 Construction Method for the Oued Hammam Scheme

The proposed structure measures for flood protection in the first stage of Oued Hammam scheme are summarized and tabulated as follows:

Stretch/Structure	Type/Length	Major Works
Hammam stretch H-1 improvement	572 m	excavation: 15,100 m3 bridge: 2,184 m2 at touristic road
Hammam stretch H-2 improvement	560 m	excavation: 37,800 m3 embankment: 2,500 m3 bridge GP-1: 576 m2 drainage sluice: 2 nos.
Hammam stretch H-3 improvement	565 m	excavation: 18,700 m3 embankment: 2,600 m3 drainage sluice: 2 nos.
Laia stretch H-4 improvement	250 m	excavation: 1,900 m3 embankment: 2,600 m3 drainage sluice: 2 nos.
Kebir stretch K-1 improvement	884 m	excavation: 23,300 m3 embankment: 8,100 m3 bridge MC-48: 450 m2 drainage sluice: 2 nos.
Kebir stretch K-4 improvement	84 m	excavation: 1,600 m3 embankment: 700 m3 bridge MC-48: 324 m2

Kebir stretch K-5 improvement	1,532 m	excavation: 14,900 m3 embankment: 10,300 m3 drainage sluice: 2 nos.

Required major works are 116,000 m3 of channel excavation, 27,000 m3 of embankment, 4 nos. of bridges, 10 sets of drainage sluices for the first stage of Oued Hamman scheme.

The proposed improvement length in the first stage of Oued Hammam is 4.5 km in total The Oued Hammam main, Oueds Laia and Kebir have bottom widths of 33-36 m, 8 m, and 4.5-7 m, respectively. Inspection road is planned to be constructed on both right and left banks by graveling.

The improvement works will be conducted from downstream towards upstream divided into several work sections. The levee embankment will be carried out following to the channel excavation using the excavated soil of channel excavation to the maximum extent. Gabion, masonry, sod facing and other works will follow the levee embankment.

As the levee embankment materials source, four (4) borrow pits from SL-1 to SL-4 are proposed that are locating along the Oued Hammam between GP-1 road and confluence with the Oueds Kebir and Laia. Hauling distance of 3.0 km is an average to the levee embankment sites. However, drying treatment is needed for borrowed soils according to the geological investigation report, so that priority is to be given to the excavated ones from economical viewpoint.

Site condition is wet and swampy in the stretches H-1, H-2 and H-3 of the Hammam main even in dry season. The stretches H-4, K-1,4 and 5 are dry and accessible by vehicle during dry season.

Major works are channel excavation of 116,000 m3 and embankment of levee of 27,400 m3 with graveling on the levee as the inspection road to be provided on both right and left banks.

In wet area of H-1, H-2 and H-3, channel improvement works will be made by middle capacity clamshell, long arm excavator and swamp type bulldozer, and carried out from right and left bank side. Excavated soil at the site will be stocked temporally for treating moisture content of the soil before use for levee embankment.

Following four (4) bridges are planned to be constructed according to the river improvement works.

Location	Width	Length
Touristic road, new	26 m	84 m
GP-1 road, new	12 m	48 m
MC-48, Kebir, renewal	15 m	30 m
MC-48, Kebir, renewal	12 m	27 m

A construction will be made in the order of touristic road bridge, GP-1 and MC-48 considering the present traffic condition at the project area. Temporary route close to the existing road will be provided during the construction period.

Construction period will be scheduled at two and a half years for four (4) bridges, of which 2 years for the touristic road and GP-1 bridges and remaining for 2 sets of MC-48 road. This bridge construction will be a critical path works on the Oued Hammam scheme.

12.3 Construction Time Schedule

12.3.1 Time schedule

Fig.12.3 shows a proposed construction time schedule for the first stage works of the Oued Hammam scheme.. The schedule was provided taking the following factors into account.

- to realize the proposed flood protection measures in an early stage,
- to minimize construction cost,
- weather, and
- to eliminate traffic congestion.

The construction period was proposed to be 30 months starting from the middle of 1996 with pre-construction activities to the end of 1998. A critical path work on the Oued Hammam scheme would be the construction of bridges at four places in total.

12.3.2 Milestones

Following the proposed flood protection plan and construction schedule, completion time of the following structures would be the key milestones.

Touristic road bridge	: End August 1997
GP-1 road bridge	: End June 1998
MC-48 road bridge	: End December 1998

CHAPTER 13 ECONOMIC EVALUATION

13.1 *Estimate of Annual Average Benefit*

The annual average benefit is defined as the reduction of probable flood damage under the with- and the without-project situations. On the basis of the estimated damages of each probable flood, the annual average benefit is calculated by the following formula.

$$B = \sum_{i=1}^{n} 1/2\left[D(Q_{i-1}) + D(Q_i)\right] \bullet \left[P(Q_{i-1}) + P(Q_i)\right]$$

where,

B	:	Annual average benefit
D(Qi-1), D(Qi)	:	Flood Damage caused by the floods with Qi-1 and Qi discharges, respectively
P(Qi-1), P(Qi)	:	Probabilities of occurrence of Qi-1 and Qi discharges, respectively
n	:	Number of floods applied

According to the flood damage studied in Chapter 10, annual average benefit for 10-yr probable flood are estimated to be DT1,015,000 in the present land use condition and to be DT2,328,000 in the future land use condition.

13.2 *Economic Project Cost*

The economic costs of the project are nominal figures that duly reflect the true economic value of goods and services involved. These costs are used only for the economic evaluation of the project. Transfer items such as taxes and duties imposed on construction materials and equipment, including government subsidy and contractor's profit, are excluded from the elements of financial cost. It is assumed that 10% of the financial construction cost is deemed as the transfer items.

Land has to be acquired for project implementation, and its economic value is considered to correspond to the production foregone by the project, which is reflected by the price. Land acquisition cost is then included in the economic cost.

Then, economic cost of the Oued Hammam flood control project for the 10-yr probable flood is estimated to be DT8,368,000.

13.3 Economic Evaluation

The project is evaluated from the economic view point by figuring out the viability in terms of economic internal rate of return (EIRR). All the monetary calculation is based on the price level of January 1994, and the project life (for economic evaluation) is fixed for 50 years.

The calculation of EIRR is based on the cost and benefit streams that is prepared from the above-said economic cost and the annual average benefit in accordance with the implementation schedule. The implementation schedule is prepared in Chapter 12, and the river improvement works are assumed to be completed by the year 1998 for 10-yr flood and by a certain time in the future for 100-yr flood respectively. The operation and maintenance cost is taken for 2.0 % of the accumulated direct construction cost in the respective year.

The cost and benefit stream prepared for the Oued Hammam flood control project is shown in Tables 13.1, and the estimated EIRR become 17.4 %. It is considered that this project is economically feasible.