# *Supporting Report E*

# *FACILITIES DESIGN AND COST ESTIMATE*

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

# FINAL REPORT

## Supporting Report E : Facilities Design and Cost Estimate

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# CHAPTER E1 BASIC CONDITIONS OF FACILITIES DESIGN

## E1.1 Principle of Facilities Design

The principle of facilities design for river improvement works in the Mejerda River comprises following two ideas:

(1) From a technical viewpoint, river channel improvement includes levee embankment, channel excavation/dredging and construction of retarding basins to utilise the in-channel flow capacity up to its maximum which is to be prioritized than other structural measures.

(2) No relocation of household/building is allowed so as to minimize social environmental impact. Therefore, it is assured that the least numbers of people will be affected by implementation of river improvement works, since relocation of a large number of households and buildings makes the project implementation difficult. If enough spaces for construction of levee embankment/channel widening is not obtained, masonry/concrete parapet walls or retaining walls are employed instead of earth works as levee embankment and channel widening. Further, if it is still insufficient even after employing leave embankment, masonry/concrete walls and channel excavation/dredging to increase flow capacity up to the design flood discharge, the following two measures are incorporated to fill the gap of the shortage of river channel capacity:

(1) Bypass Channel

A bypass channel has a function to divert excess flood discharge over the capacity of river channel. The excess discharge is detoured through the bypass channel and merged to the same river at the downstream stretch having a enough flow capacity. This structure does not have the function of retarding effect.

(2) Retarding Basin

A retarding basin is effective to mitigate the load of flood to safely convey the flood discharge along a river channel. A part of flood discharge is diverted into the retarding basin in which the excess discharge is once stored until the water level in the downstream river channel goes down to a certain level. Then, stored water will be released safely. This structure has a function to decrease the flood discharge at the downstream area.

## E1.2 Zoning for River Improvement Plan

For the study of flood protection level over the Mejerda River basin in Tunisia, the river stretches subject to improvement are divided into five zones as follows:

**Principal Features of Five Zones**

| Zone | River Stretches | | Cross * Section No. | Channel Length (m) | Flood Protection Level (Return Period) |
|---|---|---|---|---|---|
| D2 | D/S of Sidi Salem Dam | River Mouth to Larrousia Dam | MD447 to MD252 | 64,980 | 10 year |
| D1 | | Larrousia Dam to Sidi Salem Dam | MD252 to MD1 | 83,560 | 10 year |
| U2 | U/S of Sidi Salem Dam | Upstream end of reservoir of Sidi Salem Dam to Confluence with Mellegue River | MU1 to MU164 | 63,890 | 20 year |
| U1 | | Confluence with Mellegue River to Ghardimaou City | MU164 to MU360 | 94,420 | 10 year |
| M | Mellegue River (tributary) | | MG1 to MG160 | 45,043 | 10 year |

Note: * see Section E1.4

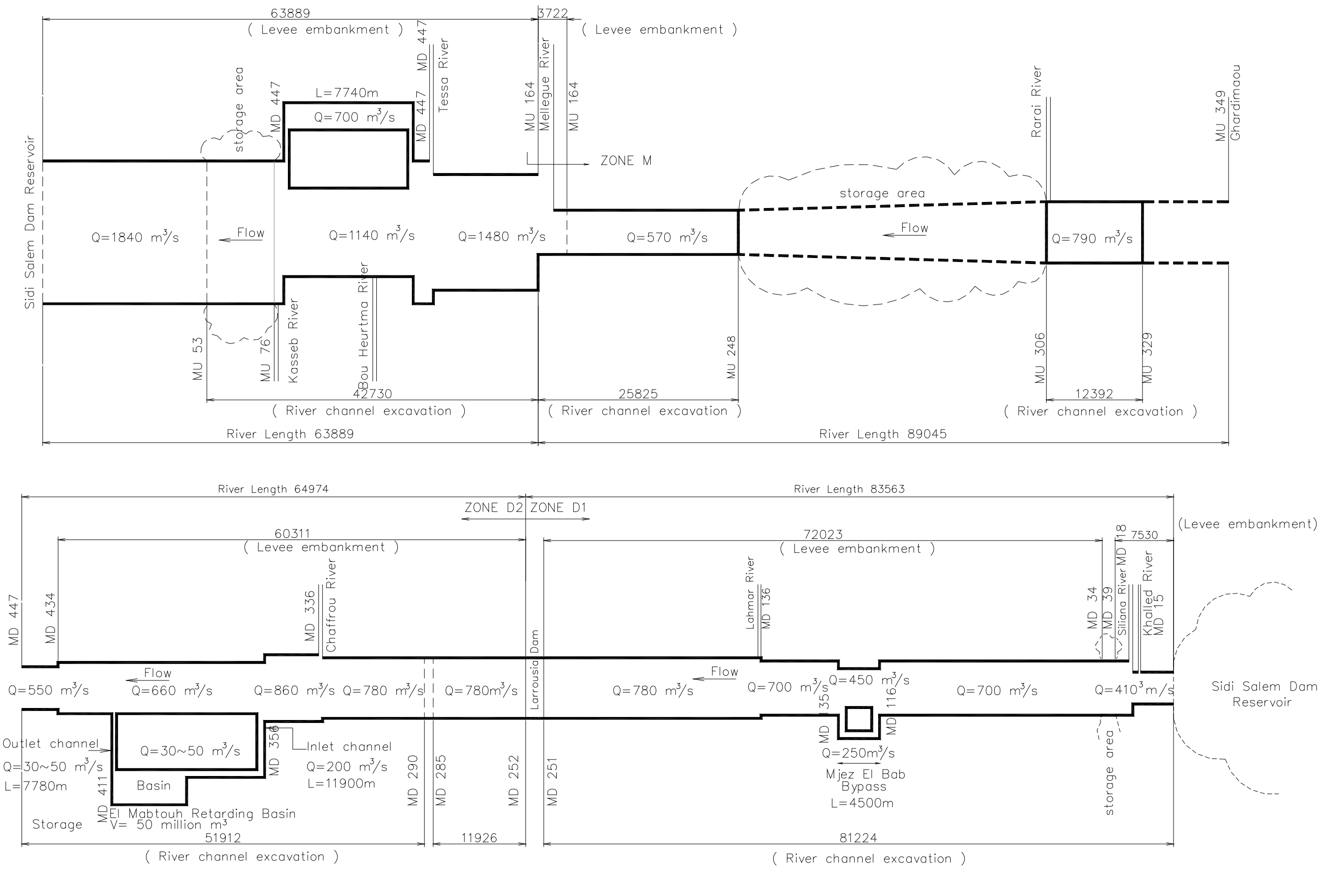
Source: the Study Team

The target year for formulation of the Master Plan is set at the year 2030. Considering the long stretches of the Mejerda River with more than 300 km, appropriate sequence of construction works to complete the improvement project until the year 2030 is essential. The five zones were considered as divided elements for construction sequence. Therefore, the quantity and the associated costs of river improvement works are individually compiled by each zone. Zoning is shown in the attached **Figures E1.2.1 and E1.2.2.**

## E1.3 Design Flood Discharge for River Improvement

The river improvement as the structural measures of flood control adopted for the Study includes, (1) river channel improvement consisting of channel excavation/widening and levee embankment, and (2) construction of new bypass channels and one new retarding basin. Distribution of design flood discharge for the river improvement is shown in the diagram below with the boundaries of zone. The design discharge for the river improvement is based on the results of hydrological analyses, discussed in Supporting Report A.

Shortcutting of river channel, as a measure of river improvement, is not applied in the proposed Master Plan. Normally, a sudden change of longitudinal gradient of river bed often makes serious adverse impact to the other adjacent stretches, like acceleration of longitudinal and lateral erosion. However, it might be advantageous and considerable at meandering portions to lower the upstream water level and stabilize the channel regime. In the subsequent feasibility study stage, it shall be further examined based on the detailed hydraulic analysis and land use conditions in the vicinity.




Source: the Study Team

**Distribution of Design Flood Discharge for River Improvement**

## E1.4 Survey Data Utilized for Facilities Design

Following survey results, which were obtained through the current Study, were utilized for facilities design. A series of topographic map with scales of 1:25000 and 1:50000 and aero-photos prepared by MARH were also referred to. Earth work quantity, such as levee embankment, river channel excavation and clearing and grubbing, were calculated based on the designed cross sections. Field reconnaissance was conducted as well to supplement and confirm the survey results and further details.

**List of Survey Data Utilized for Facilities Design**

| | | | | |
|---|---|---|---|---|
| Mejerda River | Upstream | Profile and cross section | L=158.306 km | 360 sections |
| | Downstream | Profile and cross section | L=148.537 km | 447 sections |
| Chaffrou River | | Cross section survey | L=2.0 km | 8 sections |
| Lahmer River | | Cross section survey | L=2.0 km | 8 sections |
| Kallied River | | Cross section survey | L=2.0 km | 8 sections |
| Siliana River | | Cross section survey | L=2.0 km | 8 sections |
| Kesseb River | | Profile and cross section | L=20.375 km | 86 sections |
| Bou Heurtma River | | Profile and cross section | L=17.334 km | 79 sections |
| Tessa River | | Profile and cross section | L=20.285 km | 87 sections |
| Mellegue River | | Profile and cross section | L=45.044 km | 160 sections |
| El Mabtouh Retarding Basin | Inlet to outlet channel | Profile and cross section | L=29.793 km | 9 sections |
| | Reservoir | Cross section | | 7 sections |
| Mejez El Bab Bypass | | Profile and cross section | L=4.512 km | 14 sections |
| Bou Salem Bypass | | Profile | L=7.736 km | |
| Bridges for reconstruction | | Cross section | | 6 sections |

Source: the Study Team

## E1.5 Design Standard and Criteria

(1) General

National Institute for Standardization and Industrial Property (INNORPI) has provided the general Tunisian standards and other related standards such as ISO, Norme Francaise, etc. However, technical guidelines for river improvement have not been established in Tunisia. Design standard and criteria for river structures have been usually prepared or a project basis in general.

In the Study, since it was judged that the Japanese standards and criterion could be referred to as the result of ocular inspection of the site situations and existing structures through field reconnaissance, those were referred to decide the dimensions of river structures. The standards, which are normally applied in Japan, provide the minimum requirement under the ordinary design conditions of subsoil capacity, loading and hydraulic condition, etc.

(2) Levee Embankment and channel geometry

The crest width and freeboard of levee embankment and river channel cited from the standards are as shown below.

**Design Criteria for Levee Embankment and River Channel**

| Category No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Design Discharge Q ($m^3/s$) | Q < 200 | 200 ≤ Q < 500 | 500 ≤ Q < 2000 | 2000 ≤ Q < 5000 | 5000 ≤ Q < 10000 | 10000 ≤ Q |
| Free Board (m) | 0.6 | 0.8 | 1.0 | 1.2 | 1.5 | 2.0 |
| Crest width of levee (m) | 3.0 | | 4.0 | 5.0 | 6.0 | 7.0 |

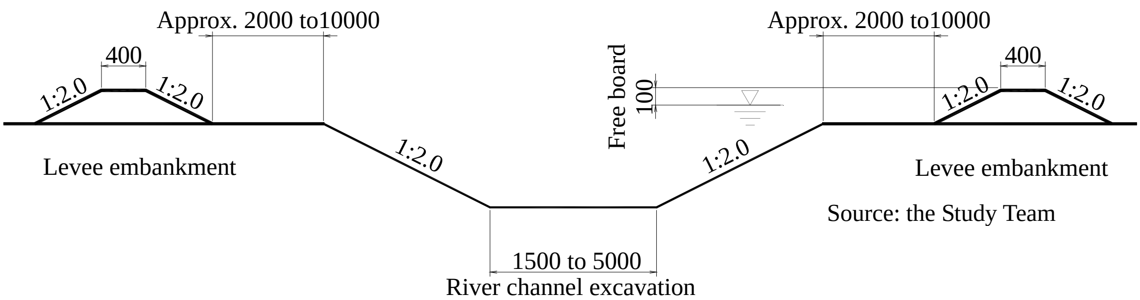
Source: the Study Team

The side slope of levee embankment shall be equal to or gentler than 1:2.0. The design discharge of river channel based on the hydrological analysis varies between 570 $m^3/s$ and 1,860 $m^3/s$ in the Study Area. In accordance with the table above, a standard section of levee embankment is set in the Mejerda River as follows:

(a) Crest width : 4.0 m wide

(b) Freeboard : 1.0m high

(c) Side slope : 1:2.0



Source: the Study Team

**Dimension of Channel Excavation and Levee Embankment**

Typical sections of river channel improvement are shown in **Sheet Nos. 21 to 27 of Data E1 in the Data Book**. In the detailed design stage of the proposed project, the stability analysis shall be conducted to check the appropriateness in dimension.

As for river channel excavation in the Mejerda River, the side slope is decided based on the following reasons:

(a) The design slope must be gentler than the present bank slope for stability against sliding.

(b) The slope must be gentle enough for maintenance work of river channel.

# CHAPTER E2 STRUCTURAL DESIGN

## E2.1 Flood Control Structures

### E2.1.1 River Channel Improvement Works

River channel improvement works for the Mejerda River is designed with combination of following three measures:

(a) Channel excavation/dredging and widening,

(b) Levee embankment, and

(c) Reservation of storage area.

In the course of flood analysis, considering land use, topography and hydraulic condition, the combination of those measures through the whole stretch of the Mejerda River is studied till optimum case is found. The longitudinal profile along the lowest river bed based on hydraulic analysis is shown in the drawings **Sheet Nos. E-3 to E-20 of Data E1 in Data Book.** Further, cross sections are shown in **Sheet Nos. E-21 to E-27 of Data E1 oinData Book.**

The river stretches of MD29 to MD24, MU 53 to MU 79 and MU207 to MU304 are reserved for storage of flood discharge so as to lessen the peak and volume of flood discharge in their downstream river channels.

The current flow capacity versus design flood discharge is shown as below:

**Current Flow Capacity and Design Flood by River Stretches**

| River Stretches | Flow Capacity ($m^3/s$) | |
|---|---|---|
| Mejerda River | Current Flow Capacity | Design Flood Discharge |
| Ghardimaou – confluence with Rarai R. | 250 | 250 |
| Confluence with Rarai R. – Jendouba | 400 | 790 |
| Jendouba – Confluence with Mellegue R. | | 520 |
| Confluence with Mellegue R. – Confluence with Tessa R. | 250 | 1480 |
| Confluence with Tessa R. – Bou Salem | 400 | 1840 (1140) |
| Bou Salem – U/S end of Sidi Salem Reservoir | 300~350 | 1840 |
| Sidi Salem Dam – Slouguia | 250~500 | 410~700 |
| Slouguia – Mejez El Bab | 600 | 700 (500) |
| Mejez El Bab – Laroussia Dam | 250 | 760 |

Source: the Study Team

### E2.1.2 Bypass Channels

With consideration of present insufficient flow capacity and difficulty of widening, El Battane, Mejez El Bab, Bou Salem and Jendouba, which are made up on the Mejerda River, were examined on necessity of bypass channel. Hydraulic study was further carried out and results are overlaid on its topography and land use. The final conclusion was obtained that bypass channels for Mejez El Bab City and Bou Salem City must be required to cope with the design flood discharge.

In the case of Mejez El Bab City, the river section of historical old bridge (Andarrous Bridge) is a critical bottle neck. However, the bridge shall be conserved as it is without removal in accordance with the request of the Tunisian side.

Bou Salem City is developed on both sides of the Mejerda River. The available space for river improvement works between both banks is quite limited. Almost whole Bou Salem City is located in flood prone area along the Mejerda River. The bypass channel is an effective measure to lower the risk of flood from the topographic point of view.

Ground sills are provided to stabilize the channel bed and alignment of bypass channel. The inlet and outlet of bypass channel are reinforced with the ground sills and revetment so as to assure diversion of flood discharge. Bridges are also provided at the existing roads, which cross over the bypass channel. A 500m long of transition is also provided from just downstream of junction of the bypass channel with the Mejerda River to mitigate the turbulence flow. And the structural design of Mejez El Bab Bypass Channel and Bou Salem Bypass Channel is shown in **Figures E2.1.1 to E2.1.5** and **Figures E2.1.6 to E2.1.9** respectively. They are shown in **Data E1 of Data Book as drawing Sheet No.36 to 46** and **drawing Sheet No.47 to 58** respectively. Salient feature is shown in the table below:

**Salient Features of Bypass Channel**

| | | | | Q'ty | Unit |
|---|---|---|---|---|---|
| **Mejez El Bab Bypass Channel** | | | | | |
| (1) | Bypass channel | | | | |
| | Length | | | 4,512 | m |
| | Channel bottom width | | | 15.00 | m |
| | Discharge | Mejerda River | | Q = 450 | $m^3/s$ |
| | | Bypass Channel | | Q = 250 | $m^3/s$ |
| | | Side Slope | | 1:2.0 | |
| (2) | Inlet structure | | | 1 | Set |
| (3) | Outlet structure | | | 1 | Set |
| (4) | Ground sill | | | 3 | Locations |
| (5) | Bridge | | | | |
| | 30m x 2 spans = 60m | | Two-lane-type | 4 | Locations |
| (6) | Drain inlet | | | 1 | Set |
| (7) | Slope protection | | | | |
| | Stone pitching | | 1 location | 1,200 | m |
| **Bou Salem Bypass Channel** | | | | | |
| (1) | Bypass channel | | | | |
| | Length | | | 7,736 | m |
| | Channel bottom width | | | 25.00 | m |
| | Discharge | Mejerda River | | Q = 1,140 | $m^3/s$ |
| | | Bypass Channel | | Q = 500 | $m^3/s$ |
| | | Side Slope | | 1:2.0 | |
| (2) | Inlet structure | | | 1 | Set |
| (3) | Outlet structure | | | 1 | Set |
| (4) | Ground sill | | | 8 | Locations |
| (5) | Bridge | | | | |
| | 30m x 2 spans = 60m | | Two-lane-type | 5 | Locations |
| (6) | Drain inlet | | | 1 | Set |
| (7) | Slope protection | | | | |
| | Stone pitching | | 3 locations, total length | 1,500 | m |

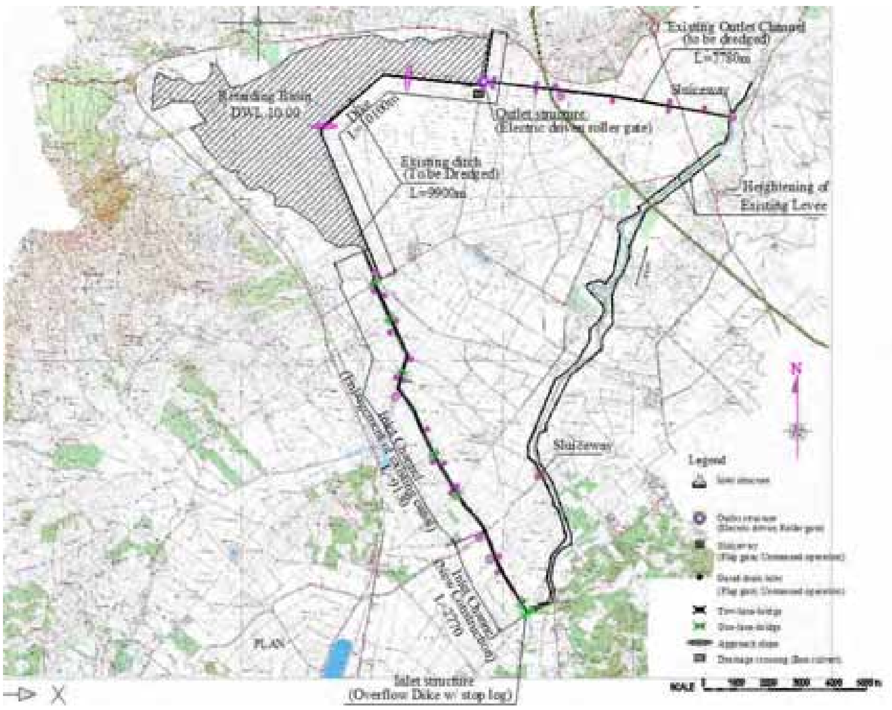
Source: the Study Team

### E2.1.3 Retarding Basin

#### (1) Basic Concept and General Layout

Two candidate sites of retarding basin upstream of Jendouba City and at the El Mabtouh plain in the lower area of the Mejerda River basin, were initially examined in the Framework Plan Study. The retarding basin is effective to mitigate flood peak discharge into the river channel. Since the viability of retarding basin depending largely on topographic condition, the natural topography is important to meet the physical requirement of low ground elevation, enough storage capacity, and access from the river channel, etc. If not, technical and cost performance become low. Although the construction of retarding basin upstream of Jendouba City was attractive for its favourable location to protect the urban area, unsuitable topography required high closing dike (15m to 20m high) to assure the enough storage capacity, which might require intensive quality control and maintenance works as same as a large dam. It does not seem to be practical as a retarding basin. In addition, failure due to lack of proper maintenance would bring crucial damage on the downstream residential area.

On the other hand, in the El Mabtouh plain, circumstances are very advantageous for creating a retarding basin. In fact, there exists an abandoned old retarding system. The structures can be replaced by means of renewal and upgrading of existing ones. The land acquisition can be minimized. The inlet channel will be renewed and the surrounding dike will be upgraded. The outlet channel will be usable after dredging and widening. Instead, the inlet structure will be completely newly provided. The existing bridges on inlet channel must be renewed and existing sluice/drain inlets along the inlet and outlet channels must be renewed as well. A general layout of the El Mabtouh Retarding Basin is shown in the figure below:

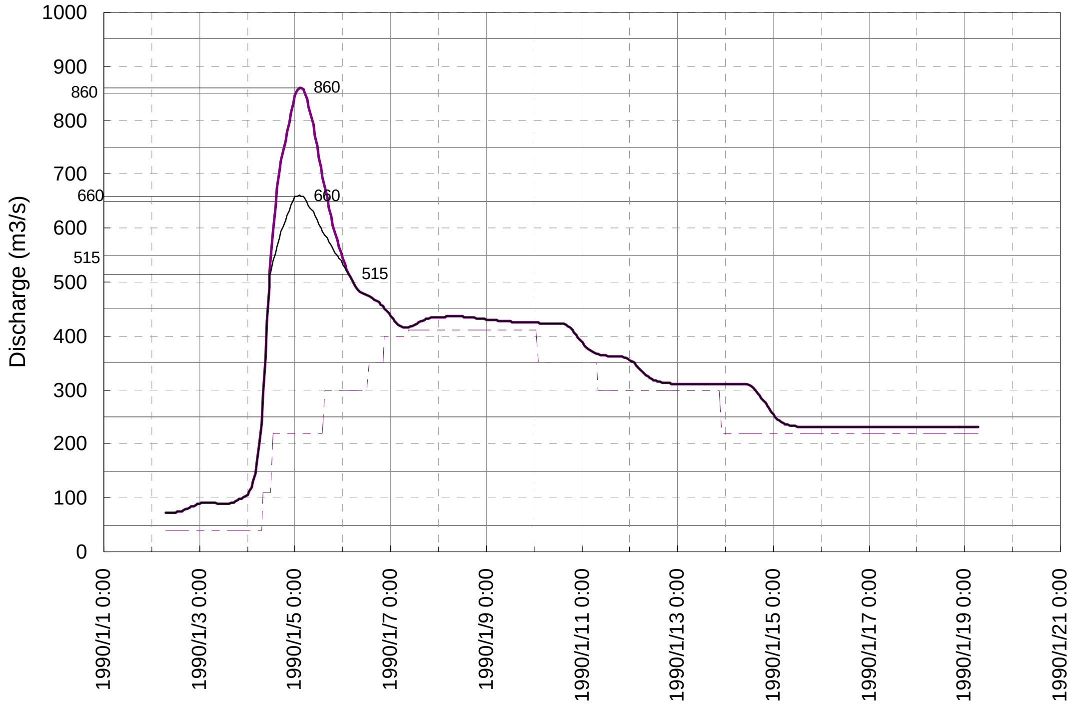



Source: the Study Team

**General Layout of El Mabtouh Retarding Basin**

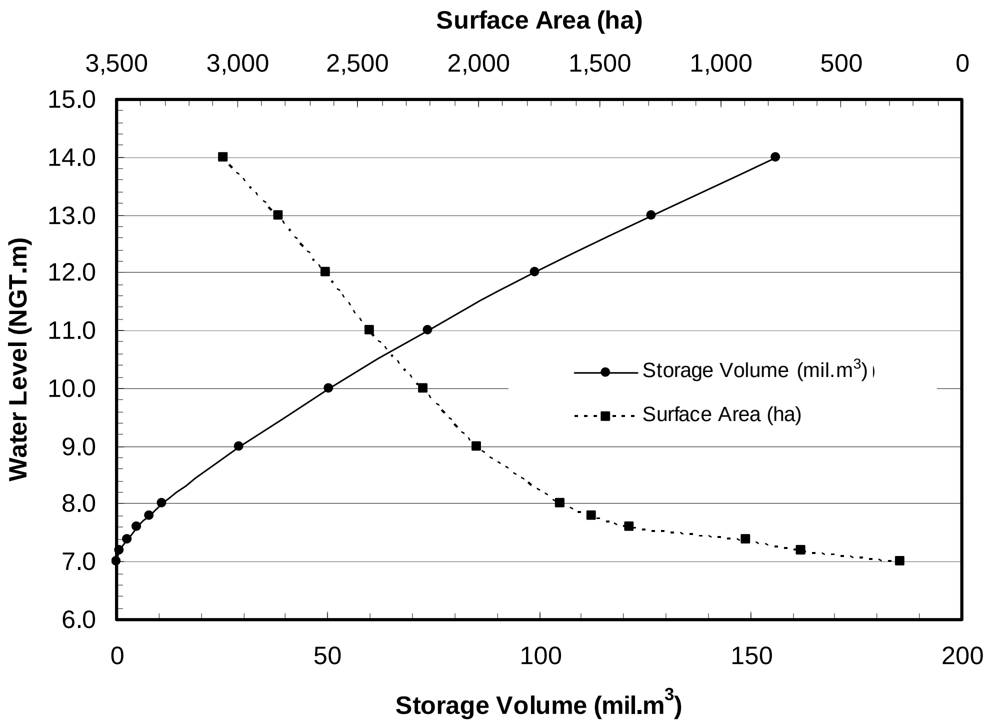
(2) Hydraulic Conditions

A maximum discharge of 200 $m^3/s$ is planned to be diverted to the retarding basin out of 860 $m^3/s$ of peak discharge at the upstream side of the inlet structure in the Mejerda River. Therefore, 660 $m^3/s$ will pass toward downstream after diversion. The inlet structure is designed as an unmanned operating overflow dike lined with concrete. The overflow dike is equipped with stop logs of concrete board for an emergency case of closure. The river discharge to start the diversion is set at 515 $m^3/s$, which corresponds with the river flow capacity at the crest elevation of dike. The crest elevation is 1.2 m lower than the design water level in the Mejerda River. The design flood hydrograph at the inlet structure is shown in the graphic below. An total volume of 14 million $m^3$ is diverted to the retarding basin. The capacity of retarding basin is about 50 million $m^3$ including an sediment volume and the runoff inflowing from its own catchment. A 10 million $m^3$ of sediment storage volume is considered in the design, which is almost free from maintenance dredging for the project life of the structure. The inflow from the own catchment is estimated at about 10 million $m^3$. A elevation-area-storage curve is as presented below. The layout and facility design is shown in **Figure E2.1.10 to Figure E2.1.15** and **drawings Sheet Nos. E-28 to E-35 of Data E1 in Data Book**.




Source: the Study Team

**Design Flood Hydrograph at Inlet Structure of El Mabtouh Retarding Basin**




Source: Prepared by the Study Team based on topographic survey results in the Study

**Elevation – Area – Storage Curve of El Mabtouh Retarding Basin**

(3) Salient Features

The salient features of the El Mabtouh Retarding Basin are tabulated as follows:

**Salient Features of El Mabtouh Retarding Basin**

| | | | | |
|---|---|---|---|---|
| (1) | Inlet channel | | | |
| | Construction of earth canal, | | | |
| | Improvement of existing channel | | 9,130 | m |
| | New construction | | 2,770 | m |
| (2) | Outlet channel | | | |
| | Dredging of existing canal | | 7,780 | m |
| (3) | Retarding basin | | | |
| | Surrounding dike | | 10,100 | m |
| | Design storage capacity | | 50 | mil. $m^3$ |
| (4) | Outlet structure | | | |
| | Sluice, roller gate | Design discharge | Q=50 | $m^3$/s max |
| | | Size | 3.00x3.00x3 nos. | |
| (5) | Inlet structure | | | |
| | Overflow dike with stop log | Design discharge | Q=200 | $m^3$/s |
| | | Crest length of overflow dike | 80 | m |
| (6) | Bridge | | | |
| | Renewal of existing bridge | | | |
| | 25m x 2 spans = 50m | One-lane-type | 6 | locations |
| | | Two-lane-type | 1 | location |
| (7) | Sluice gate | | | |
| | Flap gate | | 5 | locations |
| (8) | Drain inlet | | | |
| | Flap gate | | 23 | locations |

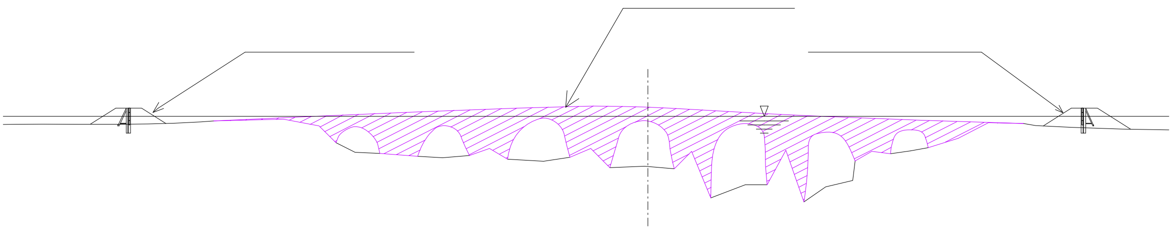
Source: the Study Team

### E2.1.4 Parapet Wall and Retaining Wall

The levee is basically constructed with earth material. When the available land is limited in residential areas for construction of levee, a parapet wall of concrete/masonry is an alternative solution to avoid relocation of people. An low water channel is also formed with concrete retaining wall to maximize the flow area in narrow section. Drawings with **Sheet No.E-59 to E-64 of Data E1 in Data Book** show the design of the structures to be provided in Judaida City and El Battane City.

### E2.1.5 Detachable Stop Log Structure

Although this is not a preferable measure, this might be one of simple solutions for closing to avoid inundation where the bridge is submerged under the design water level. Both banks of historical Anderrous Bridge in Majez El Bab and ancient El Battane Weir, are in such situation as shown in the figure below. Therefore, the stop log will be placed at the approach roads of bridges in between discontinued part of levee. This structure is made of detachable posts with stop log slots and movable steel stop log leaves. Actual operation should be related with the warning system, because the stop log must be installed timely otherwise spilled water flows into the residential area. The drawing with Sheet No.E-69 in Data Book shows typical design for this structure.



Source: the Study Team

**Typical Section of Stop Log Structure at Historical Bridge Site**

## E2.2 Structures for Channel Stabilization

### E2.2.1 Revetment for Slope Protection

Nominal river bank protection works have been carried out on the Mejerda River. Erosion has been progressing at most of meandering portions (refer to Plan and Profile of Mejerda River in Data Book). Following criteria for provision of slope protection adjacent to the structures shall be applied:

(1) Dense housing area at the risk of damage due to erosion,

(2) Pubic properties such as a national road, a railway and trunk structures as lifeline close to eroded river bank, and

(3) Upstream side and downstream side of structures, (if necessary).

As for the agricultural land areas, requirement of revetment will be substantiated in the maintenance period based on the actual erosion conditions.

Following three types of revetment for bank protection are proposed with design particulars:

(1) Concrete frame / wet cobble masonry

This is a solid structure and to be applied to dense residential areas, such as Bou Salem City, Jedeida City and so on.

(2) Gabion / stone pitching

This will be applied to transition between a solid structure and earth material.

(3) Fascine mattress / fascine hurdle

This is applied to protection for the public and/or private properties that are close to the eroded bank. This issue is discussed in Section E2.5.

Drawings with **Sheet No.E-65 to E-68 of Data E1 in Data Book** show the design of concrete frame type revetment for Bou Salem City. Typical design of fascine mattress / fascine hurdle is shown in Drawings with **Sheet No.E-70 and E-71 of Data E1 in Data Book**.

### E2.2.2 Ground Sill

Ground sill is a measure to stabilize the riverbed in a river channel regime. The proposed scheme of river improvement excludes short-cut channel so that the gradient of present riverbed profile is not drastically changed before and after improvement works. The present riverbed is anticipated to rise up due to sedimentation. Consequently, it is judged that ground sill is not necessary on the Mejerda River except special cases, which are in the bypass channels, at inlet and outlet structures and at the inlet of El Mabtouh Retarding Basin.

## E2.3 Drainage Structures

The construction of levee interrupts the existing continuous draining system connecting to the river. It is obliged that sluices shall be properly provided at the crossing point of levee and drainage canals to the Mejerda River. Most of the structures are located at remote areas. Due to the situation, the structure shall be generally unmanned operation type. The gate must react with water level fluctuation inside and outside. Therefore, a flap gate is adapted. The number, type and size of sluiceway is counted and shown in the table below. Actually without detailed topographic maps, it is difficult to determine the right places of these structures. This is preliminary estimation based on the available aerial photos. The typical design of sluiceway is shown in **drawings Sheet No.E-79 to E-88 of Data E1 in Data Boo**k.

**Salient Features of Sluiceway**

| **Zone D2** | Type | Dimensions | Q'ty | Unit |
|---|---|---|---|---|
| Mejerda River Channel | | | | |
| Sluiceway | Flap gate | 2.00x2.00x2 barrels to 2.50x2.50x3 barrels | 9 | Nos. |
| | Flap gate | 2.00x2.00x1 barrel to 1.50x1.50x1 barrel | 21 | Nos. |
| | Flap gate | 1.00x1.00x1barrel | 17 | Nos. |
| El Babtouh Retarding pond | | | | |
| Outlet structure | Roller gate | 3.00x3.00x3 barrels | 1 | No. |
| Sluice gate | Flap gate | 2.50x2.50x3 barrels | 5 | Nos. |
| Drain inlet | Flap gate | 1.00x1.00x1 barrel | 23 | Nos. |
| | | Total | 76 | |

| | | | | |
|---|---|---|---|---|
| **Zone D1** | | | | |
| Sluiceway | Flap gate | 2.00x2.00x2 barrels to 2.50x2.50x3 barrels | 11 | Nos. |
| | Flap gate | 2.00x2.00x1 barrel to 1.50x1.50x1 barrel | 27 | Nos. |
| | Flap gate | 1.00x1.00x1barrel | 34 | Nos. |
| | | Total | 72 | |
| **Zone U2** | | | | |
| Sluiceway | Flap gate | 2.00x2.00x2 barrels to 2.50x2.50x3 barrels | 6 | Nos. |
| | Flap gate | 2.00x2.00x1 barrel to 1.50x1.50x1 barrel | 16 | Nos. |
| | Flap gate | 1.00x1.00x1barrel | 20 | Nos. |
| | | Total | 42 | |
| **Zone U1** | | | | |
| Sluiceway | Flap gate | 1.00x1.00x1barrel | 3 | Nos. |
| **Zone M** | | | | |
| 3) Sluiceway | Flap gate | 1.00x1.00x1barrel | 3 | Nos. |

### E2.4 Levee on Major Tributaries

As treatment of major tributaries connected with the Mejerda mainstream, those must be opened as it is considering difficulties of operation and maintenance of gate structures at their lower ends. In other words, construction of large size gated structure at the confluence with the Mejerda River is not practical. Construction of levee embankment on tributaries with continuation of the one along the mainstream to prevent the backflow from the Mejerda is rather reasonable instead of gated structures. This levee, which works to prevent backwater invasion from the Mejerda mainstream, is to be placed in six tributaries, i.e. the Chaffrou, the Larmer, the Kasseb, the Bou Heurtma , the Tessa and the Mellegue Rivers.

### E.2.5 Bridges

Based on the hydraulic analysis with the latest river cross sections, it was clarified that four road bridges, one aqueduct with a foot path and two railway bridges would be affected. The elevations of these superstructures are lower than the design high water levels. The railway bridge at Sidi Ismail (Zone U2) seems that the superstructure can be heightened by jacking with placement of additional concrete on the top of substructure. The other six bridges should be replaced with new bridges. In Tunisia, road bridges are managed by the Ministry of Equipment and railway bridges are managed by SNCFT separately.

A 100 year return period flood discharge shall be applied to the design of the bridges in the current Study. Existing bridges subject to reconstruction are listed as below. Cross sections of these structures are shown in attached **drawing Sheet No.72 to E-78 of Data E1 in Data Book**.

**List of Bridges affected by Proposed River Improvement**

| Name of Zone | Category | Location | | Length (m) |
|---|---|---|---|---|
| | | Reconstruction | Heightening | |
| Zone D2 | Road bridge | MD436 | | 140 |
| | Road bridge | MD406 | | 160 |
| | Road bridge | MD401 | | 140 |
| | Railway bridge | | MD338 | 75 |
| Zone D1 | Aqueduct with foot bridge | MD134 | | 110 |
| Zone U2 | Railway bridge | MU40 | | 110 |
| | Road bridge | MU153 | | 100 |

Source: the Study Team

## E2.6 Treatment Measures of Thick Trees "Tamarix" in River Channels

### E2.6.1 Clearing and Grubbing of "Tamarix"

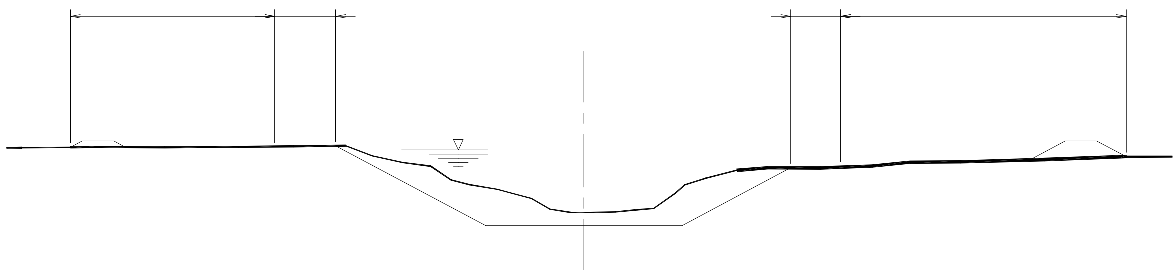
The thick bush prevailing in the high water channel mainly consists of a kind tree so-called "Tamarix" can be seen almost all stretches along the Mejerda River. Particularly, they narrow the flow area and hinder the smooth flow in the river channel. This is a serious problem to cope with flood prevention. On the contrary, it is observed that they are somewhat contributing in prevention of river bank erosion.

After the devastated flood of January to February 2003, each CRDA recognized the importance of removal of Tamarix. In fact, the CRDAs provided budget to remove Tamarix from the river channel and those have been once cleared by means of cutting down the trunks and burned afterward. However, a problem that the remained stubs and roots quickly branched off and they grew 3 to 4 m high within only 2 to 3 years according to the interview at CRDA Manouba. The prepared budget was too small to remove all from the subject river stretches.

Tamarix can spread both roots or submerged stems and by seeds. If the root is not removed, they will recover to former conditions quickly. The photo shows a high water channel widely covered with Tamarix, which had been cleared by cutting down only two years before. They seem to have already recovered completely.

**Current Condition at Downstream of Jedeida**

Therefore, it is concluded that the Tamarix must be cleared by means of grubbing the root. However, roots must be intentionally left in a range of 5.0 m from shoulder of channel section for the purpose of prevention against bank erosion as shown in the figure below:



Source: the Study Team

**Area of Tamarix to be Left for Bank Protection (Tentative)**

According to the information from CRDA, Tamarix started to prevail in the high water channel after construction of the Sidi Salem Dam. This information proves that the Tamarix can grow fast on the silted surface with sediment.

E2.6.2 Recycling of "Tamarix"

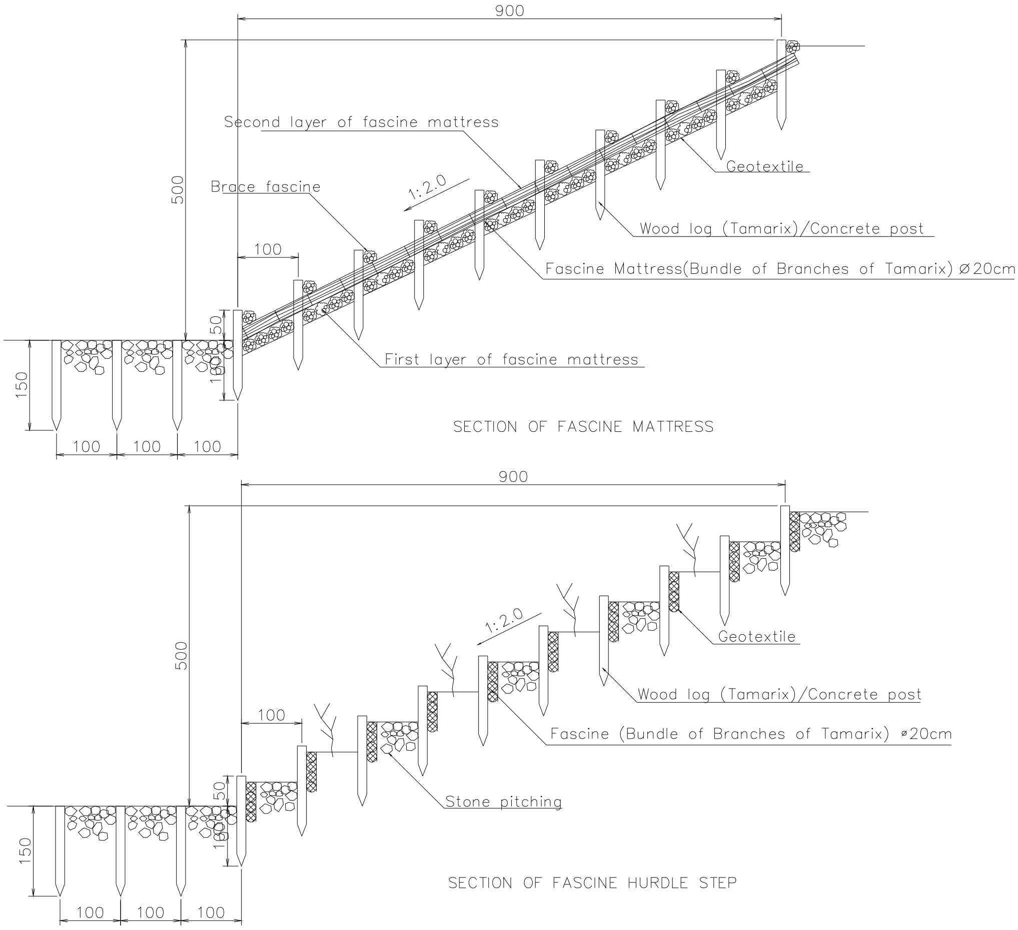
According to the information collected by the Study Team, Tamarix is not so attractive for practical use compared as other dominant trees such as "Eucalyptus", etc. Tamarix is not suitable for charcoal or fire wood either because of the smell when burned. It is somewhat usable as raw material of plywood processing, but demand is very limited and no factory is operated in the project area. The disposal cost is not negligible and disposal by burning seems to be negative to the environment impact.

**Branches of Tamarix**

On the other hand, there is a kind of construction method for the slope protection made of wood materials, which is widely adopted as a traditional way of river bank protection in Japan. This construction method seems to be applicable to the Mejerda River by using Tamarix. There are requests at many places about bank protection according to interview at site. If this method is effectively applicable with cut Tamarix, the cost of slope protection in the maintenance period can be reduced. Inhabitants, who want to protect their land from erosion, will be able to make the protection with Tamarix by them, if they know the technique how to make it. No heavy machinery is needed.

Therefore, maintenance works of river channel might be possible by participatory approach by the local people on some extent, if a certain mechanism is created between CRDAs and cities/villages concerned. This method will contribute to save the limited maintenance budget of the local government. The photo above shows the branches of Tamarix that seems to be usable for fascine mattress.

However, at any rate, as long as the efficiency and applicability of this method shall be confirmed through a Pilot Project, this method can not be directly introduced to construction. A kind of typical design of Japanese traditional slope protection works made of wood logs and branches is shown in the figure below. Drawings is also attached in **Sheet No.E-70 and E-71 of Data E1 in Data Boo**k.




Source: the Study Team

**Typical Cross Section of Slope Protection (Traditional Type in Japan)**

## E2.7 Salient Features of Proposed Structures

Based on the structural design works as explained, design drawings were prepared. The salient features of major structures proposed in the Master Plan is summarised by each zone in table below:

**Salient Features of Major Structures**

**Zone D2**

| | | | | |
|---|---|---|---|---|
| **I. Mejerda River** | | | | |
| 1) River channel length | | | | |
| MD447 to MD252 | 0.00m to 64974.36 m | | 64,974 | m |
| 2) Scope of construction boundary of levee embankment (Left bank and right bank) | | | | |
| MD434 to MD252 | 4667.73m to 64974.36 m | | 60,307 | m |
| (Heightening of existing levee) | 4667.73m to 24943.85 m | | (20,280) | m |
| Actual construction length | (Left bank) | | 29,365 | m |
| | (Right bank) | | 26,478 | m |
| | | Total | 55,843 | m |

| | | | | |
|---|---|---|---|---|
| 3) Low water channel excavation | | | | |
| MD447 to MD356, B=25 m | | 0.00 m to 31306.69 m | 31,307 | m |
| MD356 to MD329, B=35 m | | 31306.69 m to 40801.18 m | 9,494 | m |
| MD329 to MD290, B=20 m | | 40801.18 m to 51912.36 m | 11,111 | m |
| MD290 to MD285, No excavation | | 51912.36 m to 53110.71 m | | |
| MD285 to MD252, B=25 m | | 53110.71m to 64974.36 m | 11,864 | m |
| | Total length of River channel excavation | | 63,776 | m |
| 4) Sluice gate | | | | |
| 2.00x2.00x2 barrels to 2.50x2.50x3 barrels | | | 9 | Nos. |
| 2.00x2.00x1 barrel to 1.50x1.50x1 barrel | | | 21 | Nos. |
| 1.00x1.00x1barrel | | | 17 | Nos. |
| 5) Slope protection | | | | |
| | Concrete frame | Jedeida city (Left bank) | 1,000 | m |
| | | Jedeida city (Right bank) | 1,000 | m |
| | | El Battane city (Left bank) | 100 | m |
| | | El Battane city (Left bank) | 100 | m |
| | Stone pitching | | 10,000 | $m^3$ |
| | Fascine mattress | | 72,000 | $m^2$ |
| 6) Reconstruction of existing bridge | | | | |
| | MD 434 | Road bridge, L=140 m | 1 | Site |
| | MD 406 | Road bridge, L=160 m | 1 | Site |
| | MD 401 | Road bridge, L=140 m | 1 | Site |
| 7) Heightening of existing railway bridge | | | | |
| | MD 338 | L=90 m | 1 | Site |
| 8) Heightening of existing road | | | | |
| Length of heightening | | Bituminous pavement | 4,600 | m |
| **II. El Mabtouh Retarding Basin** | | | | |
| 1) Inlet channel | | | | |
| Construction of earth canal, | | | | |
| | Improvement of existing channel | | 9,130 | m |
| | New construction | | 2,770 | m |
| 2) Outlet channel | | | | |
| Dredging of existing canal | | | 7,780 | m |
| 3) Reservoir | | | | |
| Surrounding dike | | | 10,100 | m |
| Design storage capacity | | | 50,000,000 | $m^3$/s |
| 4) Outlet structure | | | | 1 set |
| Sluice, roller gate | | Design discharge | Q=50 | $m^3$/s max |
| | | Size | 3.00x3.00x3nos | |
| 5) Inlet structure | | | | |
| Overflow dike with stop log | | Design discharge | Q=200 | $m^3$/s |
| | | Crest length of overflow dike | 80 | m |
| 6) Bridge | | | | |
| Renewal of existing bridge | | | | |
| 25m x 2 spans = 50m | | One-lane-type | 6 | Sites |
| | | Two-lane-type | 1 | Sites |
| 7) Sluice gate | | | | |
| Flap gate | | | 5 | Sites |
| 8) Drain inlet | | | | |
| Flap gate | | | 23 | Sites |

**III. Chaffrou River**

| | | | | |
|---|---|---|---|---|
| 1) | Levee length (Left bank and right bank) | | | |
| | CH0 to CH8 | 0.00 m to 2,000 m | 2,000 | m |

## Zone D1

**I. Mejerda River**

| | | | | |
|---|---|---|---|---|
| 1) | River channel length | | | |
| | MD252 to MD1 | 64974.36 m to 148537.42 | 83,563.06 | m |
| 2) | Scope of construction boundary of levee embankment (Left bank and right bank) | | | |
| | MD251 to MD29 | 67312.99 m to 139335.82 | 72,022.83 | m |
| | MD24 to MD0 | 141007.44 m to 148537.42 | 7,529.98 | m |
| | | Total | 79,552.81 | m |
| | Actual construction length | (Left bank) | 36,671 | m |
| | | (Right bank) | 33,909 | m |
| | | Total | 70,580 | m |
| 3) | Low water channel excavation | | | |
| | MD251 to MD135, B=25 m | 67312.99 m to 105317.25 | 38,004 | |
| | MD251 to MD1, B=20 m | 105317.25 m to 148537.42 | 43,220 | m |
| | | Total | 81,224 | |
| 4) | Sluice gate | | | |
| | 2.00x2.00x2 barrels to 2.50x2.50x3 barrels | | 11 | Nos. |
| | 2.00x2.00x1 barrel to 1.50x1.50x1 barrel | | 27 | Nos. |
| | 1.00x1.00x1barrel | | 34 | Nos. |
| 5) | Slope protection | | | |
| | Concrete frame | | 1,000 | m |
| | Stone pitching | | 10,000 | $m^3$ |
| | Fascine mattress | | 81,000 | $m^2$ |
| 6) | Renewal of existing bridge | | | |
| | MD 134 | Road bridge, L=140 m | 1 | LS |
| 7) | Stop log at Mejez El Bab old bridge | | 2 | Sets |

**II. Majez El Bab Bypass Channel**

| | | | | |
|---|---|---|---|---|
| 1) | Bypass channel | | | |
| | Length | | 4512 | m |
| | Channel bottom width | | 15.00 | m |
| | Discharge: Mejerda River | | Q = 450 | $m^3/s$ |
| | Bypass Channel | | Q = 250 | $m^3/s$ |
| | side slope | | 1:2.0 | |
| 2) | Inlet structure | | 1 | Set |
| 3) | Outlet structure | | 1 | Set |
| 4) | Ground sill | | 3 | Sites |
| 5) | Bridge | | | |
| | 30m x 2 spans = 60m | Two-lane-type | 4 | Sites |
| 6) | Drain inlet | | 1 | Set |
| 7) | Slope protection | | | |
| | Stone pitching | 1 location | 1,200 | m |

**III. Lahmar River**

| | | | | |
|---|---|---|---|---|
| 1) | Levee length (Left bank and right bank) | | | |
| | LA0 to LA8 | 0.00 m to 2,000 m | 2,000 | m |

## Zone U2

| | | | | |
|---|---|---|---|---|
| **I. Mejerda River** | | | | |
| 1) River channel length | | | | |
| MU1 to MU164 | | 0.00 m to 63889.42 m | 63,889 | m |
| 2) Scope of construction boundary of levee embankment (Left bank and right bank) | | | | |
| MU1 to MU53 | | 0.00 m to 21159.41 m | 21,159 | |
| MU79 to MU172 | | 30077.29 m to 63889.42 m | 33,812 | m |
| | | Total | 54,972 | |
| | Actual construction length | (Left bank) | 34,833 | m |
| | | (Right bank) | 32,666 | m |
| | | Total | 67,499 | m |
| 3) Low water channel excavation | | | | |
| MU53 to MU129, B=50 m | | 21159.41 m to 50385.72 m | 29,226 | |
| MU129 to MU164, B=40 m | | 50385.72 m to 63889.42 m | 13,504 | |
| | | Total | 42,730 | |
| 4) Sluice gate | | | | |
| 2.00x2.00x2 barrels to 2.50x2.50x3 barrels | | | 6 | Nos. |
| 2.00x2.00x1 barrel to 1.50x1.50x1 barrel | | | 16 | Nos. |
| 1.00x1.00x1barrel | | | 20 | Nos. |
| 5) Slope protection | | | | |
| | Concrete frame | | 1,000 | m |
| | Stone pitching | | 10,000 | $m^3$ |
| | Fascine mattress | | 99,000 | $m^2$ |
| 6) Renewal of existing aqueduct with foot bridge | | | | |
| MD 134 | To be improved | to Road bridge, L=110 m | 1 | |
| **II. Bou Salem Bypass Channel** | | | | |
| 1) Bypass channel | | | | |
| Length | | | 7,736 | m |
| Channel bottom width | | | 25.00 | m |
| Discharge | Mejerda River | | Q = 1140 | $m^3/s$ |
| | Bypass Channel | | Q = 700 | $m^3/s$ |
| | side slope | | 1:2.0 | |
| 2) Inlet structure | | | 1 | Set |
| 3) Outlet structure | | | 1 | Set |
| 4) Ground sill | | | 8 | Sites |
| 5) Bridge | | | | |
| 30m x 2 spans = 60m | | Two-lane-type | 5 | Sites |
| 6) Drain inlet | | | 1 | Set |
| 7) Slope protection | | | | |
| Stone pitching | | 3 locations, total length | 1,500 | m |
| **III. Bou Heurtma River** | | | | |
| 1) Levee length (Left bank and right bank) | | | | |
| BH0 to BH32 | | 0.00 m to 6,742.34 m | 6,742.34 | m |
| **IV. Tessa River** | | | | |
| 1) Levee length (Left bank and right bank) | | | | |
| TS0 to TS24 | | 0.00 m to 4,348.24 m | 4,348.24 | m |

**V. Kasseb River**

| | | | |
|---|---|---|---|
| 1) Levee length (Left bank and right bank) | | | |
| KS0 to KS11 | 0.00 m to 3,056.98m | 3,056.98 | m |

## Zone U1

**I. Mejerda River**

| | | | |
|---|---|---|---|
| 1) River length | | | |
| MU164 to MU360 | 63889.42 m to 158306.49m | 94,417.07 | m |
| 2) Scope of construction boundary of levee embankment (Left bank and right bank) | | | |
| MU164 to MU172 | 63889.42 m to 67610.96m | 3,721.54 | m |
| Actual construction length | (Left bank) | 2,264 | m |
| | (Right bank) | 2,860 | m |
| | Total | 5,124.00 | m |
| 3) Low water channel excavation | | | |
| MU164 to MU208, B=10 m | 63889.42 m to 79550.78 m | 15,661 | m |
| MU208 to MU248, B=15 m | 79550.78 m to 99714.35 m | 20,164 | m |
| MU208 to MU248, No excavation | | 0 | m |
| MU305 to MU329, B=10 m | 128913.2 m to 141842.33 m | 12,929 | m |
| | Total | 48,754 | m |
| 4) Sluice gate | | | |
| 1.00x1.00x1barrel | | 3 | Nos. |
| 5) Slope protection | | | |
| Stone pitching | | 5,000 | $m^3$ |
| Fascine mattress | | 45,000 | $m^2$ |

## Zone M

**I. Mellegue River**

| | | | |
|---|---|---|---|
| 1) River length for study | | | |
| MG1 to MU114 | 63889.42 m to 158306.49m | 158,306.00 | m |
| 2) Scope of construction boundary of levee embankment (Left bank and right bank) | | | |
| MG1 to MG35 | 0.00 m to 8895.23m | 8,895.23 | m |
| Actual construction length | (Left bank) | | |
| | (Right bank) | | |
| 2) Low water channel excavation | | | |
| MG1 to MG52 | 0.00 m to 12871.42 m | 12,871 | m |
| 3) Sluice gate | | | |
| 1.00x1.00x1barrel | | 3 | Nos. |

Source: the Study Team

# CHAPTER E3 CALCULATION OF WORK QUANTITIES AND COST ESTIMATE

## E3.1 Basic Conditions for Calculation of Work Quantities

Work quantities of the river improvement works are calculated based on the preliminary design drawings. Work quantities of earth works for river channel improvement are calculated based on the rive cross sections from field survey data. Following assumptions, which supplement incomplete information, are also applied to the quantity calculation.

Clearing and disposing of surface vegetation in the high water channel and construction site is divided into three work items as follows:

Code No.

A1. Clearing and grubbing (Dense bush)

A2. Clearing and grubbing (Thin bush)

A3. Stripping

"A3. Stripping" is defined as clearing of land on which weeds only grow without trees and bushes.

Since above three items are not separately shown on the cross section design, with the judgment by site inspection, it is assumed that the total quantity (A1, A2 and A3 together) measured in CAD is distributed in a proportion of A1:A2:A3=3:2:5.

Further, two items for disposal of excavated material are provided as follows:

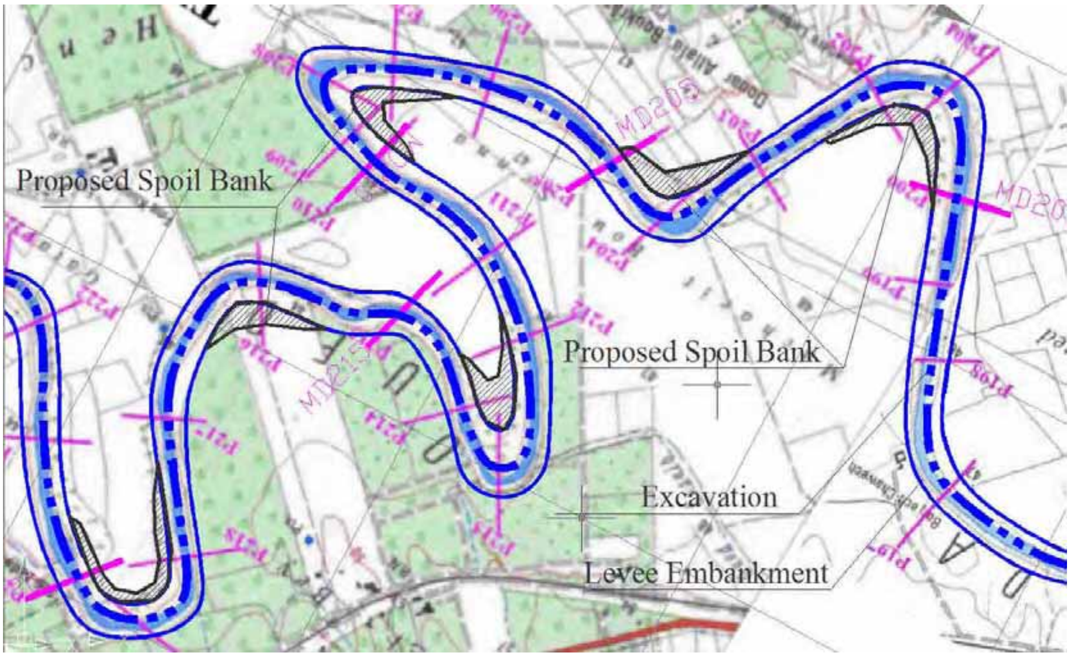
Code No.

A14. Disposal of excavated material, without haul

A15. Disposal of excavated material, with average hauling distance of 2.0 km

As it is mentioned below, an average hauling distance for disposal of material is assumed to be 2.0 km. However, since some of excavation sites are very close to spoil bank/stock yards, hauling of the disposing material is not required. Therefore, a proportion of A14: A15 with 2:8 was applied

.Costs of earth works are generally dominated by transportation cost. The channel excavation is major earth work of the proposed river improvement works. In particular, the excavation volume has a lot of surplus over the embankment volume. Even though majority of embankment works are done with excavated material without using borrow material, a large amount of excavated materials must be disposed by a proper manner.




Source: the Study Team

**Layout Plan of Potential Spoil Bank Sites of Excavated Material**

Under this situation, the project cost will be affected by the price of disposing of excess materials. Its unit cost is affected by hauling distance. The location of spoil bank is the key factor to lower the construction cost of earth works. The areas hatched shown in the figure above are promising sites for spoil banks. Generally, the elevations of lands inside of meanders are lower than the opposite sites. The low land of especially wheat field is once employed for the spoil bank and the land is backfilled with spoil materials up to proper elevation. Subsequently the land can be turned to wheat field again. In cost estimate of the current Study, a hauling distance to the spoil bank is assumed to be 2.0 km on an average.

## E3.2 Work Quantities

The work quantities of major structures are summarized as follows:

**Summary of Work Quantities**

| | | | |
|---|---|---|---|
| Works of river channel improvement in Zone D2 | | | |
| (1) | River channel length | | 64,974m |
| (2) | Levee embankment | Left bank | 29,365m |
| | | Right bank | 26,478m |
| | | Total | 55,843m |
| (3) | Low water channel excavation | | 63,776m |
| Works of river channel improvement in Zone D1 | | | |
| (1) | River channel length | | 83,563m |
| (2) | Levee embankment | Left bank | 36,671m |
| | | Right bank | 33,909m |
| | | Total | 70,580m |
| (3) | Low water channel excavation | | 81,224m |
| Works of river channel improvement in Zone U2 | | | |
| (1) | River channel length | | 63,889m |
| (2) | Levee embankment | Left bank | 34,833m |
| | | Right bank | 32,666m |
| | | Total | 67,499m |
| (3) | Low water channel excavation | | 42,730m |

Works of river channel improvement in Zone U1

| | | | |
|---|---|---|---|
| (1) | River channel length | | 94,417m |
| (2) | Levee embankment | Left bank | 2,264m |
| | | Right bank | 2,860m |
| | | Total | 5,124m |
| (3) | Low water channel excavation | | 48,754m |

Works of river channel improvement in Zone M

| | | | |
|---|---|---|---|
| (1) | River channel length | | 158,306m |
| (2) | Levee embankment | Left bank | 4,195m |
| | | Right bank | 3,210m |
| | | Total | 7,405m |
| (3) | Low water channel excavation | | 12,871m |

Source: the Study Team

## E3.3 Unit Cost

The unit cost finally applied for the cost estimate is summarized as follows:

**Summary of Unit Cost for Cost Estimate**

| No. | Work Item | Description | Unit | Unit price (TND) |
|---|---|---|---|---|
| | **EARTH WORKS** | | | |
| A1 | Clearing and grubbing (Dense bush) | with average hauling distance of 1.00 km | $m^2$ | 2.267 |
| A2 | Clearing and grubbing (Thin bush) | with average hauling distance of 1.00 km | $m^2$ | 1.491 |
| A3 | Stripping | with average hauling distance of 1.00 km | $m^2$ | 0.267 |
| A4 | Excavation for river channel, common soil | with average hauling distance of 0.50 km | $m^3$ | 2.300 |
| A5 | Excavation for river channel, indurated | with average hauling distance of 0.50 km | $m^3$ | 3.840 |
| A6 | Excavation for river channel, rock | with average hauling distance of 0.50 km | $m^3$ | 8.180 |
| A7 | Excavation for Bypass channel, common soil | with average hauling distance of 1.00 km | $m^3$ | 2.414 |
| A8 | Excavation for structures | | $m^3$ | 3.580 |
| A9 | Embankment | with average hauling distance of 2.00 km | $m^3$ | 3.759 |
| A10 | Embankment | Directly from excavation site | $m^3$ | 2.039 |
| A11 | Backfill to structures w/o haul | | $m^3$ | 4.160 |
| A12 | Gravel metalling for inspection roads | | $m^3$ | 27.310 |
| A13 | One-way hauling distance per 1.00 km | | $m^3$ | 0.477 |
| A14 | Disposal of excavated materials | Directly from excavation site | $m^3$ | 0.250 |
| A15 | Disposal of excavated materials | with average hauling distance of 2.00 km | $m^3$ | 1.220 |
| | **CONCRETE WORKS** | | | |
| B1 | Lean concrete (32/10) | 0.1 $m^2$ of form included | $m^3$ | 82.000 |
| B2 | Concrete Type A (63/17), Plain concrete | 0.5 $m^2$ of form included | $m^3$ | 114.000 |
| B3 | Concrete Type B (32/26), Reinforced concrete | 2.5 $m^2$ of form included | $m^3$ | 173.545 |
| B4 | Concrete Type C (16/26), Reinforced concrete | 4.0 $m^2$ of form included | $m^3$ | 215.846 |
| B5 | Reinforcement - plain round bar | | kg | 1.791 |
| B6 | Reinforcement - deformed bar | | kg | 1.791 |
| B7 | Stone masonry Type A, with 1:3 mortar | | $m^3$ | 75.386 |
| | **STONE WORKS** | | | |
| C1 | Gabion mattress | | $m^3$ | 94.225 |
| C2 | Stone pitching (Rough finishing) | | $m^3$ | 26.822 |
| C3 | Stone pitching (Fine finishing) | | $m^3$ | 42.862 |
| C4 | Fascine mattress | | $m^2$ | 17.907 |
| C5 | Cobble stone fill | | $m^3$ | 16.360 |
| C6 | Graded sand and gravel filter | | $m^3$ | 16.360 |
| C7 | Demolition and disposal of existing masonry and concrete | | $m^3$ | 155.720 |
| C8 | Asphalt concrete | | | 250.000 |
| | **OTHER MAJOR WORKS** | | | |
| D1 | Prestressed concrete beam L=30m | | Unit | 26,300.000 |
| D2 | Prestressed concrete beam L=25m | | Unit | 20,300.000 |
| D3 | Prestressed concrete beam L=20m | | Unit | 12,700.000 |
| D4 | Cast-in place concrete pile with steel pipe pile casing | | Unit | 6,900.000 |
| D5 | Steel sheet pile (Permanent cutoff) | | $m^2$ | 46.610 |
| D6 | Heightening and removal of existing railway | | m | 400.000 |

| | **Metal Works** | | |
|---|---|---|---|
| E1 | Slide gate (Manual operation hoist), Max size W = 1.50m, H = 1.50m | kg | 4.680 |
| E2 | Slide gate/Roller gate (Electric driven hoist), larger than W = 2.00m, H = 2.00m | kg | 6.240 |
| E3 | Other metal works | kg | 3.230 |
| | **Miscellaneous** | | |
| F1 | Restoration of affected existing structures, etc. | % | 3.000 |
| F2 | Miscellaneous works such as drainage crossing, inspection road, Accessories of bridge, Sod facing, etc. | % | 7.000 |

Source: the Study Team

The unit costs for each work items are calculated based mainly on bid prices of the past executed projects issued by MARH. The unit costs have been converted to the price level of June 2008 and the conversion rate applied to unit cost estimation is as follows (source: INS). The major items are selected to simplify the estimation of cost considering the requirement of master plan study level. The items and unit price applied to the cost estimate is shown in table below. Detailed background data are also attached in Data Book.

**Adjustment of Unit Cost**

| Date for Calculation of Unit Price in Documents of Past Projects | Date of Prices to be Converted | Nos of Reference Project | Rate of Price Escalation |
|---|---|---|---|
| June 2003 | to June 2008 | 3 | 20.544 % |
| June 2004 | | 1 | 14.830 % |
| November 2006 | | 1 | 7.083 % |

Source: National Statistics Office in Tunisia

For the crosschecking purpose, the unit costs of selected work Items dominantly affecting to the project cost, such as clearing and grubbing, embankment, excavation, disposal of waste material, concrete, gabion mattress, stone pitching and fascine mattress are estimated by preparing breakdown based on market prices in Tunisia. The breakdown is attached in **Data E2 of the Data Book**.

## E3.4 Direct Construction Cost

The summary of direct construction cost estimated based on the work quantities and unit costs is shown in the table below:

**Summary of Direct Construction Cost**

| Work Item | Zone | | | | (Unit: 1,000 TND) |
|---|---|---|---|---|---|
| | Zone D2 | Zone D1 | Zone U2 | Zone U1 | Zone M |
| Earth works | 43,244 | 49,203 | 54,093 | 15,427 | 2,352 |
| Concrete works | 9,937 | 641 | 7,038 | 52 | 52 |
| Stone works | 4,656 | 5,524 | 7,160 | 1,182 | 28 |
| Other major works | 4,273 | 1,466 | 3,553 | 7 | 7 |
| Metal Works | 229 | 128 | 90 | 2 | 2 |
| Miscellaneous | 6,234 | 5,996 | 7,193 | 1,667 | 244 |
| Total | 68,572 | 65,958 | 79,127 | 18,337 | 2,685 |
| Total of all zones | | | | | 234,679 |

Source: the Study Team

Work quantities and direct construction costs of each zone is shown in attached **Tables E3.4.1 to E3.4.5**.

Using the costs breakdown of excavation, embankment, stone pitching and concrete, a rough estimation on the ratio of foreign and local currency portions is made. Following proportion between foreign and local currency portions is applied in the current Study:

**Proportion of Foreign and Local Currency Portions**

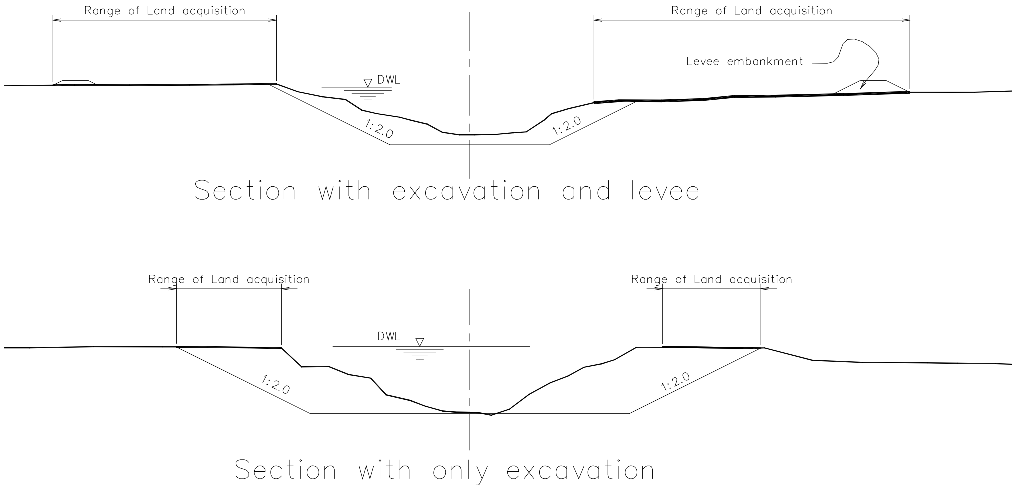
| Zone | Proportion | |
|---|---|---|
| | Foreign currency | Local currency |
| D2 | 0.40 | 0.60 |
| D1 | 0.45 | 0.55 |
| U2 | 0.45 | 0.55 |
| U1 | 0.50 | 0.50 |
| M | 0.50 | 0.50 |

Source: the Study Team

### E3.5 Land Acquisition Cost

The Mejerda River basin spreads over rich farming lands. The lands are greatly productive in agriculture. Mostly the farm land is developed almost up to the shoulder of river bank, which are provided with public irrigation facilities or private irrigation facilities.

According to the interview with CRDA Jendouba, 95% of land along the Mejerda River is possessed by private owners. The estimate of necessary area for land acquisition was made and then the associated cost was estimated on the premises that the lands are 100 % privately owned. Applied unit costs are obtained from interview at site or information from CRDA. The necessary area of land acquisition is shown in figure below. The total amount of land acquisition area is shown in the table below:




Source: the Study Team

**Range of Area subject to Land Acquisition**

The price of land acquisition is assumed as follows based on the interviews with CRDAs:

| | | | |
|---|---|---|---|
| Jendouba | 18,000 TND/ha | - | Zone U2 and Zone M |
| Beja | 22,000 TND/ha | - | Zone U1 and D1 |
| Mannouba | 35,000 TND/ha | - | Zone D2 |
| Aliana | 35,000 TND/ha | - | Zone D2 |
| Bizerte | 35,000 TND/ha | - | Zone D2 |

**Land Acquisition Cost**

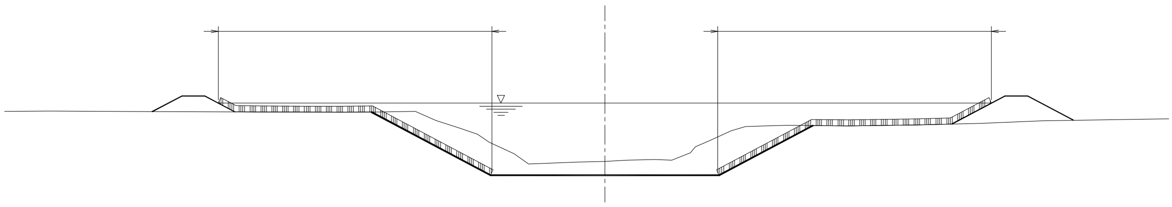
| Work Item | Area subject to land acquisition (ha) | | | | |
|---|---|---|---|---|---|
| | Zone D2 | Zone D1 | Zone U2 | Zone U1 | Zone M |
| Mejerda River improvement and El Mabtouh retarding basin | 263.2 | 260.5 | 579.0 | 118.3 | |
| Chaffrou River improvement | 1.5 | | | | |
| Lahmar River improvement | | 9.3 | | | |
| Siliana River improvement | | | | | |
| Khalled River improvement | | | | | |
| Kasseb River improvement | | | 18.2 | | |
| Bou Heurtma River improvement | | | 35.8 | | |
| Tessa River improvement | | | 25.4 | | |
| Mellegue River improvement | | | | | 36.7 |
| Bou Salem Bypass | | | 48.5 | | |
| Mejez El Bab Bypass | | 32.8 | | | |
| Total Area (ha) | 264.7 | 302.6 | 706.9 | 118.3 | 36.7 |
| Unit Price of Land (TND/ha) | 35,000 | 22,000 | 18,000 | 18,000 | 18,000 |
| Total Cost for Land Acquisition | 9,264,500 | 6,657,200 | 12,724,200 | 2,129,400 | 660,600 |

Source: the Study Team

# CHAPTER E4 MAINTENANCE WORKS OF RIVER CHANNEL

In order to conduct proper maintenance of the Mejerda River, grubbing the roots of Tamarix in all stretch at the high water channel between the levee except around the shoulder portion of river bank will be quite crucial. A manner of the grubbing shall be appropriately applied. In general, where the roots of Tamarix are removed, the growth of young Tamarix thereafter is relatively detained. For the purpose of keeping ideal condition of river channel, the regular maintenance activities to clean the river channel are very important. When Tamarix grows up to 3.0 m to 4.0 m in height with trunks of 2 to 3 cm or more in diameter, the portable grass cutter won't be applicable anymore and the cost of removal of Tamarix becomes considerably high.

Combination of following two maintenance methods is recommended so as to keep the river channel in good condition within an affordable budget. The necessary range to be cleaned in the river section is shown in a sketch as below:



**Required range for Clearing and Grubbing of Tamarix**

(1) Annual maintenance work

Vegetation in the channel shall be cleared by using a portable grass cutter. This is manual work. No heavy equipment is needed. The cut vegetation is just wasted in the site. The area where clearing is required shall be selected based on the rate of growth of vegetation. Some of lands might be still kept as they are with bare surface, which are not subject to clearing soon. Thus, the area to be cleared within one year is assumed to be 50 % of all areas. The unit cost of this wok is estimated to be 0.07 TND/$m^2$.

(2) 5-year periodical maintenance work

This work needs heavy equipment to extract the roots. Even the annual maintenance is carried out, the Tamarix might be left grown in overlooked areas. If the Tamarix continues to grow, maintenance of river channel becomes more difficult year by year and the maintenance schedule might deteriorate eventually. The bulldozer with a rake or a ripper, an excavator is to be applied to this work. As long as the annual maintenance is regularly carried out, the target areas of this work is limited and it is assumed that 20 % of the annual maintenance area is probably enough for this work. The unit cost of this work is estimated to be 0.267 TND/$m^2$.

The total maintenance cost for grubbing/clearing of river channel is estimated as shown in the table below:

| Zone | Total area (m²) | Annual maintenance | | | Periodical maintenance[1] | | |
|---|---|---|---|---|---|---|---|
| | | Target area (m²)[2] | Unit rate (TND/m²) | Amount (TND x1,000) | Target area (m²)[3] | Unit rate (TND/m²) | Amount (TND 1,000)[4] |
| U1 | 294063 | 147032 | 0.070 | 10.3 | 29,406 | 0.267 | 7.9 |
| U2 | 6827696 | 3413848 | 0.070 | 239.0 | 682,770 | 0.267 | 182.3 |
| M | 36300 | 18150 | 0.070 | 1.3 | 3,630 | 0.267 | 1.0 |
| D1 | 4230650 | 2115325 | 0.070 | 148.1 | 423,065 | 0.267 | 113.0 |
| D2 | 3871191 | 1935596 | 0.070 | 135.5 | 387,119 | 0.267 | 103.4 |
| | Total | 7629951 | | 534.1 | | | 407.4 |

Note: (1, Assumed once in every 5 years
(2, Assumed 50% of total area
(3, Assumed 20% of target area for annual maintenance
(4, Incremental cost to annual maintenance

Source: the Study Team

# *Tables*

## Table E3.4.1 Quantity and Direct Construction Cost of Zone D2

| No. | Work Item | Description | Unit | Quantity | Total | |
|---|---|---|---|---|---|---|
| | | | | | Unit price (TND) | Amount (TND) |
| | **EARTH WORKS** | | | | | |
| A1 | Clearing and grubbing (Dense bush) | with average hauling distance of 1.00 km | $m^2$ | 1,152,387 | 2.267 | 2,612,462 |
| A2 | Clearing and grubbing (Thin bush) | with average hauling distance of 1.00 km | $m^2$ | 768,258 | 1.491 | 1,145,473 |
| A3 | Stripping | with average hauling distance of 1.00 km | $m^2$ | 1,950,546 | 0.267 | 520,796 |
| A4 | Excavation for river channel, common soil | with average hauling distance of 0.50 km | $m^3$ | 9,216,281 | 2.300 | 21,197,446 |
| A5 | Excavation for river channel, indurated | with average hauling distance of 0.50 km | $m^3$ | 659,047 | 3.840 | 2,530,741 |
| A6 | Excavation for river channel, rock | with average hauling distance of 0.50 km | $m^3$ | 164,762 | 8.180 | 1,347,752 |
| A7 | Excavation for Bypass channel, common soil | with average hauling distance of 1.00 km | $m^3$ | | 2.414 | |
| A8 | Excavation for structures | | $m^3$ | 98,308 | 3.580 | 351,943 |
| A9 | Embankment | with average hauling distance of 2.00 km | $m^3$ | 160,740 | 3.759 | 604,222 |
| A10 | Embankment | Directly from excavation site | $m^3$ | 1,574,660 | 2.039 | 3,210,732 |
| A11 | Backfill to structures w/o haul | | $m^3$ | 76,450 | 4.160 | 318,032 |
| A12 | Gravel metalling for inspection roads | | $m^3$ | | 27.310 | |
| A13 | One-way hauling distance per 1.00 km | | $m^3$ | 10,000 | 0.477 | 4,770 |
| A14 | Disposal of excavated materials | Directly from excavation site | $m^3$ | 1,577,286 | 0.250 | 394,322 |
| A15 | Disposal of excavated materials | with average hauling distance of 2.00 km | $m^3$ | 7,381,002 | 1.220 | 9,004,822 |
| | | | | | Subtotal | 43,243,512 |
| | **CONCRETE WORKS** | | | | | |
| B1 | Lean concrete (32/10) | 0.1 m2 of form included | $m^3$ | 1,250 | 82.000 | 102,483 |
| B2 | Concrete Type A (63/17), Plain concrete | 0.5 m2 of form included | $m^3$ | 2,580 | 114.000 | 294,171 |
| B3 | Concrete Type B (32/26), Reinforced concrete | 2.5 m2 of form included | $m^3$ | 24,115 | 173.545 | 4,184,994 |
| B4 | Concrete Type C (16/26), Reinforced concrete | 4.0 m2 of form included | $m^3$ | 1,688 | 215.846 | 364,380 |
| B5 | Reinforcement - plain round bar | | kg | | 1.791 | |
| B6 | Reinforcement - deformed bar | | kg | 2,131,758 | 1.791 | 3,817,978 |
| B7 | Stone masonry Type A, with 1:3 mortar | | $m^3$ | 15,554 | 75.386 | 1,172,562 |
| | | | | | Subtotal | 9,936,570 |
| | **STONE WORKS** | | | | | |
| C1 | Gabion mattress | | $m^3$ | 9,494 | 94.225 | 894,525 |
| C2 | Stone pitching (Rough finishing) | | $m^3$ | 36,528 | 26.822 | 979,744 |
| C3 | Stone pitching (Fine finishing) | | $m^3$ | 10,000 | 42.862 | 428,620 |
| C4 | Fascine mattress | | $m^2$ | 72,000 | 17.907 | 1,289,304 |
| C5 | Cobble stone fill | | $m^3$ | 8,064 | 16.360 | 131,927 |
| C6 | Graded sand and gravel filter | | $m^3$ | 21,833 | 16.360 | 357,185 |
| C7 | Demolition and disposal of existing masonry and concrete | | $m^3$ | 2,008 | 155.720 | 312,686 |
| C8 | Asphalt concrete | | $m^3$ | 1,050 | 250.000 | 262,500 |
| | | | | | Subtotal | 4,656,491 |
| | **OTHER MAJOR WORKS** | | | | | |
| D1 | Prestressed concrete beam L=30m | | Unit | 40 | 26,300.000 | 1,052,000 |
| D2 | Prestressed concrete beam L=25m | | Unit | 60 | 20,300.000 | 1,218,000 |
| D3 | Prestressed concrete beam L=20m | | Unit | 20 | 12,700.000 | 254,000 |
| D4 | Cast-in place concrete pile with steel pipe pile casing | | Unit | 140 | 6,900.000 | 966,000 |
| D5 | Steel sheet pile (Permanent cutoff) | | $m^2$ | 6,500 | 46.610 | 302,965 |
| D6 | Heightening and removal of existing railway | | m | 1,200 | 400.000 | 480,000 |
| | | | | | Subtotal | 4,272,965 |
| | **Metal Works** | | | | | |
| E1 | Slide gate (Manual operation hoist), Max size W = 1.50m, H = 1.50m | | kg | 34,529 | 4.680 | 161,596 |
| E2 | Slide gate/Roller gate (Electric driven hoist), larger than W = 2.00m, H = 2.00m | | kg | 10,800 | 6.240 | 67,392 |
| E3 | Other metal works | | kg | | 3.230 | |
| | | | | | Subtotal | 228,988 |
| | **Miscellaneous** | | | | | |
| F1 | Restoration of affected existing structures, etc. | | % | 3.000 | 62,338,525.309 | 1,870,156 |
| F2 | Miscellaneous works such as drainage crossing, inspection road, Accessories of bridge, Sod facing etc. | | % | 7.000 | 62,338,525.309 | 4,363,697 |
| | | | | | Subtotal | 6,233,853 |
| | | | | | **Total of Direct Construction Cost of Zone D2** | **68,572,378** |

## Table E3.4.2 Quantity and Direct Construction Cost of Zone D1

| No. | Work Item | Description | Unit | Quantity | Total | |
|---|---|---|---|---|---|---|
| | | | | | Unit price (TND) | Amount (TND) |
| | **EARTH WORKS** | | | | | |
| A1 | Clearing and grubbing (Dense bush) | with average hauling distance of 1.00 km | $m^2$ | 1,259,835 | 2.267 | 2,856,046 |
| A2 | Clearing and grubbing (Thin bush) | with average hauling distance of 1.00 km | $m^2$ | 855,490 | 1.491 | 1,275,536 |
| A3 | Stripping | with average hauling distance of 1.00 km | $m^2$ | 2,115,325 | 0.267 | 564,792 |
| A4 | Excavation for river channel, common soil | with average hauling distance of 0.50 km | $m^3$ | 8,489,729 | 2.300 | 19,526,376 |
| A5 | Excavation for river channel, indurated | with average hauling distance of 0.50 km | $m^3$ | 754,643 | 3.840 | 2,897,827 |
| A6 | Excavation for river channel, rock | with average hauling distance of 0.50 km | $m^3$ | 188,661 | 8.180 | 1,543,244 |
| A7 | Excavation for Bypass channel, common soil | with average hauling distance of 1.00 km | $m^3$ | 2,647,844 | 2.414 | 6,391,895 |
| A8 | Excavation for structures | | $m^3$ | 40,200 | 3.580 | 143,916 |
| A9 | Embankment | with average hauling distance of 2.00 km | $m^3$ | 25,800 | 3.759 | 96,982 |
| A10 | Embankment | Directly from excavation site | $m^3$ | 822,600 | 2.039 | 1,677,281 |
| A11 | Backfill to structures w/o haul | | $m^3$ | 14,950 | 4.160 | 62,192 |
| A12 | Gravel metalling for inspection roads | | $m^3$ | 97,500 | 27.310 | 2,662,725 |
| A13 | One-way hauling distance per 1.00 km | | $m^3$ | | 0.477 | |
| A14 | Disposal of excavated materials | Directly from excavation site | $m^3$ | 4,400,080 | 0.250 | 1,100,020 |
| A15 | Disposal of excavated materials | with average hauling distance of 2.00 km | $m^3$ | 6,888,346 | 1.220 | 8,403,782 |
| | | | | | Subtotal | 49,202,616 |
| | **CONCRETE WORKS** | | | | | |
| B1 | Lean concrete (32/10) | 0.1 m2 of form included | $m^3$ | | 82.000 | |
| B2 | Concrete Type A (63/17), Plain concrete | 0.5 m2 of form included | $m^3$ | 1,408 | 114.000 | 160,494 |
| B3 | Concrete Type B (32/26), Reinforced concrete | 2.5 m2 of form included | $m^3$ | 11,519 | 173.545 | 1,998,978 |
| B4 | Concrete Type C (16/26), Reinforced concrete | 4.0 m2 of form included | $m^3$ | 855 | 215.846 | 184,548 |
| B5 | Reinforcement - plain round bar | | kg | | 1.791 | |
| B6 | Reinforcement - deformed bar | | kg | 724,240 | 1.791 | 1,297,114 |
| B7 | Stone masonry Type A, with 1:3 mortar | | $m^3$ | | 75.386 | |
| | | | | | Subtotal | 3,641,134 |
| | **STONE WORKS** | | | | | |
| C1 | Gabion mattress | | $m^3$ | 11,226 | 94.225 | 1,057,770 |
| C2 | Stone pitching (Rough finishing) | | $m^3$ | 63,738 | 26.822 | 1,709,567 |
| C3 | Stone pitching (Fine finishing) | | $m^3$ | 10,000 | 42.862 | 428,620 |
| C4 | Fascine mattress | | $m^2$ | 81,000 | 17.907 | 1,450,467 |
| C5 | Cobble stone fill | | $m^3$ | | 16.360 | |
| C6 | Graded sand and gravel filter | | $m^3$ | 6,075 | 16.360 | 99,387 |
| C7 | Demolition and disposal of existing masonry and concrete | | $m^3$ | 5,000 | 155.720 | 778,600 |
| C8 | Asphalt concrete | | $m^3$ | | 250.000 | |
| | | | | | Subtotal | 5,524,411 |
| | **OTHER MAJOR WORKS** | | | | | |
| D1 | Prestressed concrete beam L=30m | | Unit | 24 | 26,300.000 | 631,200 |
| D2 | Prestressed concrete beam L=25m | | Unit | 24 | 20,300.000 | 487,200 |
| D3 | Prestressed concrete beam L=20m | | Unit | | 12,700.000 | |
| D4 | Cast-in place concrete pile with steel pipe pile casing | | Unit | 30 | 6,900.000 | 207,000 |
| D5 | Steel sheet pile (Permanent cutoff) | | $m^2$ | 3,010 | 46.610 | 140,296 |
| D6 | Heightening and removal of existing railway | | m | | 400.000 | |
| | | | | | Subtotal | 1,465,696 |
| | **Metal Works** | | | | | |
| E1 | Slide gate (Manual operation hoist), Max size W = 1.50m, H = 1.50m | | kg | 24,710 | 4.680 | 115,643 |
| E2 | Slide gate/Roller gate (Electric driven hoist), larger than W = 2.00m, H = 2.00m | | kg | 2,000 | 6.240 | 12,480 |
| E3 | Other metal works | | kg | | 3.230 | |
| | | | | | Subtotal | 128,123 |
| | **Miscellaneous** | | | | | |
| F1 | Restoration of affected existing structures, etc. | | % | 3.000 | 59,961,979.641 | 1,798,859 |
| F2 | Miscellaneous works such as drainage crossing, inspection road, Accessories of bridge, Sod facing etc. | | % | 7.000 | 59,961,979.641 | 4,197,339 |
| | | | | | Subtotal | 5,996,198 |
| | | | | | **Total of Direct Construction Cost of Zone D1** | **65,958,178** |

## Table E3.4.3 Quantity and Direct Construction Cost of Zone U2

| No. | Work Item | Description | Unit | Quantity | Total | |
|---|---|---|---|---|---|---|
| | | | | | Unit price (TND) | Amount (TND) |
| | **EARTH WORKS** | | | | | |
| A1 | Clearing and grubbing (Dense bush) | with average hauling distance of 1.00 km | $m^2$ | 1,847,132 | 2.267 | 4,187,449 |
| A2 | Clearing and grubbing (Thin bush) | with average hauling distance of 1.00 km | $m^2$ | 1,230,755 | 1.491 | 1,835,056 |
| A3 | Stripping | with average hauling distance of 1.00 km | $m^2$ | 3,562,887 | 0.267 | 951,291 |
| A4 | Excavation for river channel, common soil | with average hauling distance of 0.50 km | $m^3$ | 8,628,281 | 2.300 | 19,845,045 |
| A5 | Excavation for river channel, indurated | with average hauling distance of 0.50 km | $m^3$ | 766,216 | 3.840 | 2,942,269 |
| A6 | Excavation for river channel, rock | with average hauling distance of 0.50 km | $m^3$ | 191,554 | 8.180 | 1,566,912 |
| A7 | Excavation for Bypass channel, common soil | with average hauling distance of 1.00 km | $m^3$ | 3,205,040 | 2.414 | 7,736,967 |
| A8 | Excavation for structures | | $m^3$ | 57,400 | 3.580 | 205,492 |
| A9 | Embankment | with average hauling distance of 2.00 km | $m^3$ | 556,288 | 3.759 | 2,091,085 |
| A10 | Embankment | Directly from excavation site | $m^3$ | 2,838,939 | 2.039 | 5,788,597 |
| A11 | Backfill to structures w/o haul | | $m^3$ | 17,220 | 4.160 | 71,635 |
| A12 | Gravel metalling for inspection roads | | $m^3$ | | 27.310 | |
| A13 | One-way hauling distance per 1.00 km | | $m^3$ | 1,000,000 | 0.477 | 477,000 |
| A14 | Disposal of excavated materials | Directly from excavation site | $m^3$ | 4,313,835 | 0.250 | 1,078,459 |
| A15 | Disposal of excavated materials | with average hauling distance of 2.00 km | $m^3$ | 4,356,937 | 1.220 | 5,315,463 |
| | | | | | Subtotal | 54,092,719 |
| | **CONCRETE WORKS** | | | | | |
| B1 | Lean concrete (32/10) | 0.1 m2 of form included | $m^3$ | 422 | 82.000 | 34,612 |
| B2 | Concrete Type A (63/17), Plain concrete | 0.5 m2 of form included | $m^3$ | 4,422 | 114.000 | 504,097 |
| B3 | Concrete Type B (32/26), Reinforced concrete | 2.5 m2 of form included | $m^3$ | 18,554 | 173.545 | 3,219,954 |
| B4 | Concrete Type C (16/26), Reinforced concrete | 4.0 m2 of form included | $m^3$ | 544 | 215.846 | 117,420 |
| B5 | Reinforcement - plain round bar | | kg | | 1.791 | |
| B6 | Reinforcement - deformed bar | | kg | 1,441,880 | 1.791 | 2,582,407 |
| B7 | Stone masonry Type A, with 1:3 mortar | | $m^3$ | 7,686 | 75.386 | 579,417 |
| | | | | | Subtotal | 7,037,907 |
| | **STONE WORKS** | | | | | |
| C1 | Gabion mattress | | $m^3$ | 18,445 | 94.225 | 1,737,980 |
| C2 | Stone pitching (Rough finishing) | | $m^3$ | 86,705 | 26.822 | 2,325,602 |
| C3 | Stone pitching (Fine finishing) | | $m^3$ | 16,451 | 42.862 | 705,131 |
| C4 | Fascine mattress | | $m^2$ | 99,000 | 17.907 | 1,772,793 |
| C5 | Cobble stone fill | | $m^3$ | | 16.360 | |
| C6 | Graded sand and gravel filter | | $m^3$ | 28,311 | 16.360 | 463,161 |
| C7 | Demolition and disposal of existing masonry and concrete | | $m^3$ | 1,000 | 155.720 | 155,720 |
| C8 | Asphalt concrete | | $m^3$ | | 250.000 | |
| | | | | | Subtotal | 7,160,387 |
| | **OTHER MAJOR WORKS** | | | | | |
| D1 | Prestressed concrete beam L=30m | | Unit | 56 | 26,300.000 | 1,472,800 |
| D2 | Prestressed concrete beam L=25m | | Unit | 8 | 20,300.000 | 162,400 |
| D3 | Prestressed concrete beam L=20m | | Unit | 8 | 12,700.000 | 101,600 |
| D4 | Cast-in place concrete pile with steel pipe pile casing | | Unit | 72 | 6,900.000 | 496,800 |
| D5 | Steel sheet pile (Permanent cutoff) | | $m^2$ | 2,560 | 46.610 | 119,322 |
| D6 | Heightening and removal of existing railway | | m | 3,000 | 400.000 | 1,200,000 |
| | | | | | Subtotal | 3,552,922 |
| | **Metal Works** | | | | | |
| E1 | Slide gate (Manual operation hoist), Max size W = 1.50m, H = 1.50m | | kg | 19,200 | 4.680 | 89,856 |
| E2 | Slide gate/Roller gate (Electric driven hoist), larger than W = 2.00m, H = 2.00m | | kg | | 6.240 | |
| E3 | Other metal works | | kg | | 3.230 | |
| | | | | | Subtotal | 89,856 |
| | **Miscellaneous** | | | | | |
| F1 | Restoration of affected existing structures, etc. | | % | 3.000 | 71,933,790.416 | 2,158,014 |
| F2 | Miscellaneous works such as drainage crossing, inspection road, Accessories of bridge, Sod facing etc. | | % | 7.000 | 71,933,790.416 | 5,035,365 |
| | | | | | Subtotal | 7,193,379 |
| | | | | | **Total of Direct Construction Cost of Zone U2** | **79,127,169** |

## Table E3.4.4 Quantity and Direct Construction Cost of Zone U1

| No. | Work Item | Description | Unit | Quantity | Total | |
|---|---|---|---|---|---|---|
| | | | | | Unit price (TND) | Amount (TND) |
| | **EARTH WORKS** | | | | | |
| A1 | Clearing and grubbing (Dense bush) | with average hauling distance of 1.00 km | $m^2$ | 29,406 | 2.267 | 66,664 |
| A2 | Clearing and grubbing (Thin bush) | with average hauling distance of 1.00 km | $m^2$ | 58,813 | 1.491 | 87,690 |
| A3 | Stripping | with average hauling distance of 1.00 km | $m^2$ | 205,844 | 0.267 | 54,960 |
| A4 | Excavation for river channel, common soil | with average hauling distance of 0.50 km | $m^3$ | 3,810,168 | 2.300 | 8,763,386 |
| A5 | Excavation for river channel, indurated | with average hauling distance of 0.50 km | $m^3$ | 338,682 | 3.840 | 1,300,537 |
| A6 | Excavation for river channel, rock | with average hauling distance of 0.50 km | $m^3$ | 84,670 | 8.180 | 692,604 |
| A7 | Excavation for Bypass channel, common soil | with average hauling distance of 1.00 km | $m^3$ | | 2.414 | |
| A8 | Excavation for structures | | $m^3$ | 900 | 3.580 | 3,222 |
| A9 | Embankment | with average hauling distance of 2.00 km | $m^3$ | 8,780 | 3.759 | 33,004 |
| A10 | Embankment | Directly from excavation site | $m^3$ | 79,020 | 2.039 | 161,122 |
| A11 | Backfill to structures w/o haul | | $m^3$ | 300 | 4.160 | 1,248 |
| A12 | Gravel metalling for inspection roads | | $m^3$ | | 27.310 | |
| A13 | One-way hauling distance per 1.00 km | | $m^3$ | | 0.477 | |
| A14 | Disposal of excavated materials | Directly from excavation site | $m^3$ | 831,500 | 0.250 | 207,875 |
| A15 | Disposal of excavated materials | with average hauling distance of 2.00 km | $m^3$ | 3,323,600 | 1.220 | 4,054,792 |
| | | | | | Subtotal | 15,427,104 |
| | **CONCRETE WORKS** | | | | | |
| B1 | Lean concrete (32/10) | 0.1 m2 of form included | $m^3$ | | 82.000 | |
| B2 | Concrete Type A (63/17), Plain concrete | 0.5 m2 of form included | $m^3$ | | 114.000 | |
| B3 | Concrete Type B (32/26), Reinforced concrete | 2.5 m2 of form included | $m^3$ | 164 | 173.545 | 28,513 |
| B4 | Concrete Type C (16/26), Reinforced concrete | 4.0 m2 of form included | $m^3$ | | 215.846 | |
| B5 | Reinforcement - plain round bar | | kg | | 1.791 | |
| B6 | Reinforcement - deformed bar | | kg | 13,144 | 1.791 | 23,540 |
| B7 | Stone masonry Type A, with 1:3 mortar | | $m^3$ | | 75.386 | |
| | | | | | Subtotal | 52,053 |
| | **STONE WORKS** | | | | | |
| C1 | Gabion mattress | | $m^3$ | 162 | 94.225 | 15,264 |
| C2 | Stone pitching (Rough finishing) | | $m^3$ | 5,469 | 26.822 | 146,700 |
| C3 | Stone pitching (Fine finishing) | | $m^3$ | 5,000 | 42.862 | 214,310 |
| C4 | Fascine mattress | | $m^2$ | 45,000 | 17.907 | 805,815 |
| C5 | Cobble stone fill | | $m^3$ | | 16.360 | |
| C6 | Graded sand and gravel filter | | $m^3$ | | 16.360 | |
| C7 | Demolition and disposal of existing masonry and concrete | | $m^3$ | | 155.720 | |
| C8 | Asphalt concrete | | $m^3$ | | 250.000 | |
| | | | | | Subtotal | 1,182,089 |
| | **OTHER MAJOR WORKS** | | | | | |
| D1 | Prestressed concrete beam L=30m | | Unit | | 26,300.000 | |
| D2 | Prestressed concrete beam L=25m | | Unit | | 20,300.000 | |
| D3 | Prestressed concrete beam L=20m | | Unit | | 12,700.000 | |
| D4 | Cast-in place concrete pile with steel pipe pile casing | | Unit | | 6,900.000 | |
| D5 | Steel sheet pile (Permanent cutoff) | | $m^2$ | 150 | 46.610 | 6,992 |
| D6 | Heightening and removal of existing railway | | m | | 400.000 | |
| | | | | | Subtotal | 6,992 |
| | **Metal Works** | | | | | |
| E1 | Slide gate (Manual operation hoist), Max size W = 1.50m, H = 1.50m | | kg | 390 | 4.680 | 1,825 |
| E2 | Slide gate/Roller gate (Electric driven hoist), larger than W = 2.00m, H = 2.00m | | kg | | 6.240 | |
| E3 | Other metal works | | kg | | 3.230 | |
| | | | | | Subtotal | 1,825 |
| | **Miscellaneous** | | | | | |
| F1 | Restoration of affected existing structures, etc. | | % | 3.000 | 16,670,063.083 | 500,102 |
| F2 | Miscellaneous works such as drainage crossing, inspection road, Accessories of bridge, Sod facing etc. | | % | 7.000 | 16,670,063.083 | 1,166,904 |
| | | | | | Subtotal | 1,667,006 |
| | | | | | **Total of Direct Construction Cost of Zone U1** | **18,337,069** |

## Table E3.4.5 Quantity and Direct Construction Cost of Zone M

| No. | Work Item | Description | Unit | Quantity | Total | |
|---|---|---|---|---|---|---|
| | | | | | Unit price (TND) | Amount (TND) |
| | **EARTH WORKS** | | | | | |
| A1 | Clearing and grubbing (Dense bush) | with average hauling distance of 1.00 km | $m^2$ | 11,000 | 2.267 | 24,937 |
| A2 | Clearing and grubbing (Thin bush) | with average hauling distance of 1.00 km | $m^2$ | 7,300 | 1.491 | 10,884 |
| A3 | Stripping | with average hauling distance of 1.00 km | $m^2$ | 18,000 | 0.267 | 4,806 |
| A4 | Excavation for river channel, common soil | with average hauling distance of 0.50 km | $m^3$ | 575,550 | 2.300 | 1,323,765 |
| A5 | Excavation for river channel, indurated | with average hauling distance of 0.50 km | $m^3$ | 51,160 | 3.840 | 196,454 |
| A6 | Excavation for river channel, rock | with average hauling distance of 0.50 km | $m^3$ | 12,790 | 8.180 | 104,622 |
| A7 | Excavation for Bypass channel, common soil | with average hauling distance of 1.00 km | $m^3$ | | 2.414 | |
| A8 | Excavation for structures | | $m^3$ | 15,100 | 3.580 | 54,058 |
| A9 | Embankment | with average hauling distance of 2.00 km | $m^3$ | 127,800 | 3.759 | 480,400 |
| A10 | Embankment | Directly from excavation site | $m^3$ | | 2.039 | |
| A11 | Backfill to structures w/o haul | | $m^3$ | 300 | 4.160 | 1,248 |
| A12 | Gravel metalling for inspection roads | | $m^3$ | | 27.310 | |
| A13 | One-way hauling distance per 1.00 km | | $m^3$ | 102,340 | 0.477 | 48,816 |
| A14 | Disposal of excavated materials | Directly from excavation site | $m^3$ | 409,960 | 0.250 | 102,490 |
| A15 | Disposal of excavated materials | with average hauling distance of 2.00 km | $m^3$ | | 1.220 | |
| | | | | | Subtotal | 2,352,481 |
| | **CONCRETE WORKS** | | | | | |
| B1 | Lean concrete (32/10) | 0.1 m2 of form included | $m^3$ | | 82.000 | |
| B2 | Concrete Type A (63/17), Plain concrete | 0.5 m2 of form included | $m^3$ | | 114.000 | |
| B3 | Concrete Type B (32/26), Reinforced concrete | 2.5 m2 of form included | $m^3$ | 164 | 173.545 | 28,513 |
| B4 | Concrete Type C (16/26), Reinforced concrete | 4.0 m2 of form included | $m^3$ | | 215.846 | |
| B5 | Reinforcement - plain round bar | | kg | | 1.791 | |
| B6 | Reinforcement - deformed bar | | kg | 13,144 | 1.791 | 23,540 |
| B7 | Stone masonry Type A, with 1:3 mortar | | $m^3$ | | 75.386 | |
| | | | | | Subtotal | 52,053 |
| | **STONE WORKS** | | | | | |
| C1 | Gabion mattress | | $m^3$ | 162 | 94.225 | 15,264 |
| C2 | Stone pitching (Rough finishing) | | $m^3$ | 469 | 26.822 | 12,590 |
| C3 | Stone pitching (Fine finishing) | | $m^3$ | | 42.862 | |
| C4 | Fascine mattress | | $m^2$ | | 17.907 | |
| C5 | Cobble stone fill | | $m^3$ | | 16.360 | |
| C6 | Graded sand and gravel filter | | $m^3$ | | 16.360 | |
| C7 | Demolition and disposal of existing masonry and concrete | | $m^3$ | | 155.720 | |
| C8 | Asphalt concrete | | $m^3$ | | 250.000 | |
| | | | | | Subtotal | 27,854 |
| | **OTHER MAJOR WORKS** | | | | | |
| D1 | Prestressed concrete beam L=30m | | Unit | | 26,300.000 | |
| D2 | Prestressed concrete beam L=25m | | Unit | | 20,300.000 | |
| D3 | Prestressed concrete beam L=20m | | Unit | | 12,700.000 | |
| D4 | Cast-in place concrete pile with steel pipe pile casing | | Unit | | 6,900.000 | |
| D5 | Steel sheet pile (Permanent cutoff) | | $m^2$ | 150 | 46.610 | 6,992 |
| D6 | Heightening and removal of existing railway | | m | | 400.000 | |
| | | | | | Subtotal | 6,992 |
| | **Metal Works** | | | | | |
| E1 | Slide gate (Manual operation hoist), Max size W = 1.50m, H = 1.50m | | kg | 390 | 4.680 | 1,825 |
| E2 | Slide gate/Roller gate (Electric driven hoist), larger than W = 2.00m, H = 2.00m | | kg | | 6.240 | |
| E3 | Other metal works | | kg | | 3.230 | |
| | | | | | Subtotal | 1,825 |
| | **Miscellaneous** | | | | | |
| F1 | Restoration of affected existing structures, etc. | | % | 3.000 | 2,441,204.904 | 73,236 |
| F2 | Miscellaneous works such as drainage crossing, inspection road, Accessories of bridge, Sod facing etc. | | % | 7.000 | 2,441,204.904 | 170,884 |
| | | | | | Subtotal | 244,120 |
| | | | | | **Total of Direct Construction Cost of Zone M** | **2,685,325** |

# *Figures*

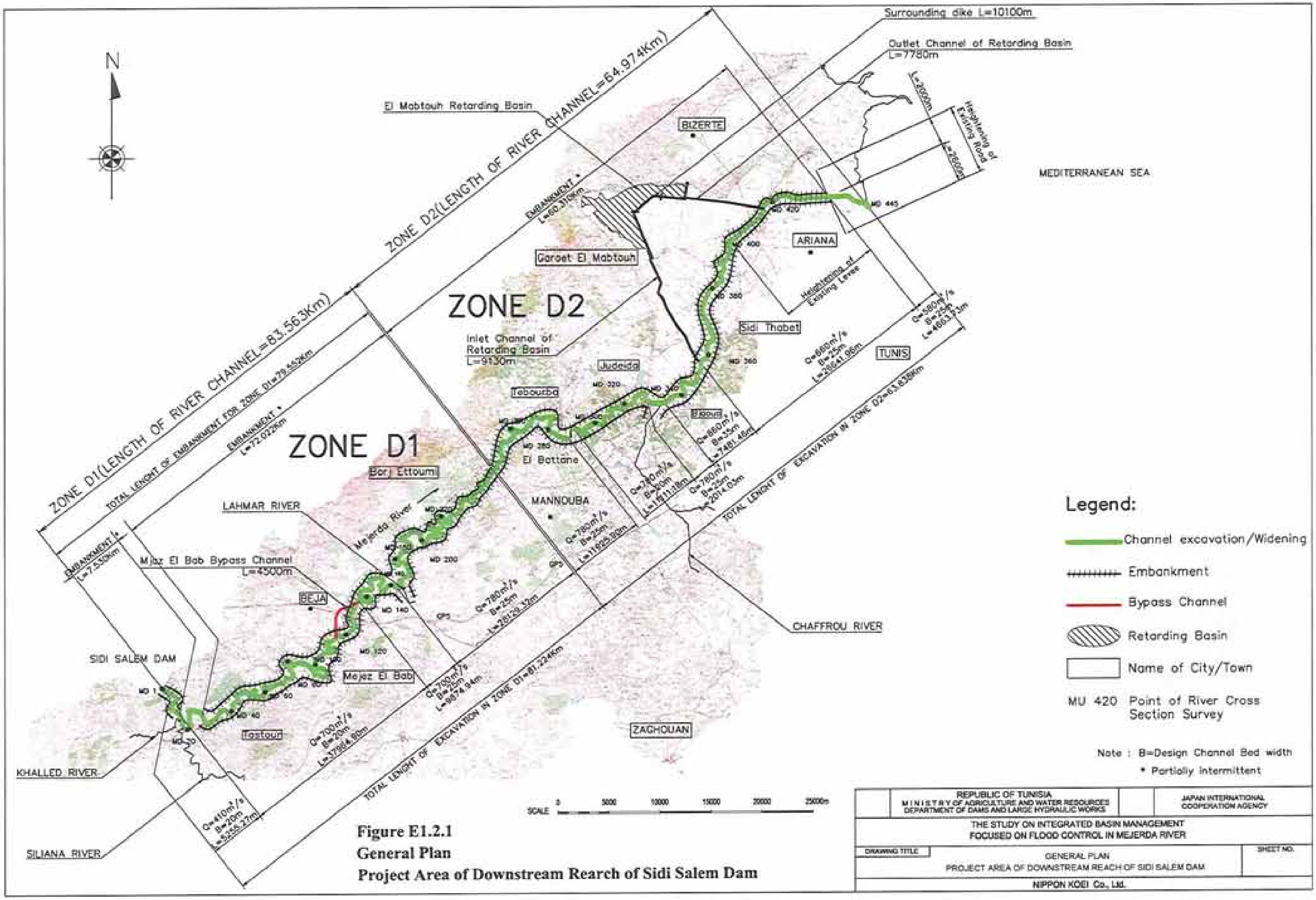



**Figure E1.2.1**
**General Plan**
**Project Area of Downstream Rearch of Sidi Salem Dam**

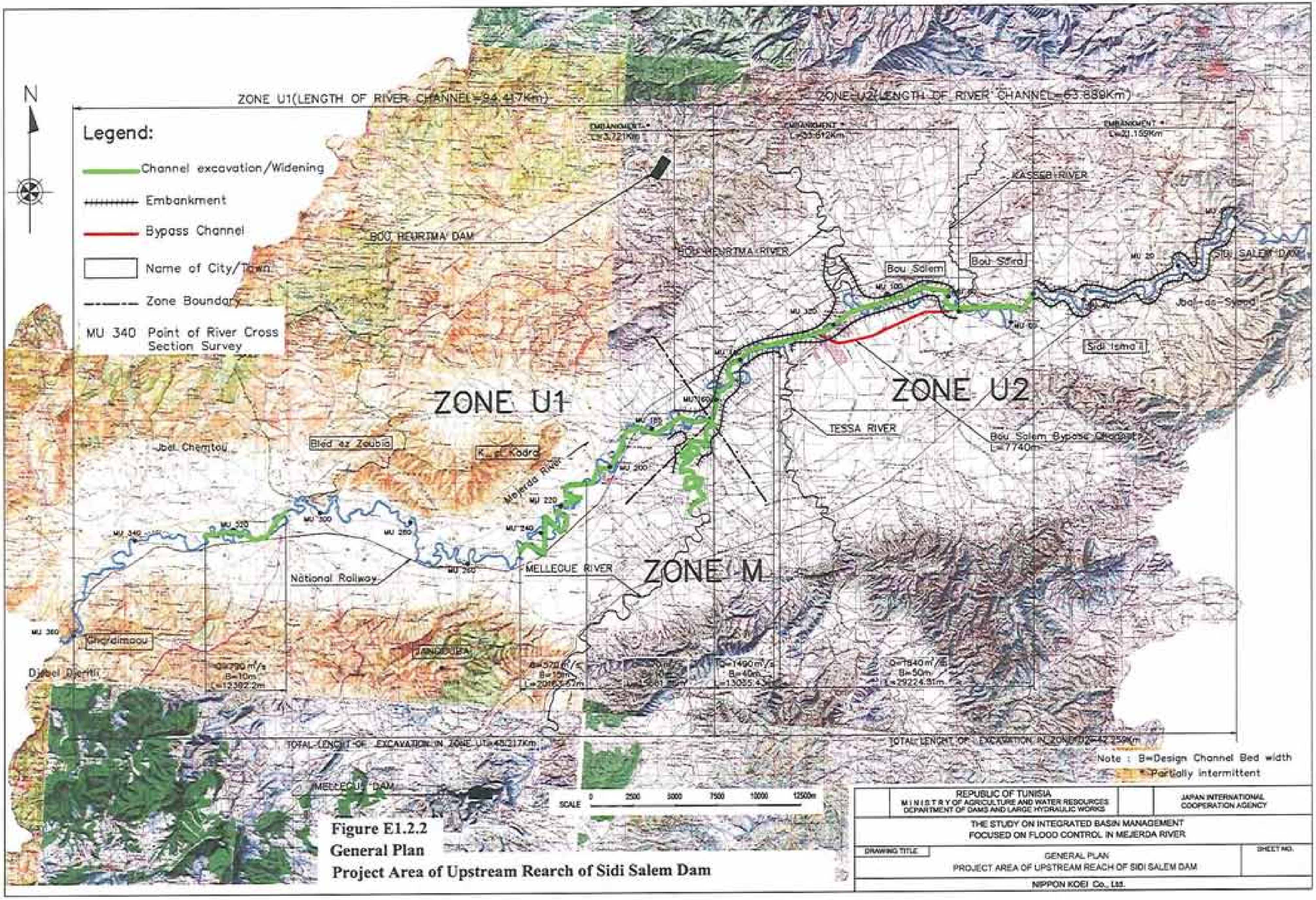



**Figure E1.2.2**
**General Plan**
**Project Area of Upstream Rearch of Sidi Salem Dam**

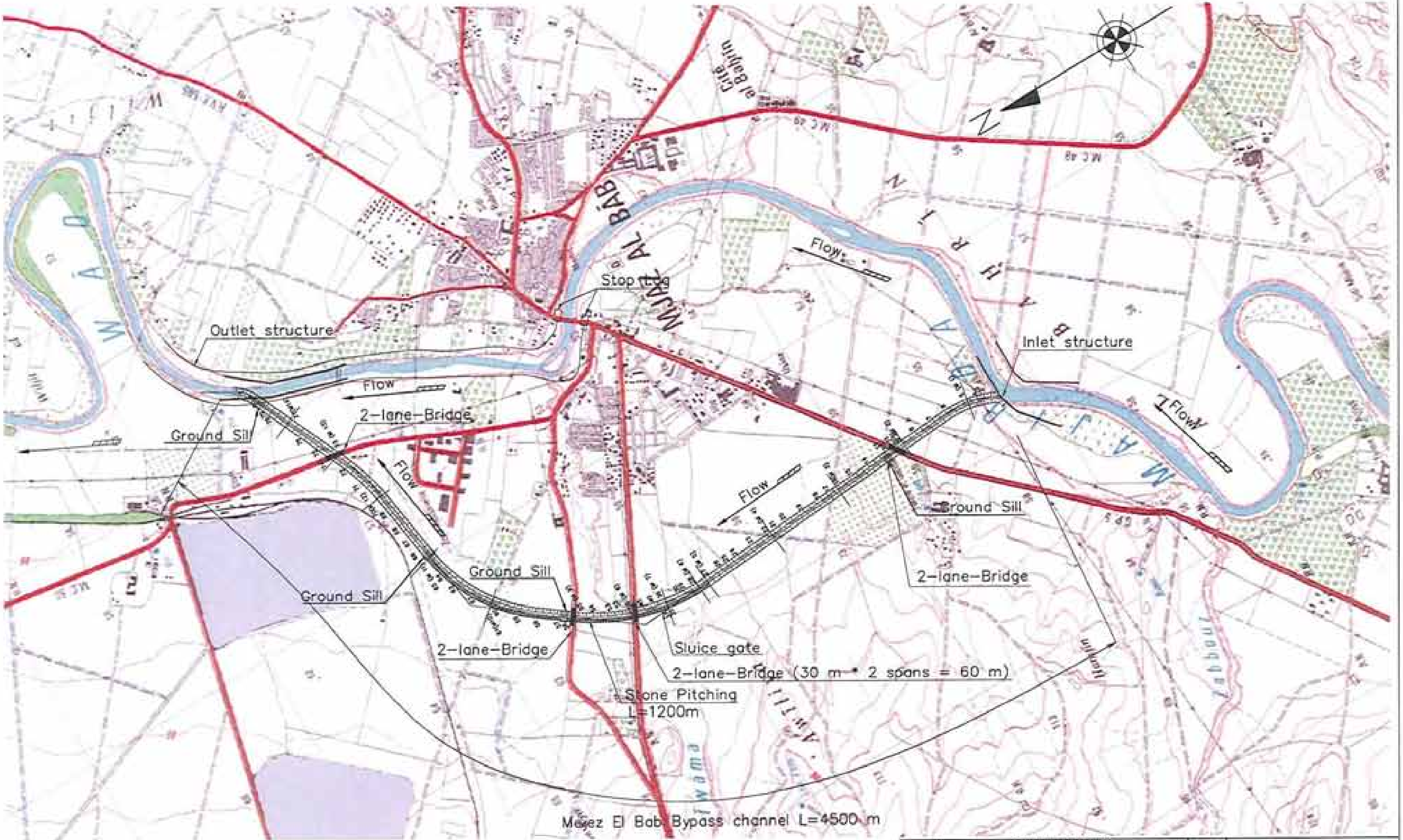



**Figure E2.1.1 Mejez El Bab Bypass Channel ( Zone D1 )**
**Plan**

SCALE 0 200 400 600 800 1000 m

| | |
|---|---|
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| DRAWING TITLE: MEJEZ EL BAB BYPASS CHANNEL ( ZONE D1 )<br>PLAN | SHEET NO. |
| NIPPON KOEI Co., Ltd. | |

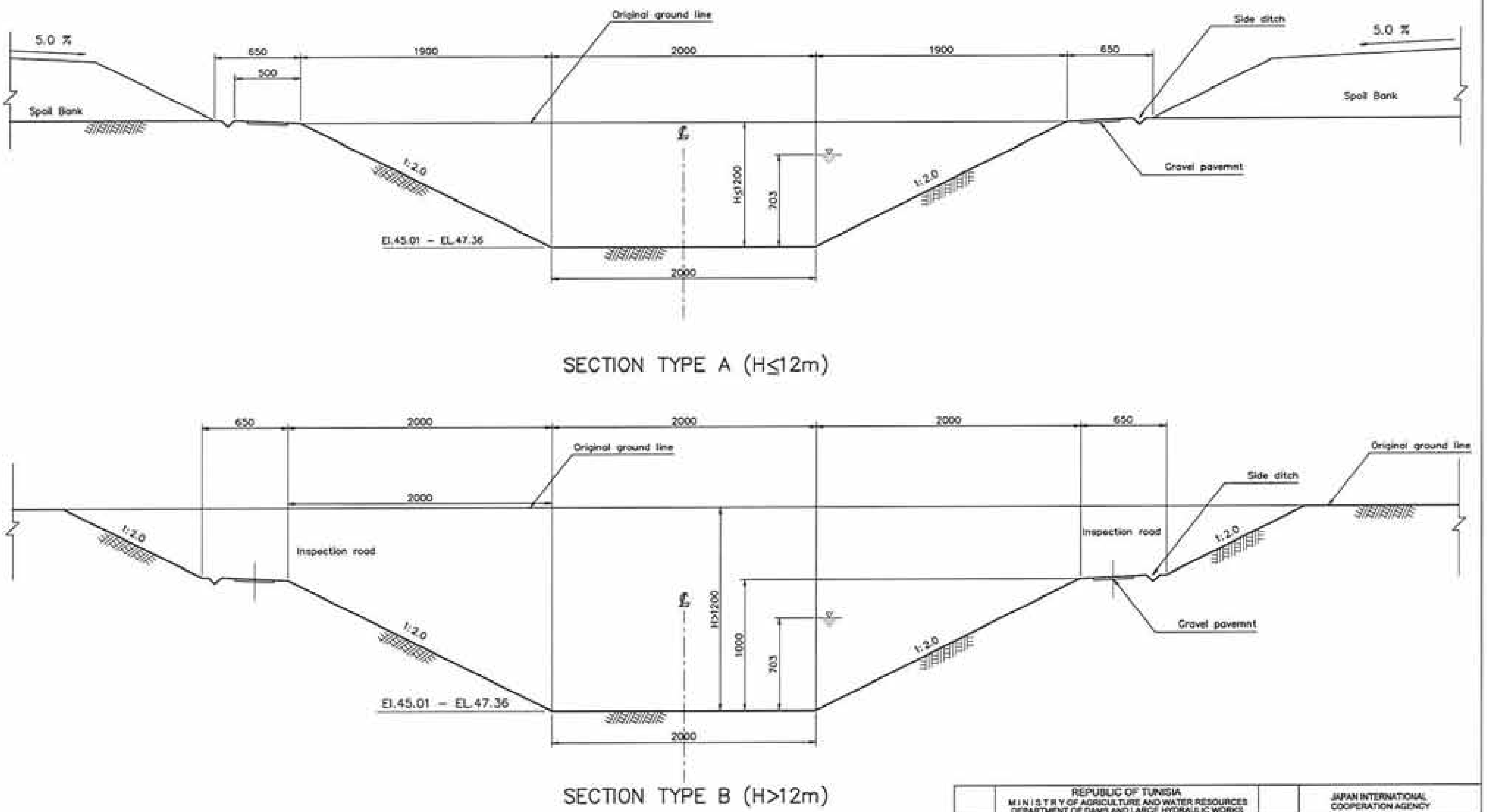


**Figure E2.1.2 Mejez El Bab Bypass Channel ( Zone D1 )**
**Typical Sections of Bypass Channel**

SCALE 0 400 800 1200 1600 2000 cm

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DRAWING TITLE: MEJEZ EL BAB BYPASS CHANNEL ( ZONE D1 )
TYPICAL SECTIONS OF BYPASS CHANNEL

SHEET NO.

NIPPON KOEI Co., Ltd.

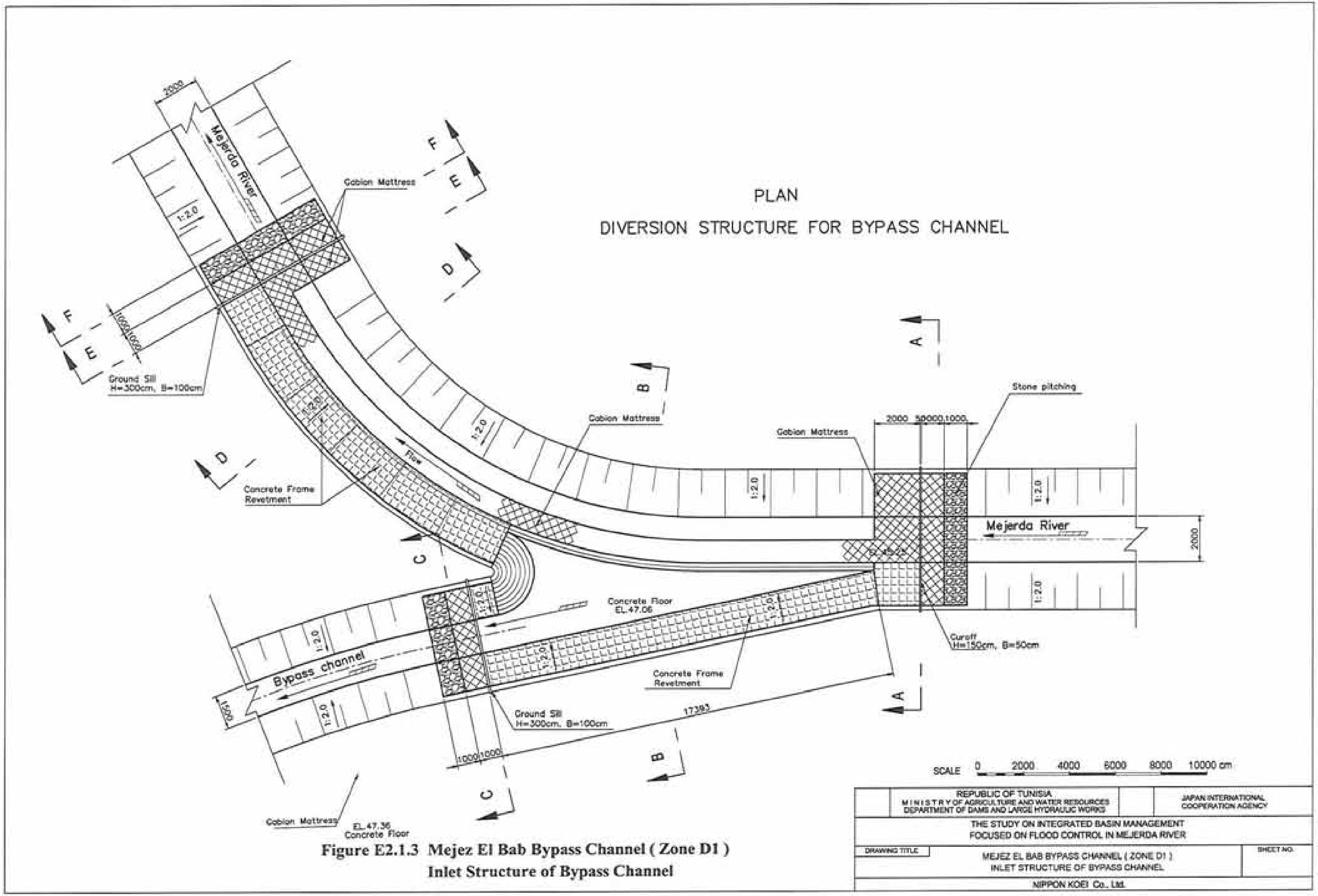


**Figure E2.1.3 Mejez El Bab Bypass Channel ( Zone D1 )**
**Inlet Structure of Bypass Channel**

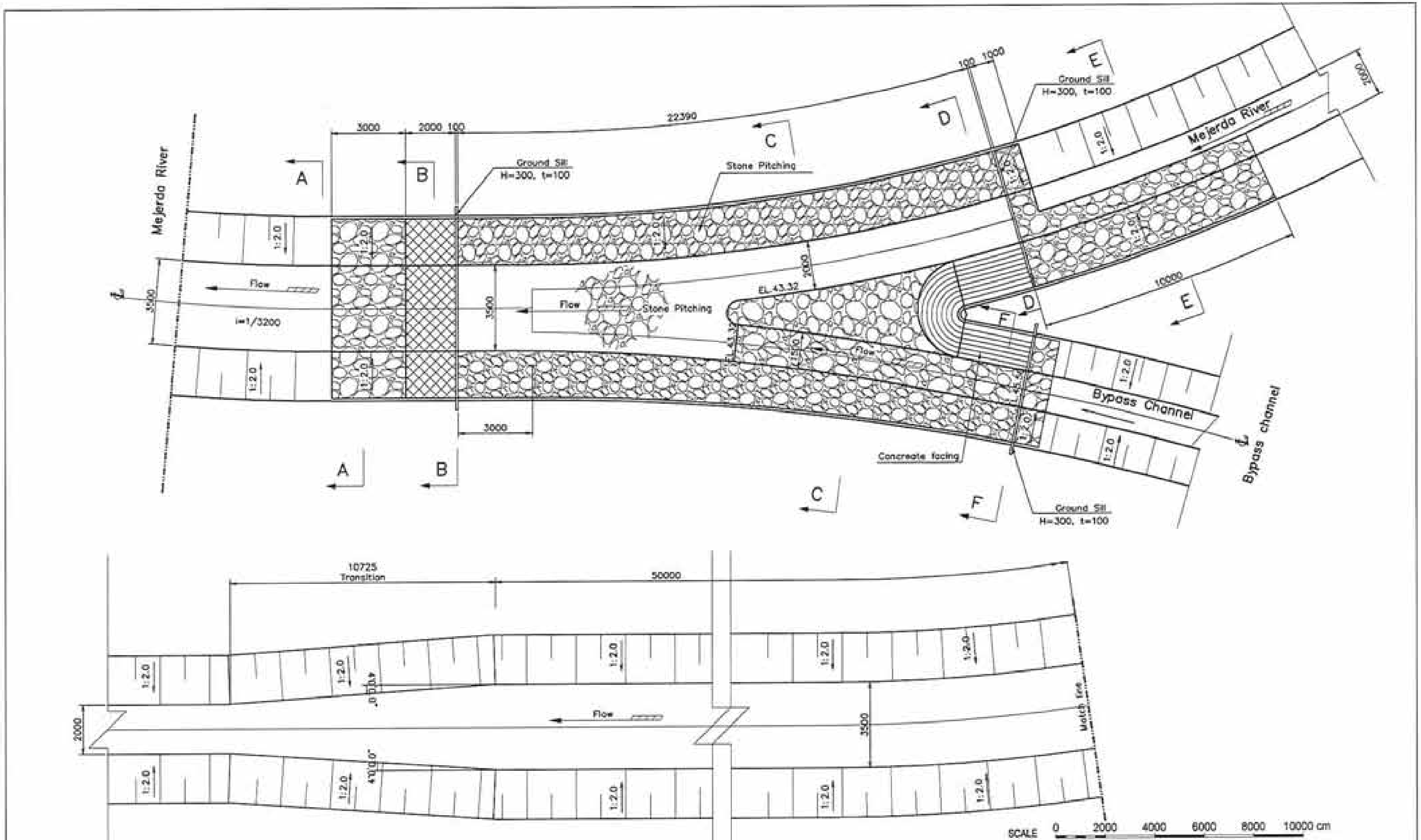


Figure E2.1.4 Mejez El Bab Bypass Channel ( Zone D1 )
Plan of Outlet Structure

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FOCUSED ON FLOOD CONTROL IN MEJERDA RIVER

DRAWING TITLE: MEJEZ EL BAB BYPASS CHANNEL ( ZONE D1 )
PLAN OF OUTLET STRUCTURE

SHEET NO.

NIPPON KOEI Co., Ltd.

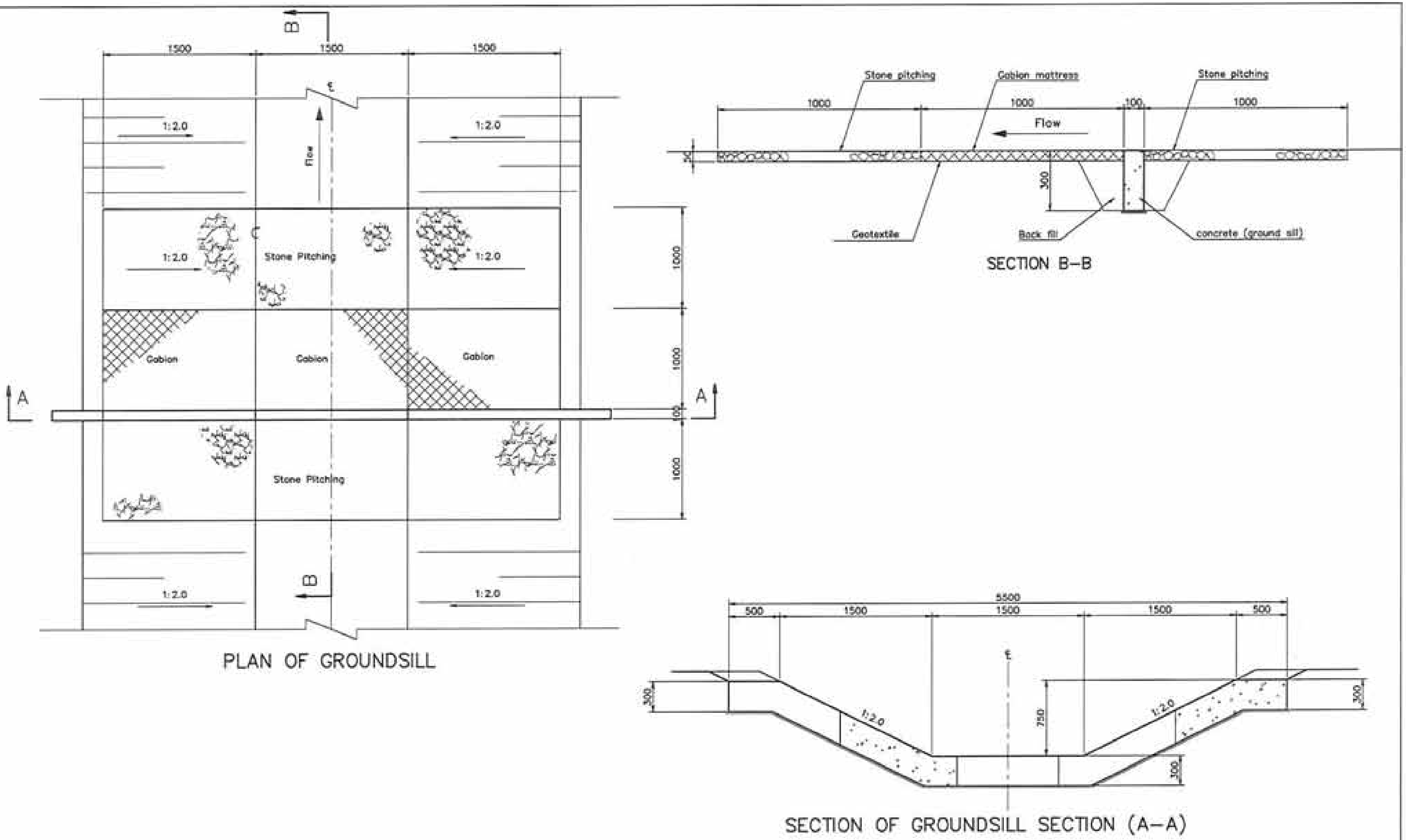


**Figure E2.1.5 Mejez El Bab Bypass Channel ( Zone D1 )**
**Typical Design of Ground Sill**

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FOCUSED ON FLOOD CONTROL IN MEJERDA RIVER

DRAWING TITLE

MEJEZ EL BAB BYPASS CHANNEL ( ZONE D1 )
TYPICAL DESIGN OF GROUND SILL

SHEET NO.

NIPPON KOEI Co., Ltd.

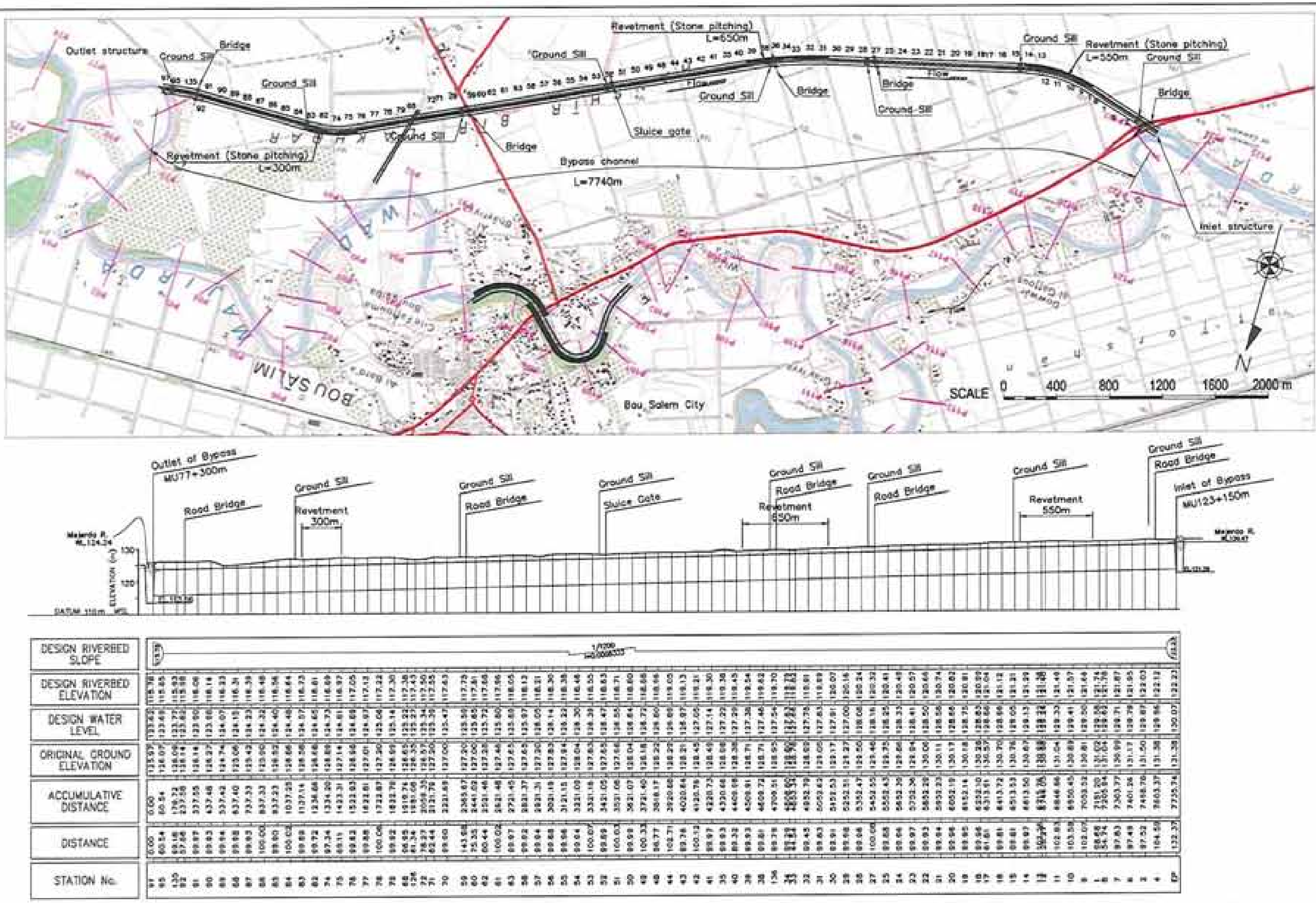


Figure E2.1.6 Bou Salem Bypass Channel ( Zone U2 )
Plan and Profile

HORIZONTAL 0 20 40 60 80 m

VERTICAL 0 400 800 1200 1600 2000 m

| | |
|---|---|
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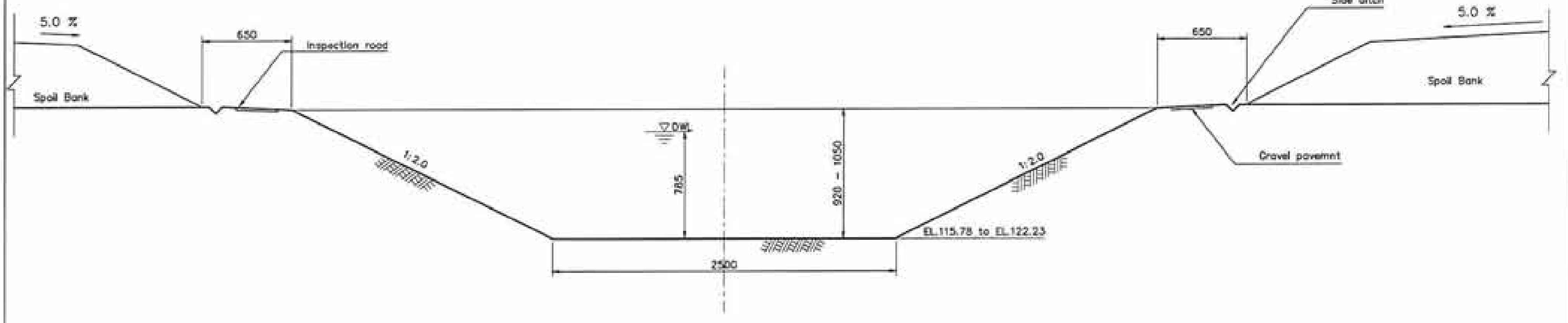
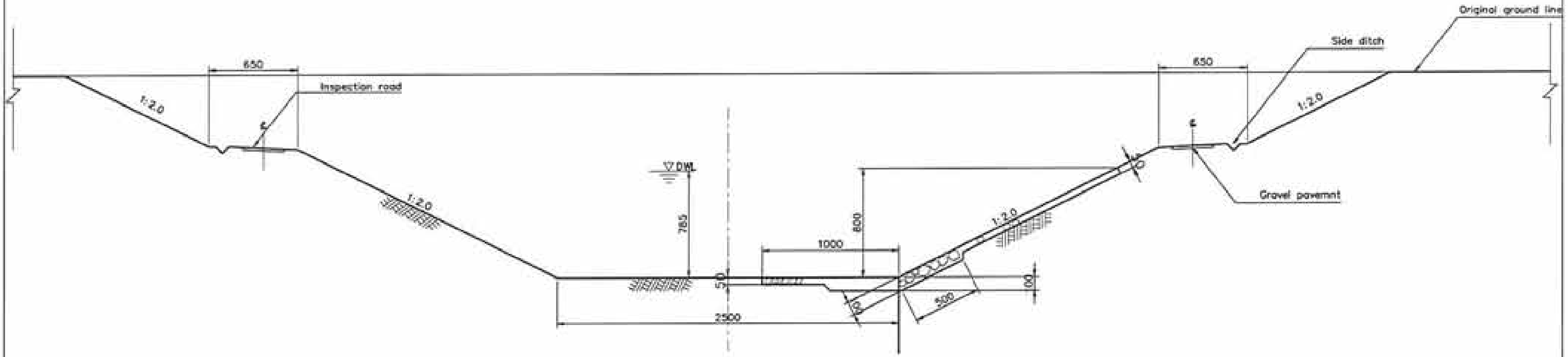
| DRAWING TITLE: BOUSALEM BYPASS CHANNEL ( ZONE U2 )<br>PLAN AND PROFILE | SHEET NO. |
| NIPPON KOEI Co., Ltd. | |




TYPICAL SECTION OF BYPASS CHANNEL
(Q=700m3/s)




TYPICAL SECTION OF REVETMENT
(STONE PITCHING)

| | | |
|---|---|---|
| REPUBLIC OF TUNISIA<br>MINISTRY OF AGRICULTURE AND WATER RESOURCES<br>DEPARTMENT OF DAMS AND LARGE HYDRAULIC WORKS | | JAPAN INTERNATIONAL COOPERATION AGENCY |
| THE STUDY ON INTEGRATED BASIN MANAGEMENT<br>FOCUSED ON FLOOD CONTROL IN MEJERDA RIVER | | |
| DRAWING TITLE | BOUSALEM BYPASS CHANNEL ( ZONE U2 )<br>TYPICAL SECTION OF BYPASS CHANNEL | SHEET NO. |
| NIPPON KOEI Co., Ltd. | | |

**Figure E2.1.7 Bou Salem Bypass Channel ( Zone U2 )**
**Typical Section of Bypass Channel**

SCALE 0 400 800 1200 1600 2000 cm

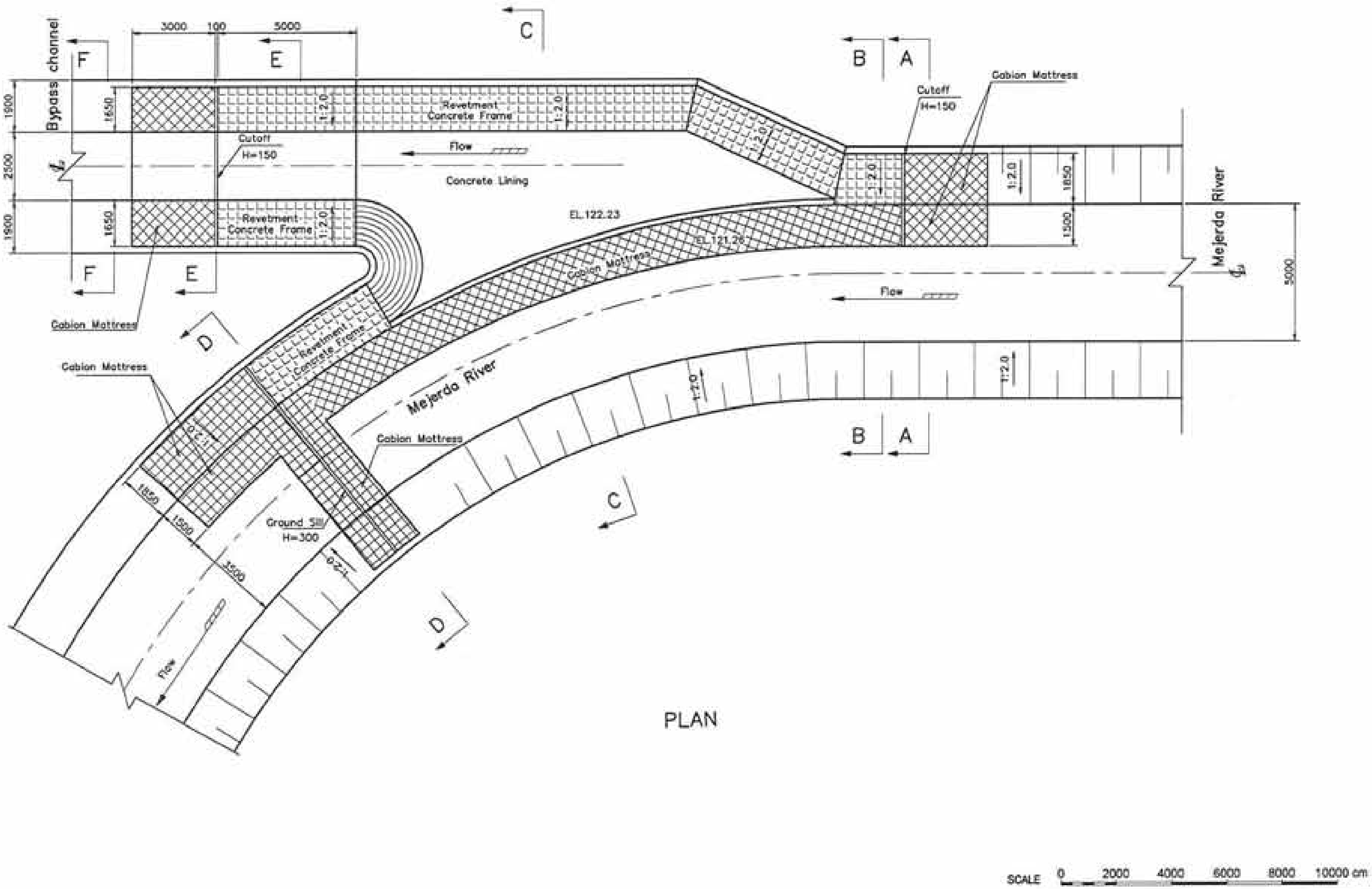



**Figure E2.1.8 Bou Salem Bypass Channel ( Zone U2 )**
**Inlet Structure - Plan**

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FOCUSED ON FLOOD CONTROL IN MEJERDA RIVER

DRAWING TITLE
BOUSALEM BYPASS CHANNEL ( ZONE U2 )
INLET STRUCURE
PLAN

SHEET NO.

NIPPON KOEI Co., Ltd.

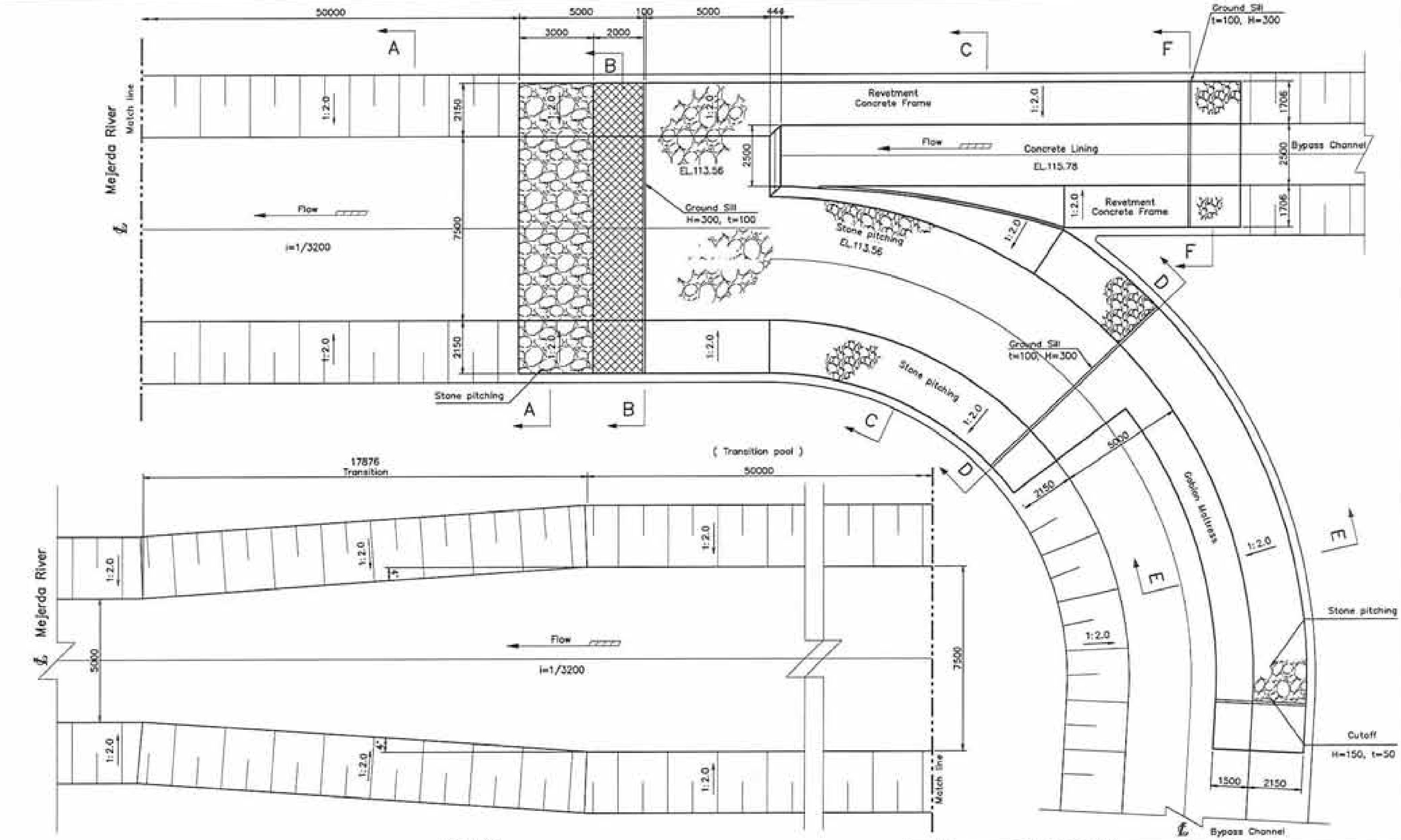


Figure E2.1.9 Bou Salem Bypass Channel ( Zone U2 )
Outlet Structure - Plan

SCALE 0 2000 4000 6000 8000 10000 cm

| | |
|---|---|
| REPUBLIC OF TUNISIA<br>MINISTRY OF AGRICULTURE AND WATER RESOURCES<br>DEPARTMENT OF DAMS AND LARGE HYDRAULIC WORKS | JAPAN INTERNATIONAL COOPERATION AGENCY |
| THE STUDY ON INTEGRATED BASIN MANAGEMENT FOCUSED ON FLOOD CONTROL IN MEJERDA RIVER | |
| DRAWING TITLE: BOUSALEM BYPASS CHANNEL ( ZONE U2 ) OUTLET STRUCTURE PLAN | SHEET NO. |
| NIPPON KOEI Co., Ltd. | |

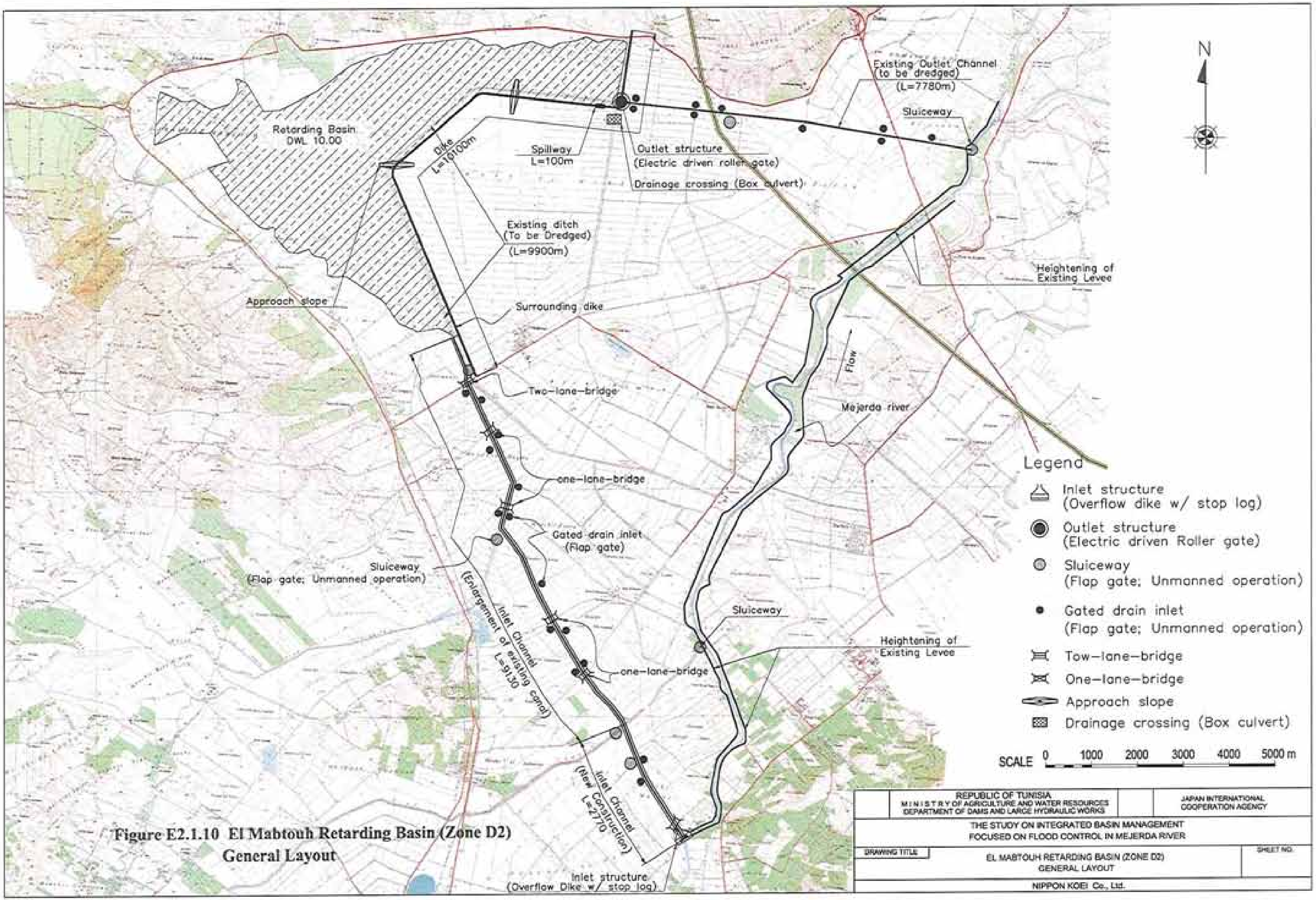


**Figure E2.1.10 El Mabtouh Retarding Basin (Zone D2)**
**General Layout**

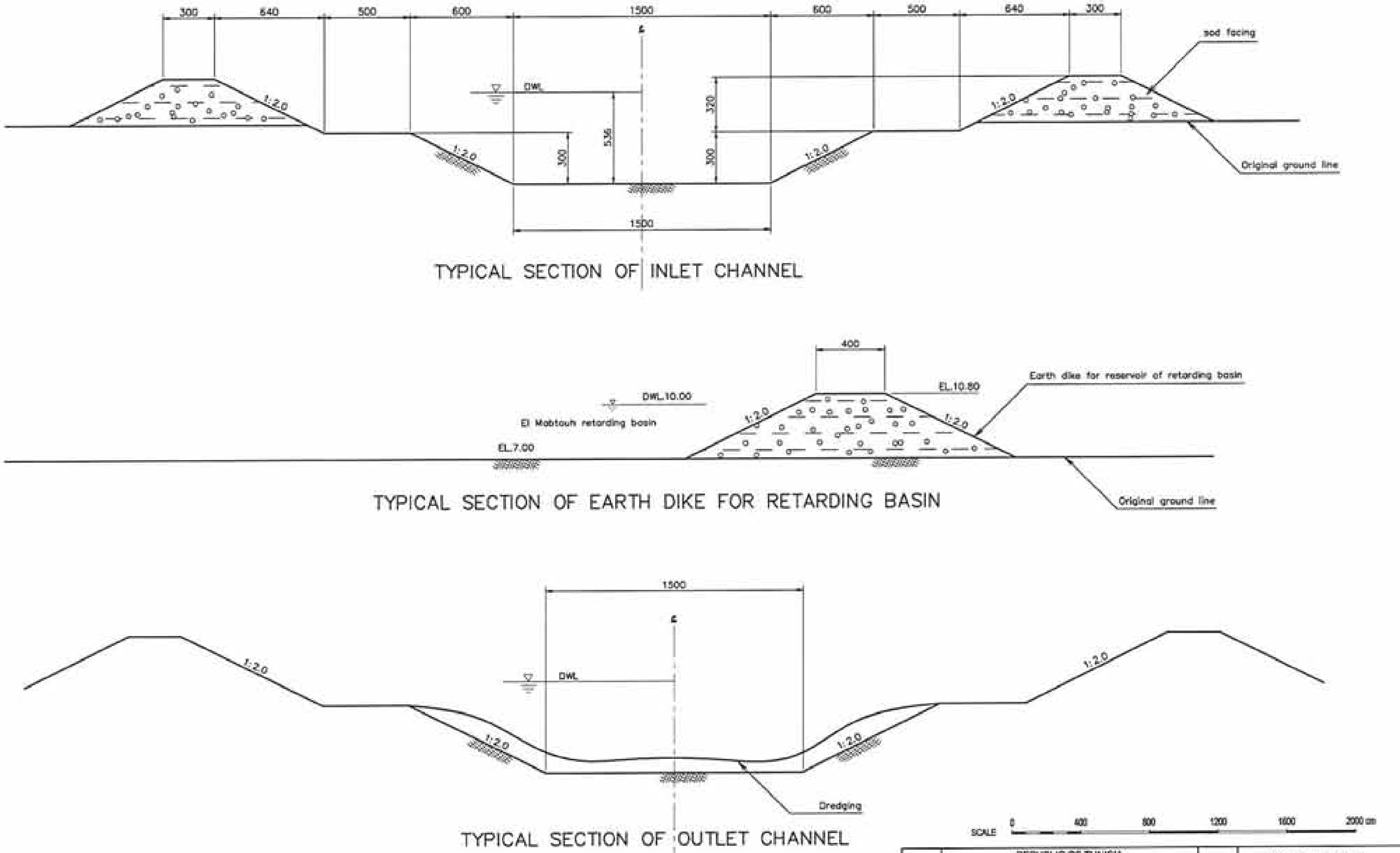


**Figure E2.1.11 El Mabtouh Retarding Basin (Zone D2)**
**Inlet Structure of Retarding Basin-Overflow Dike with Stop Log**
**Typical Sections for Earth Works**

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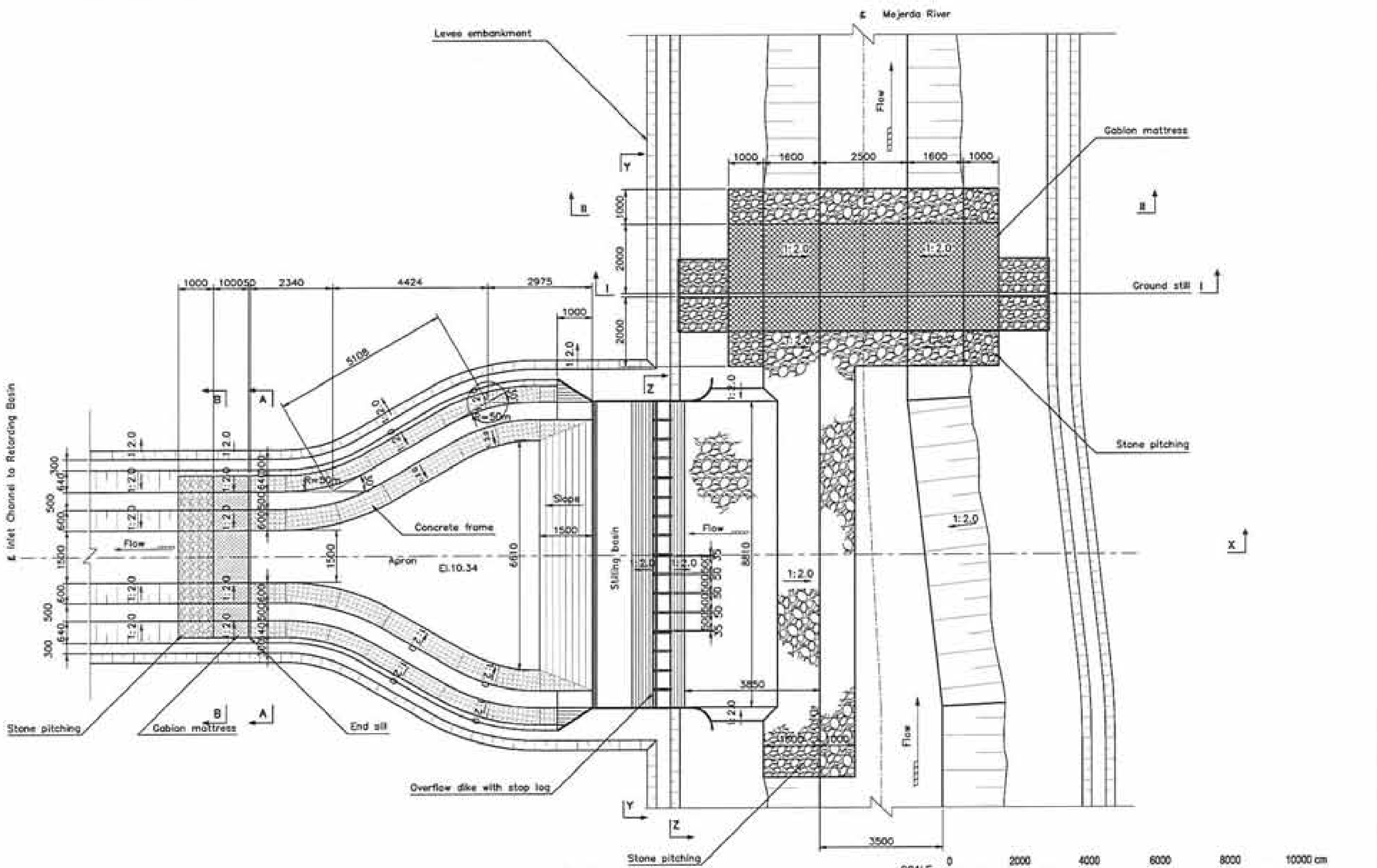
FOCUSED ON FLOOD CONTROL IN MEJERDA RIVER

DRAWING TITLE
EL MABTOUH RETARDING BASIN (ZONE D2)
INTEL STRUCTURE OF RETARDING BASIN-OVERFLOW DIKE WITH STOP LOG
TYPICAL SECTIONS FOR EARTH WORKS

SHEET NO.

NIPPON KOEI Co., Ltd.




PLAN

**Figure E2.1.12 El Mabtouh Retarding Basin (Zone D2)**
**Inlet Structure of Retarding Basin-Overflow Dike with Stop Log**
**Plan**

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MINISTRY OF AGRICULTURE AND WATER RESOURCES
DEPARTMENT OF DAMS AND LARGE HYDRAULIC WORKS

JAPAN INTERNATIONAL COOPERATION AGENCY

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

DRAWING TITLE: EL MABTOUH RETARDING BASIN (ZONE D2) INLET STRUCTURE OF RETARDING BASIN - OVERFLOW DIKE WITH STOP LOG PLAN

SHEET NO.

NIPPON KOEI Co., Ltd.

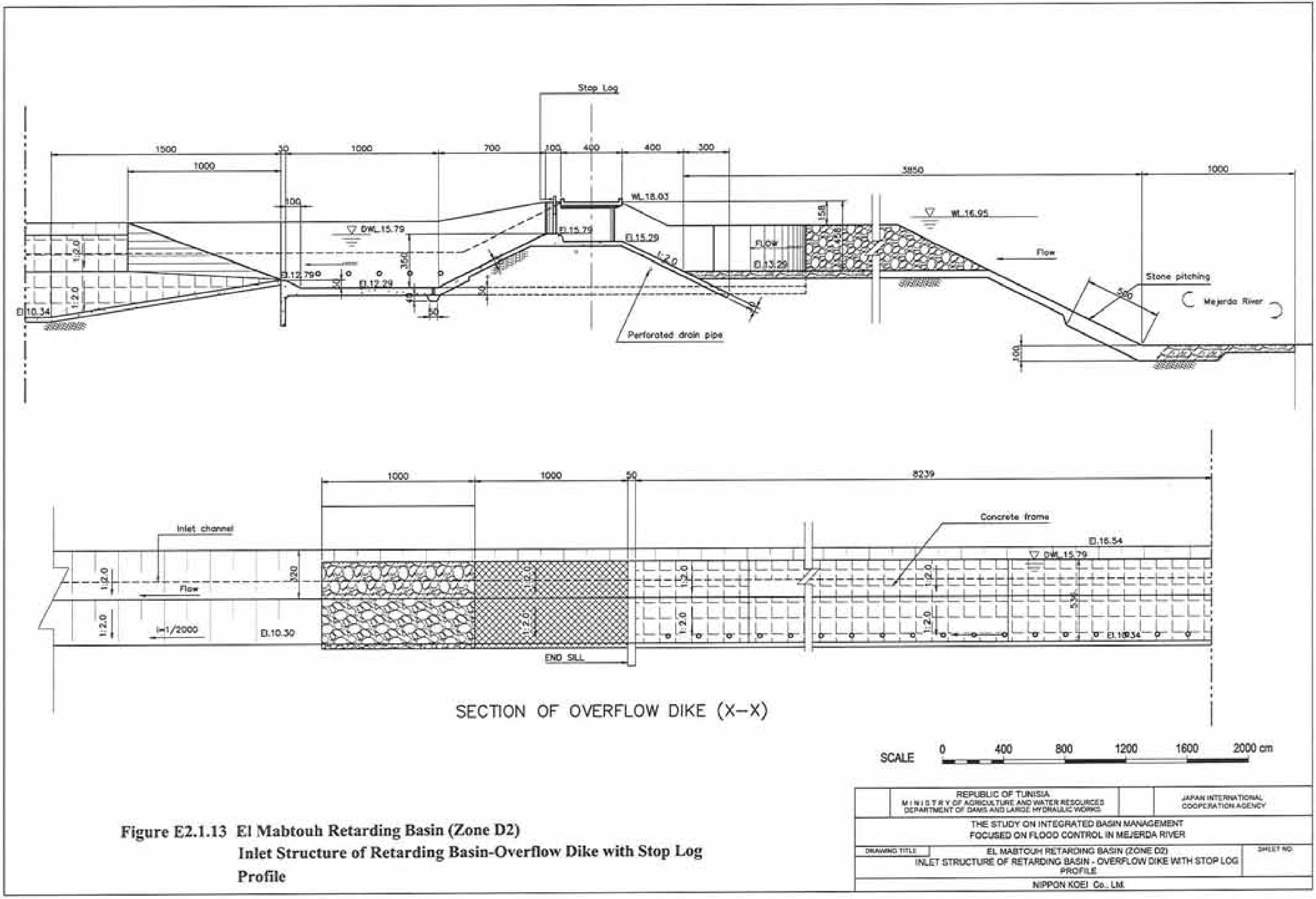
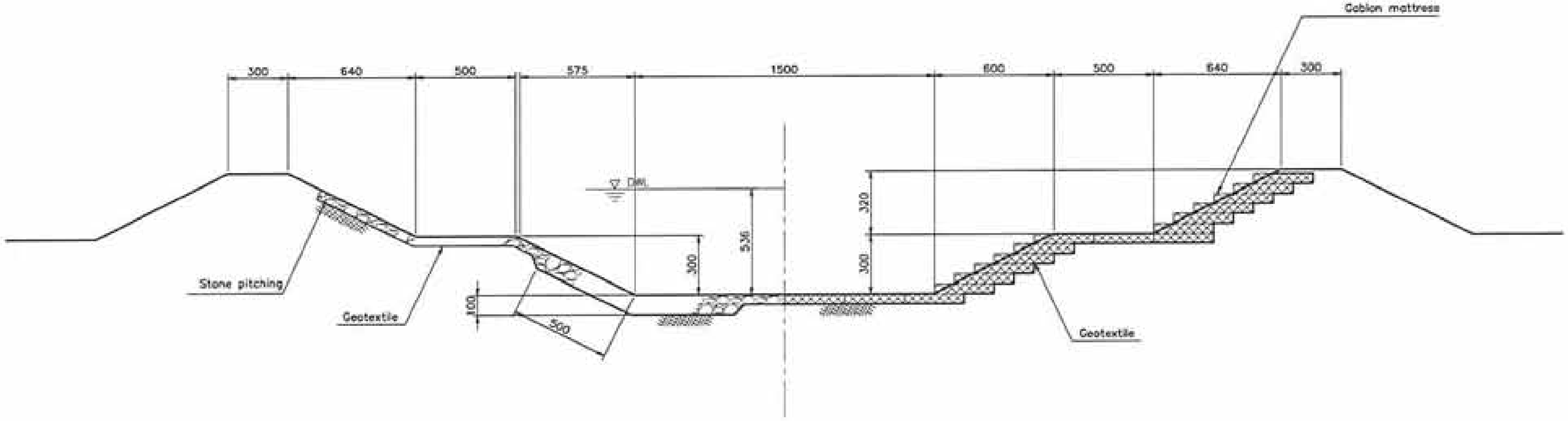
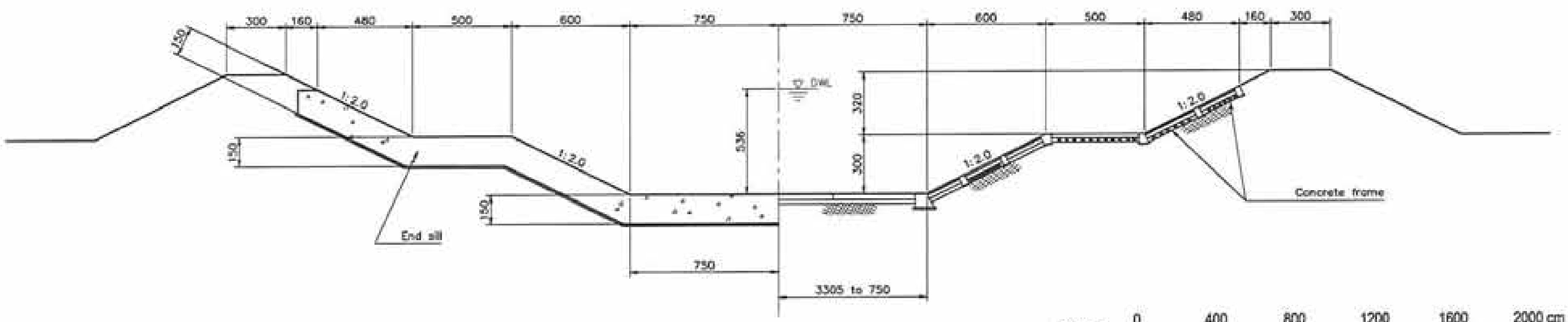



**Figure E2.1.13 El Mabtouh Retarding Basin (Zone D2)**
**Inlet Structure of Retarding Basin-Overflow Dike with Stop Log Profile**

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DEPARTMENT OF DAMS AND LARGE HYDRAULIC WORKS

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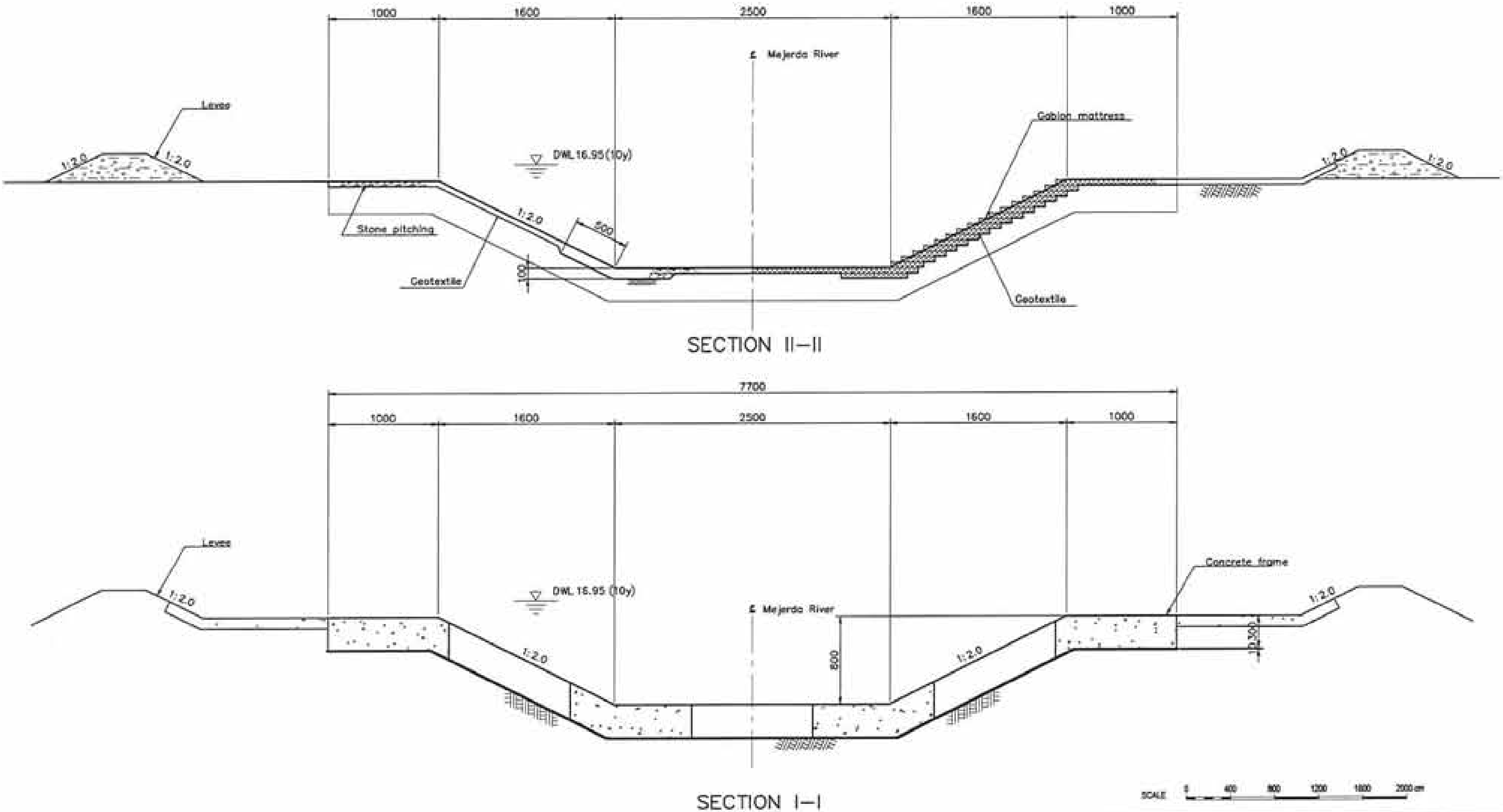
THE STUDY ON INTEGRATED BASIN MANAGEMENT FOCUSED ON FLOOD CONTROL IN MEJERDA RIVER

DRAWING TITLE: EL MABTOUH RETARDING BASIN (ZONE D2)
INLET STRUCTURE OF RETARDING BASIN - OVERFLOW DIKE WITH STOP LOG
CROSS SECTIONS (1/2)

SHEET NO.

NIPPON KOEI Co., Ltd.

**Figure E2.1.14 El Mabtouh Retarding Basin (Zone D2)**
**Inlet Structure of Retarding Basin-Overflow Dike with Stop Log**
**Cross Sections (1/2)**

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INLET STRUCTURE OF RETARDING BASIN - OVERFLOW DIKE WITH STOP LOG
CROSS SECTIONS (2/2)

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**Figure E2.1.15 El Mabtouh Retarding Basin (Zone D2)**
**Inlet Structure of Retarding Basin-Overflow Dike with Stop Log**
**Cross Sections (2/2)**

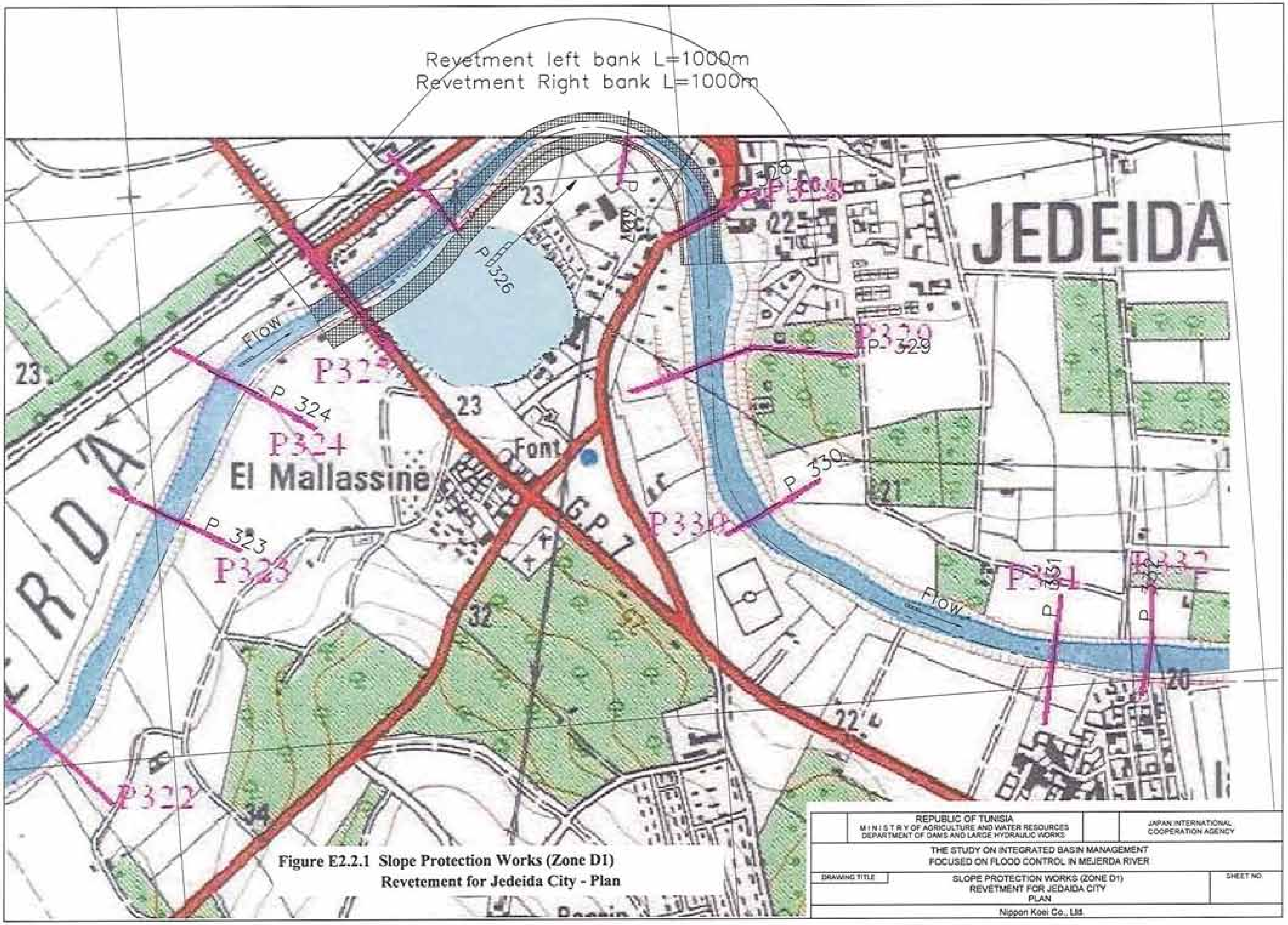


**Figure E2.2.1 Slope Protection Works (Zone D1)**
**Revetement for Jedeida City - Plan**

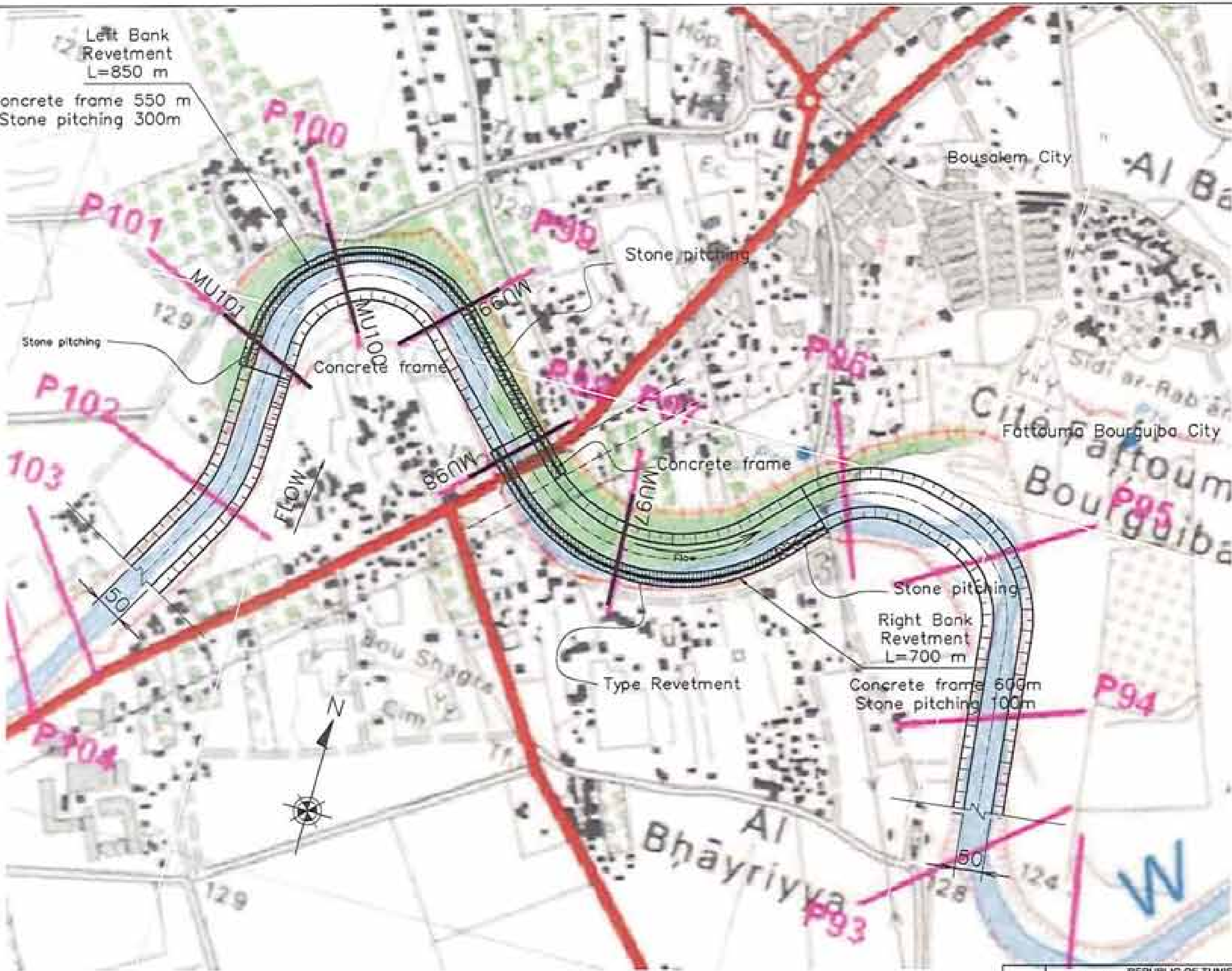


Figure E2.2.2 Slope Protection Works ( Zone U2 )
Revetement for Bou Salem City - Plan

| | |
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| DRAWING TITLE: SLOPE PROTECTION WORKS ( ZONE U2 )<br>REVETMENT FOR BOU SALEM CITY<br>PLAN | SHEET NO. |
| NIPPON KOEI Co., Ltd. | |

# *Supporting Report F*

# *BASIN PRESERVATION*

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

# FINAL REPORT

## Supporting Report F : Basin Preservation

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# CHAPTER F1 INTRODUCTION

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

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

(1) In the northwestern region, where Jendouba and Beja Governorates are located, over deforestation resulting from land reclamation for expansion of farming, forest grazing and disorderly lumbering through carbonization for domestic use and illegal business has led to acceleration of surface soil erosion and destruction of vegetation.

(2) In the south areas of Le Kef and Siliana Governorates, mechanized large-scale farmlands and small-scale lands cultivated by peasants are coexisting, and most of the peasants have cultivated cereals leasing small lands on the steep slope of clayey soil. The cultivated slope lands are forced to be vulnerable to rain erosion and eventually subjected to serious gully erosion.

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

(a) Decrease of flow capacity in rivers

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

(b) Reservoir sedimentation

Sedimentation has been in progress at the existing reservoirs in the Mejerda River basin with terrible high rates, as shown below.

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

In the case of the Sidi Salem Dam, the initial storage volume is feared to be filled with sediment to 60% in 100 years after construction and the storage volumes at other two dams to be filled with sedimentation completely in 60 to 65 years.

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

# CHAPTER F2 SEDIMENT YIELD IN THE BASIN

In order to quantitatively grasp the current progression of erosion in the Mejerda River basin, the sediment yields in several sub-basins are examined based on reservoir sediment data at seven (7) dams reported in "Le Transport Solide des Oueds en Tunisie, Apr 2001". These dams are the Sidi Salem, Mellegue, Bou Heurtma, Ben Metir, Kasseb, Lakhmes, and Siliana Dams, which have data on sediment volumes regularly surveyed in the reservoirs. Their locations are shown in **Figure F2.1.1**.

The sediment yield in a sub-basin at a dam is calculated by adding the sediment trapped in the reservoir and the sediment released from the dam.

(1) Net annual sediment volume trapped in reservoir

$Md = (1-\nu/100) \times Md'$ (M $m^3$/y) (Eq.-F2.1)

where, Md = net annual sediment volume trapped in reservoir (M $m^3$/y)

ν = porosity of sediment in reservoir (35%)

Md' = annual sediment volume measured in reservoir (M $m^3$/y)

(2) Sediment released from dam

The sediment released from a dam is estimated based on the water released from the dam during desilting operation and also floods by using the following equation:

$Ms = Ma \times (Wm-Ww)/(Ws-Ww)$ (Eq.-F2.2)

where, Ms = annual sediment volume released from the dam (M $m^3$/y)

Ma = annual amount of water released from the dam (M $m^3$/y)

Wm = unit weight of water released from the dam (t/ $m^3$)

Ww = unit weight of water (1 t/ $m^3$)

Ws = unit weight of sediment material (2.65 t/ $m^3$)

However, Wm is usually nearly equal to 1 t/$m^3$ according to the actually measured records on dam released water, as exemplified below, and therefore this study applies Ms=0 since it is considered that the sediment released from the dam is negligibly small, compared to Md, based on the above equation (Eq.-F2.2).

| Dam Name | Nibutani Dam (Japan) | Miwa Dam (Japan) | Wonogiri Dam (Indonesia) |
|---|---|---|---|
| SS (mg/L, Max) | 5,930* | 16,900* | 1,524 |
| Wm (t/$m^3$) | 1.00 | 1.01 | 1.00 |

Note: * maximum SS during past serious flood

The sediment yield in a sub-basin at a dam is converted to a denudation rate using the following equation:

Denudation Rate (mm/yr) = M / As $\times$ $10^3$ (Eq-F2.3)

where, M = annual sediment yield in sub-basin (M $m^3$/y)

= Md + Ms – Mi

Mi = annual sediment volume released from the dam(s) located upstream of the dam (M $m^3$/y)

As = catchment area of the dam ($km^2$)

Although there are several dams located upstream of the Sidi Salem, Bou Heurtma and Siliana Dams as shown below, Mi is to be 0 since the sediment released from a dam is negligibly small as mentioned above.

| Dam | Upstream dams |
|---|---|
| Sidi Salem | Mellegue, Bou Heurtma, Kasseb |
| Bou Heurtma | Ben Metir |
| Siliana | Lakhmes |

The computation results of denudation rate in the sub-basins at the 7 dams are compiled as referred to in **Table F2.1.1** and summarized below:

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

# CHAPTER F3 CORRELATION BETWEEN SEDIMENT YIELD AND BASIN CONDITIONS

The correlation between the sediment yield and basin conditions is examined selecting three conditions of the basin, such as distribution of land surface slope, land use and riverbank erosion, because the data on the conditions are available in this study.

It is noted that the drainage basins of the Sidi Salem and Mellegue Dams are dropped from clarifying the correlation of sediment yield with land surface slope and land use because of their huge catchment areas which might be unsuitable for specifying the basin conditions.

## F3.1 Sediment Yield and Land Surface Slope

The distribution of land surface slope in the sub-basins of 5 dams based on GIS data is as shown in the next two figures. From both figures the following are found.

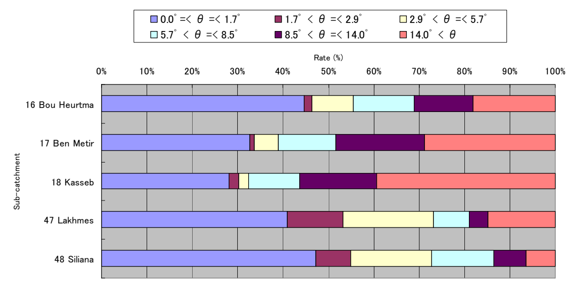



Figure-4-7 Rate of Ground Serface Slopes in 5 Sub-catchments

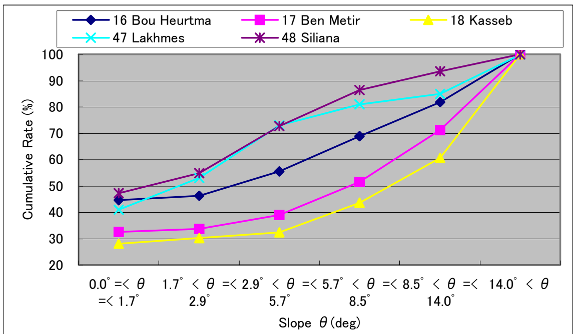



Figure -4-8 Cumulative Rate of Ground Serface Slopes

(a) The trend in distribution of land surface slope in the basins of three dams, namely the Bou Heurtma, Ben Metir and the Kasseb Dams located in the north of the Mejerda River, is different from that in the basins of two dams of Lakhmes and Silian Dams in the south of the Mejerd River. In other words, the basins in the north reveals a trend for the percentage of steep slope land to be higher, while that of moderate slope land is higher in the southern basins.

(b) The next figure presents the relation of the denudation rates with percentages of lands having slopes of less than 1.7°and more than 14.0°. There is a trend shown in the figure that the higher the percentage of lands with slopes of less than 1.7° are, the smaller the denudation rate is, and on the contrary the higher the percentage of lands with slopes of more than 14.0°, the higher the denudation rate is, which means that the denudation rate in the basin having a higher percentage of steep slope lands tends to become higher.

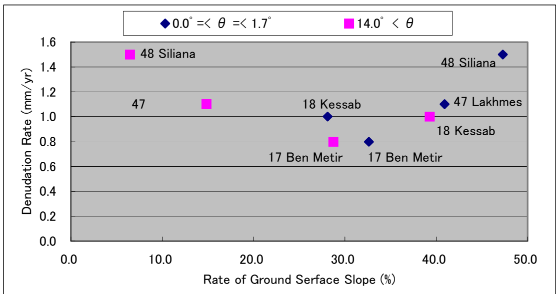



Figure -4-9 Relationship between Rate of Ground Serface Slopes and Denudation

## F3.2 Sediment Yield and Land Use

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

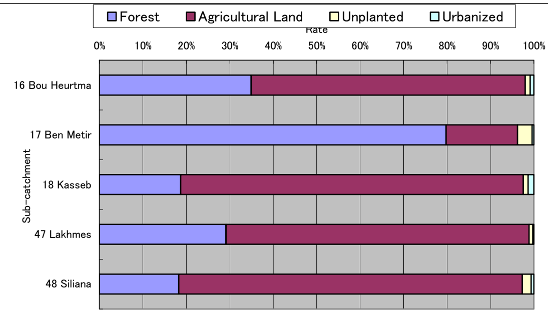


Figure-4-10 Rates of Land Use in 5 Sub-catchments

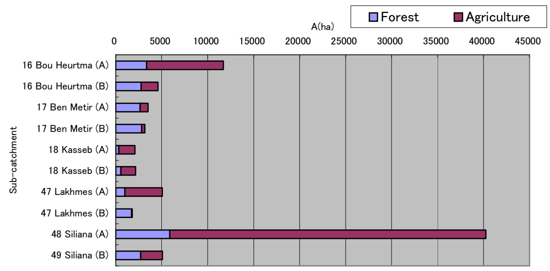


Figure-4-11 Areas of Forest and Agriculure Land in 5 Sub-catchments

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

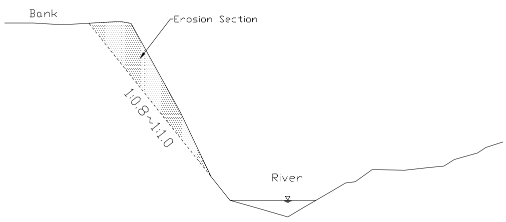
(a) Comparing the basins of the Ben Metir and Kasseb Dams in the north of the Mejerda River, the Kasseb basin has more agricultural lands in the "14.0° < θ" areas than those of the Ben Metir Dam and a higher denudation rate of 1.0 (mm/y) than 0.8 (mm/y) of Ben Metir Dam. Furthermore, in comparison of the denudation rates of 0.2 (mm/y) and 0.4 (m/y) in the basins of the Lakhmes and Siliana Dams respectively, the basin with a higher percentage of agricultural lands in the "14.0° < θ" areas has a higher denudation rate. The findings suggest that some measures for erosion control are to be taken in the case where steep slope lands are used as agricultural land.

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

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

## F3.3 Impact of Riverbank Failure/Erosion on Sediment Yield

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




On the above assumption, the total sediment volume produced in the river is computed at 0.314 $Mm^3$ (= 0.19 $Mm^3$ from the main stream + 0.124 $Mm^3$ from major 7 tributaries) and the sediment volume is compared to the reservoir sediment at the Sidi Salem Dam, as tabulated below:

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

Note: C = 0.314 ($Mm^3$)/A (years)

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

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

# CHAPTER F4 MEASURES OF EROSION CONTROL FOR BASIN PRESERVATON

The impacts of surface soil erosion recognized in the Mejerda River basin are characterized by the following points, as discussed in Chapter F3:

(a) The higher percentage of steep slope lands a basin has, the more sediment yield has been experienced by the basin; and

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

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

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

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

Furthermore, the measures applicable to the selected land use classifications for erosion control are examined, on the premise that the measures are to be taken under implementation of a proper management plan/system of forest and farmland resources to prevent sediment related problems, such as disorderly reclamation of land and illegal lumbering.

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

1) The measures have a superior durability against erosive action,

2) The measures are technically and economically suited also to extensive lands, and

3) The works of the measures are easily realized.

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

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

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

The cereal field and fallow has a large occupation in the Mejerda River basin and hence it is essential to formulate an erosion control scheme giving careful attention to cereal field and fallow.

# *Tables*

## Table F2.1.1 Calculation of Denudation Rate

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Name of Dam | Sidi Salem | | | | | |
| | Capacity at Normal Water Level ($Mm^3$) | 814.0 | Date of Measure | Jun-87 | Aug-89 | Mar-91 | Oct-98 |
| | Catchment Area As($km^2$) | 18191 | Period of Time t(year) | 6.0 | 8.0 | 10.0 | 17.0 |
| | Date of Service Start | 1981 | Sediment Volume ($Mm^3$) | 30.6 | 47.0 | 52.0 | 87.5 |
| | | | Annual Sediment Volume Md'($Mm^3$/yr) | 5.1 | 5.9 | 5.2 | 5.1 |
| | | | Annual Net Swdiment Volume Md($Mm^3$/yr) | 3.3 | 3.8 | 3.4 | 3.3 |
| | Data Source | ① ② | Denudation Rate (mm/yr) | 0.2 | 0.2 | 0.2 | 0.2 |
| 2 | Name of Dam | Mellegue | | | | | |
| | Capacity at Normal Water Level ($Mm^3$) | 270.0 | Date of Measure | Jun-75 | May-80 | Dec-91 | Jun-00 |
| | Catchment Area As($km^2$) | 10309 | Period of Time t(year) | 21.0 | 26.0 | 37.5 | 46.0 |
| | Date of Service Start | 1954 | Sediment Volume ($Mm^3$) | 54.5 | 90.0 | 142.0 | 179.0 |
| | | | Annual Sediment Volume Md'($Mm^3$/yr) | 2.6 | 3.5 | 3.8 | 3.9 |
| | | | Annual Net Swdiment Volume Md($Mm^3$/yr) | 1.7 | 2.3 | 2.5 | 2.5 |
| | Data Source | ① ② | Denudation Rate (mm/yr) | 0.2 | 0.2 | 0.2 | 0.2 |
| 3 | Name of Dam | Bou Heurtma | | | | | |
| | Capacity at Normal Water Level ($Mm^3$) | 117.5 | Date of Measure | Mar-93 | | | |
| | Catchment Area As($km^2$) | 390 | Period of Time t(year) | 16.0 | | | |
| | Date of Service Start | 1976 | Sediment Volume ($Mm^3$) | 2.0 | | | |
| | | | Annual Sediment Volume Md'($Mm^3$/yr) | 0.1 | | | |
| | | | Annual Net Swdiment Volume Md($Mm^3$/yr) | 0.1 | | | |
| | Data Source | ① ② | Denudation Rate (mm/yr) | 0.2 | | | |
| 4 | Name of Dam | Ben Metir | | | | | |
| | Capacity at Normal Water Level ($Mm^3$) | 62.0 | Date of Measure | 1986 | | | |
| | Catchment Area As($km^2$) | 103 | Period of Time t(year) | 32.0 | | | |
| | Date of Service Start | 1954 | Sediment Volume ($Mm^3$) | 4.0 | | | |
| | | | Annual Sediment Volume Md'($Mm^3$/yr) | 0.1 | | | |
| | | | Annual Net Swdiment Volume Md($Mm^3$/yr) | 0.1 | | | |
| | Data Source | ① ② | Denudation Rate (mm/yr) | 0.8 | | | |
| 5 | Name of Dam | Kasseb | | | | | |
| | Capacity at Normal Water Level ($Mm^3$) | 82.0 | Date of Measure | 1986 | | | |
| | Catchment Area As($km^2$) | 101 | Period of Time t(year) | 18.0 | | | |
| | Date of Service Start | 1968 | Sediment Volume ($Mm^3$) | 2.8 | | | |
| | | | Annual Sediment Volume Md'($Mm^3$/yr) | 0.2 | | | |
| | | | Annual Net Swdiment Volume Md($Mm^3$/yr) | 0.1 | | | |
| | Data Source | ① ② | Denudation Rate (mm/yr) | 1.0 | | | |
| 6 | Name of Dam | Lakhmes | | | | | |
| | Capacity at Normal Water Level ($Mm^3$) | 8 | Date of Measure | 1975 | 1991 | Jun-00 | |
| | Catchment Area As($km^2$) | 127 | Period of Time t(year) | 9.0 | 25.0 | 34.0 | |
| | Date of Service Start | Apr-66 | Sediment Volume ($Mm^3$) | 2.0 | 1.2 | 1.0 | |
| | | | Annual Sediment Volume Md'($Mm^3$/yr) | 0.2 | 0.0 | 0.0 | |
| | | | Annual Net Swdiment Volume Md($Mm^3$/yr) | 0.1 | 0.0 | 0.0 | |
| | Data Source | ① ② | Denudation Rate (mm/yr) | 1.1 | 0.2 | 0.2 | |
| 7 | Name of Dam | Siliana | | | | | |
| | Capacity at Normal Water Level ($Mm^3$) | 70.0 | Date of Measure | May-94 | | | |
| | Catchment Area As($km^2$) | 1,040 | Period of Time t(year) | 7.0 | | | |
| | Date of Service Start | Dec-87 | Sediment Volume ($Mm^3$) | 4.1 | | | |
| | | | Annual Sediment Volume Md'($Mm^3$/yr) | 0.6 | | | |
| | | | Annual Net Swdiment Volume Md($Mm^3$/yr) | 0.4 | | | |
| | Data Source | ① ② | Denudation Rate (mm/yr) | 0.4 | | | |

Data Source
①Le Transport Solide des Oueds en Tunisie, Apr 2001 (The Strong Transportation of the Wadis in Tunisia, Apr 2001)
②Monthly data of dams
(shaded) : The original data are questionable.

# *Figures*

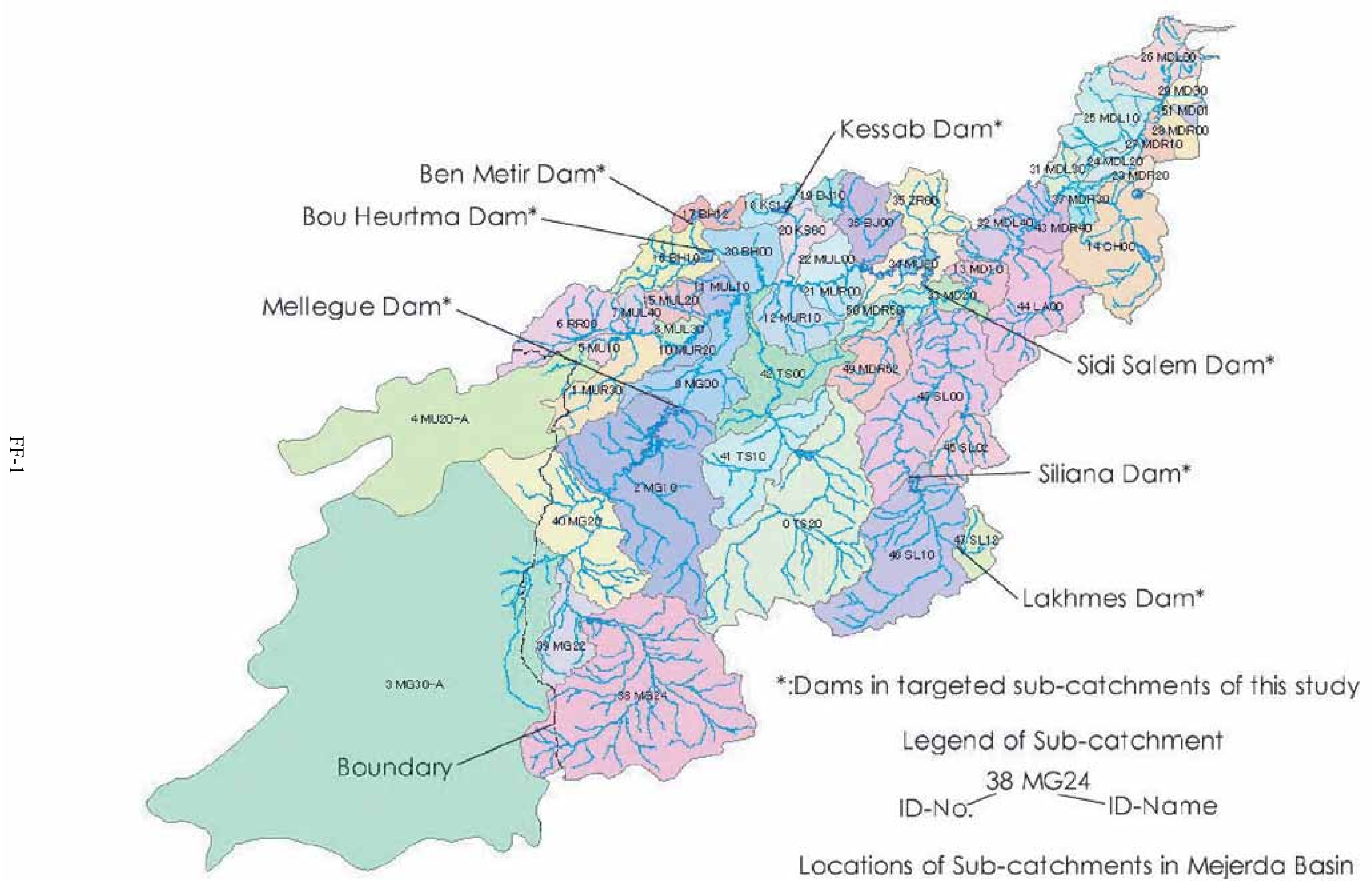



**Figure F2.1.1 Locations of Sub-catchments in Mejerda River Basin**

*Supporting Report G*

# *FFWS AND EVACUATION/ FLOOD FIGHTING*

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

# FINAL REPORT

## Supporting Report G: FFWS and Evacuation/Flood Fighting

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# CHAPTER G1 INTRODUCTION

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

In this study, alternative plans for FFWS and evacuation / flood fighting system were elaborated from the following viewpoints in due consideration of the important elements for formulating a master plan on integrated basin management focused on flood control in the Mejerda River:

1) As immediate measures to minimize the risk of and mitigate flood damage before completion of structural measures;
2) As measures to minimize the risk of and mitigate damage due to extraordinary floods exceeding a planning/design level of structural measures; and
3) As measures to contribute to coordinated operation of dams by providing hydrological information timely and accurately.

This **Supporting Report G** pertains to the flood forecasting and warning system, and evacuation / flood fighting system, with the following contents:

<u>Chapter G2: Flood forecasting and warning system</u>

Problems / issues on the existing FFWS were identified and studied based on the information obtained from the institutions concerned and through interviews with them. Based on the identified problems/issues, alternative plans addressing them were formulated for each sub-system consisting the FFWS.

<u>Chapter G3: Evacuation / flood fighting system</u>

Problems / issues on the existing evacuation / flood fighting system were identified based on the information obtained from the institutions concerned and through interviews with them. Based on the identified problems/issues, alternative plans addressing them were formulated.

# CHAPTER G2 FLOOD FORECASTING AND WARNING SYSTEM

## G2.1 Identifications and Study of Problems / Issues on Current FFWS

### G2.1.1 Overview of FFWS in Mejerda River Basin

(1) Background

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

(2) Installation of the existing telemetry system

The installation of the existing telemetry system, which covers the whole Tunisian territory, was completed at 75 gauging stations in August 2007 and 55 gauging stations in January 2008, and it commenced experimental operation immediately after the respective completion. Out of 130 stations in total, 57 stations exist in the Mejerda River basin.

(3) Coordination and reporting of FFWS

The flow chart of coordination and reporting of the FFWS is shown in **Figure G2.1.1**. The major agencies concerned to flood forecasting are DGRE, DGBGTH, IRESA and CRDAs, which are organized under the authority of the Ministry of Agriculture and Water Resources (MARH). Also, the major agencies concerned to the warning system are governorate offices, the Civil Protection, the National Security, the National Guard, the police and their regional offices at the governorate level, which are under the authority of the Ministry of Interior.

Although more than two Ministries are concerned to the overall missions of the FFWS, the respective agencies cooperate through the contribution of the National and Regional Disaster Commissions, which consist of representatives from Ministries.

### G2.1.2 Observation System

(1) Responsible institutions

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

(2) Gauging stations

As shown in **Table G2.1.1**, there are 57 gauging stations in the Mejerda River basin, including 19 rainfall gauging stations, 18 water level gauging stations and 20 rainfall and water level gauging stations. Out of 57 stations, 8 stations are located at dam sites.

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

(3) Observation frequency

Observation for data recording is made every 15 minutes at any condition; namely, normal condition and flooding condition. Also, the monitoring displays in the call center in DGRE can show real-time water level data per second.

(4) Issues identified

Regarding the observation system, the following issues were identified:

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

G2.1.3 Data Transmission System

(1) Flow of data

The observed data at the respective gauging stations are automatically transmitted to the call center in DGRE via the GSM network system as shown in **Figure G2.1.1**. Those data are stored in the database managed by IRESA, which is a research institution of MARH and is responsible for data management and security management in the telemetry system under instruction of DGRE.

**Memory Device at Gauging Stations**

(2) Transmission frequency

Data transmission is made once a day at 6:00 in normal condition, and at anytime on a request basis in flooding condition. Data observed every 15 minutes are stored in memory devices in the gauging stations for 24 hours until the data is transmitted to the call center at 6:00.

(3) Issues identified

As to the data transmission system, the following issues were identified:

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

G2.1.4 Analysis System

(1) Hydrograph forecasting

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

(2) Setting of alert level

In the telemetry system, alert and overflow levels are set as shown in the table below. Once a water level reaches the alert level, an alert message is automatically sent to mobile phones of pre-selected persons in charge, who mostly belong to DGRE or DGBGTH, by SMS (Short Message Service) in order to commence actions against flooding.

**Alert Level and Overflow Level at Water Level Gauging Stations**

| CRDA | No. | Station Name | River | Alert Level | | Overflow Level | |
|---|---|---|---|---|---|---|---|
| | | | | Water level (cm) | Discharge ($m^3/s$) | Water level (cm) | Discharge ($m^3/s$) |
| Ariana | 2 | AR-PT BIZERTE-MEJ- | Mejerda | 600 | 140 | 750 | 266 |
| | 4 | AR-TOBIAS MEJ- | Mejerda | 590 | --- | 694 | --- |
| Beja | 6 | BJ-EL HERRI-MEJ- | Mejerda | 300 | 38 | 590 | 199 |
| | 8 | BJ-GP5 LHR- | Lahmar | 450 | 50 | --- | 3 |
| | 9 | BJ-JBL LAOUEJ-SI- | Siliana | 200 | 17 | --- | --- |
| | 10 | BJ-MJZ GP5-MEJ- | Mejerda | 670 | 149 | 730 | 200 |
| | 11 | BJ-MJZ MORADI-MJ | Mejerda | 800 | --- | 860 | --- |
| | 12 | BJ-PT BEJA-BEJ- | Beja | --- | --- | --- | --- |
| | 14 | BJ-SLOUGHIA-MEJ- | Mejerda | 450 | 109 | 750 | 274 |
| | 17 | BJ-KALED AVL-KH | Khalled | 350 | --- | --- | --- |
| | 18 | BJ-MKHACHBIA-AVAL | Mekhashiba | 178 | --- | --- | --- |
| Jendouba | 20 | JD-BOUSALEM-MEJ- | Mejerda | 900 | 351 | 1,077 | 684 |
| | 22 | JD-GARDIMAOU-MEJ- | Mejerda | 400 | 153 | 650 | 1,560 |
| | 24 | JD-JENDOUBA-MEJ- | Mejerda | 900 | 227 | 1,050 | 400 |
| | 26 | JD-PLAINE RAGHAI- | Raghai | 1,800 | 10 | 2,300 | 242 |
| | 27 | JD-PT GP17 MLG- | Mellegue | 500 | --- | 820 | --- |
| | 28 | JD-PT GP6 MLZ- | Mliz | 500 | --- | 850 | --- |
| | 29 | JD-S/ABID TSA- | Tessa | 300 | --- | 450 | --- |
| El Kef | 31 | KF-HAIDRA SRT- | Sarrat | 200 | --- | 599 | --- |
| | 32 | KF-K13 MLG- | Mellegue | 350 | --- | --- | --- |
| | 36 | KF-PT ROUTE RMEL- | Rmel | 450 | --- | --- | --- |
| | 37 | KF-PT RTE SARRAT- | Sarrat | 400 | --- | 700 | --- |
| | 39 | KF-S/MEDIEN TSA- | Tessa | 505 | --- | --- | --- |
| | 40 | KF-SERS VILLE-TSA- | Tessa | 100 | --- | --- | --- |
| Manouba | 44 | MN-BJ TOUMI-MEJ- | Mejerda | 400 | --- | 500 | --- |
| | 45 | MN-CHAFROU- | Chafrou | --- | --- | --- | --- |
| | 46 | MN-JEDEIDA-MEJ- | Mejerda | 750 | --- | 820 | --- |
| | 48 | MN-LAROUSIA AVAL- | Mejerda | 190 | --- | --- | --- |
| Siliana | 51 | SL-M12 OSAFA-SIL- | Siliana | 300 | --- | 400 | --- |
| | 52 | SL-PT ROUTE-SIL- | Siliana | 519 | 101 | 800 | 385 |

Source: DGRE

However, the above alert and overflow levels have been provided by trial and error, and those levels do not correspond to the ground elevation system.

(3) Propagation time

Propagation times for the Mejerda River and its tributaries are provided based on the past floods as shown in **Figure G2.1.2**. It covers 23 major gauging stations including those located upstream and downstream of the Sidi Salem Dam. Propagation times between some major stations are shown in the table below:

**Propagation Time between the Major Stations**

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

Source: DGRE

(4) Dam release calculation

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

(5) Issues identified

Regarding the analysis system, the following issues were identified:

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

G2.1.5 Warning Dissemination System

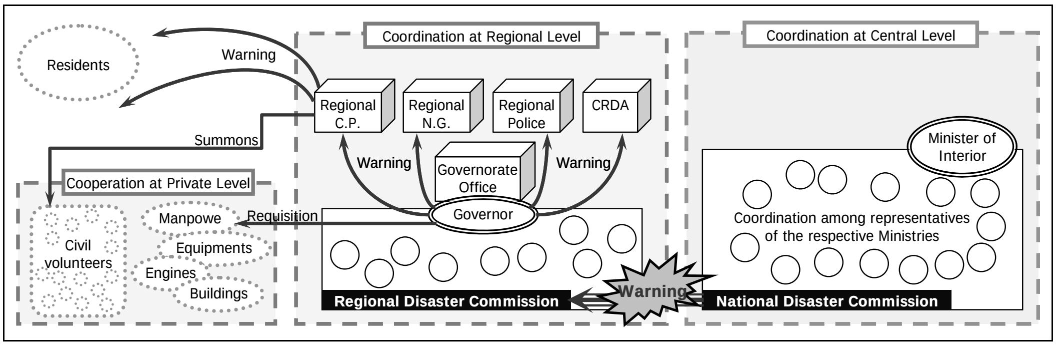
(1) Dissemination steps

There are three steps to disseminate a flood warning from the central government to terminal destinations, namely residents living near rivers.

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

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

In the third step, the regional Civil Protection announces the warning to residents through patrol around river areas or directly visiting residents' houses to advise evacuation.




Source: Interviews with MARH

**Warning Dissemination System**

(2) Issues identified

As to the warning dissemination system, the following issues were identified:

i) A flood warning is not reached to some residents, or is reached out of time because a forecasting time is not enough.
ii) A dam release warning is not given to downstream residents.

## G2.2 Alternative Plans for FFWS

### G2.2.1 Overview of Basic Conditions for Flood Forecasting and Warning System

(1) Basic composition of FFWS

The FFWS in the Mejerda River basin is composed of four sub-systems, namely a) observation, b) data transmission, c) analysis, and d) warning dissemination systems. The recommended development and improvement plans for each sub-system are discussed in Sub-sections G2.2.3 to G2.2.6.

(2) Objectives of FFWS

The objectives of FFWS in the Mejerda River basin are:

i) To provide hydrological information in order to conduct integrated management of river structures including coordinated operation of dams, which would contribute to mitigation of inundation areas, and
ii) To provide hydrological information in order to make decisions of required actions for evacuation / flood fighting system.

(3) Areas to be covered by FFWS

The objective areas of the FFWS are defined such cities and towns as Jendouba, Bou Salem, Sidi Smail, Slouguia, Medjez El Bab, El Herri, Tebourba, El Battan, Jedeida, El Henna, and El Mabtou, which have been seriously damaged by past significant floods.

(4) Required and possible lead time

There are 4 kinds of lead time defined, as follows, in relation to FFWS.

<u>Lead time</u>

A lead time is defined as the difference between the time when the possible phenomenon of flood is recognized in the field and the time when the flood phenomenon reaches to the objective place concerned.

<u>Required lead time</u>

A required lead time is defined as the time necessary to complete activities after flood phenomenon is recognized. Based on the interviews with the institutions responsible for the respective response activities, necessary times for the activities were preliminarily established as follows in this study:

**Necessary Time by Response Activity**

<table>
<tr><th>Response Activity</th><th>Responsible Institution</th><th colspan="2">Necessary Time for Completion of Activity</th></tr>
<tr><td>Hydraulic analysis and decision making for issuance of flood warning</td><td>DGRE/DGBGTH/ National Commission</td><td>1.5 hours</td><td rowspan="3">3.0 hour</td></tr>
<tr><td>Warning dissemination to residents</td><td>Civil Protection</td><td>0.5 hours</td></tr>
<tr><td>Evacuation with minimum necessary belongings</td><td>Civil Protection</td><td>1.0 hour</td></tr>
<tr><td>Evacuation of livestock</td><td>Civil Protection</td><td>1.5 hours</td><td>1.5 hours</td></tr>
</table>

Source: Interview with DGRE, DGBGTH and Civil Protection Manouba

<u>Possible lead time</u>

This lead time is defined as the time available for activities between recognition of flood phenomenon in upstream and occurrence of flood in objective area under the current condition. The possible lead time differs throughout the river basin according to the local hydrological and structural conditions. The following table shows the minimum and maximum possible lead time based on the propagation times of the past floods. The gauging stations have been set, as compiled below, to recognize a flood phenomenon, namely a water level or a reservoir outflow, for each objective area.

**Possible Lead Time by Object Areas (Example)**

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

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

Target lead time

The target lead time is defined as the time necessary to protect the objects, which are set to be human lives in this study. Based on the required lead time from the viewpoint of the recipients of flood warning, target lead time to be provided by this FFWS is estimated at 3.0 hours. To ensure this target lead time, it is necessary to acquire the hydrometeorological information in the upstream basin.

### G2.2.2 Responsible Institutions for FFWS

The major institutions concerned with flood forecasting are DGRE, DGBGTH, IRESA and CRDAs, which are organized under the authority of MARH. The Minister of Interior is responsible for issuance of flood warning based on the hydrological information provided by MARH. The flood warning is finally disseminated to residents by Civil Protection offices.

### G2.2.3 Recommended Plan for Observation System

(1) Additional installation of telemetric rainfall gauges

The number of rainfall gauges, particularly in southern part of the Mejerda River basin, seems to be insufficient in the light of its large catchment area. In this study, the suitable number of stations was statistically analyzed by using average basin rainfall data estimated by the representative coefficient method. This analysis focused on only large scale floods in view of the large damages in the past floods. The procedure is as follows:

i) Division into sub-basins

This analysis was made for each sub-basin because the whole catchment area is too large and each sub-basin would have different characteristic of rainfall. The whole basin was divided into eight sub-basins taking into consideration the division for runoff analysis in this study. The sub-basin areas are shown in **Figure G2.2.1**.

ii) Selection of data on subject floods

In the analysis, important rainfall data which caused the past significant floods shall be selected as representative rainstorm events in perspective in view of seasonal characteristics.

In general, rainfall types are classified by its origin into: (a) orographic rain, (b) convective rain, and (c) frontal or cyclonic rain. According to the participant in the steering committee meeting for Progress Report (1) and complemental interviews with DGBGTH, there are mainly two kinds of rainfall origin which have caused large floods in the Mejerda River basin as tabulated below:

**Origin and Characteristics of Rainfall in the Mejerda River Basin**

| | Type-1 | Type-2 |
|---|---|---|
| Origin of rainfall | Convective rain | Cyclonic rain<br>(Perturbation coming from the north that bring cyclonic rains) |
| Main season | Sep and Oct | Dec, Jan and Feb |
| Extent of rainy area | Localized torrential rain | Wide range |
| Regional characteristic | Southern part of Mejerda basin | Whole area of Mejerda basin |
| Rainfall duration | Very repetitive rains | Continuous rains |

Source: Minutes of the steering committee meeting on Progress Report (1) on March 6, 2007 in Tunis

Taking into account the origins of rainfall, the data on subject floods should cover from the beginning to the end of rainy season so as to include all types of origin. In this analysis, four floods were selected from the past significant floods, namely, May 22-27 in 2000, Jan 8-13 in 2003, Jan 22-27 in 2003, and Dec 8-13 in 2004.

Among 175 existing stations equipped with manual rainfall gauges in the Mejerda River basin, 142 stations were selected in consideration of availability of daily rainfall data in view of missing period and reliability analysis on daily rainfall data during the above four floods. The 142 stations are listed in **Table G2.2.1**.

iii) True value of basin average rainfall

True value (a virtual true value) of basin average rainfall is necessary for consideration of representative rainfall stations. Judging from the number of gauging stations and its distribution obtained through the rainfall gauging information, the true value was estimated by “arithmetic mean method”.

iv) Selection of representative rainfall gauging stations

Through the following procedure, minimum numbers of representative rainfall gauging stations were selected so as to be able to estimate sub-basin average rainfall with an acceptable observation error of less than 10%. In order to evaluate observation errors in views of both temporal distribution of rainfall and total rainfall volume during one flood, the following indexes were applied to every one continuous rainfall:

- Standard error : $E1 = \sqrt{\frac{\sum\left(\frac{R_O - R_S}{\max R_O}\right)^2}{N}}$
- Error of total rainfall : $E2 = \frac{\sum R_O - \sum R_S}{\sum R_S}$

Where, $R_O$ : True value of basin average rainfall (mm/day)
$\max R_O$ : Maximum true value of basin average rainfall (mm/day)
$R_S$ : Estimated value of basin average rainfall (mm/day)
N : Number of rainfall sample
$\Sigma R_O$ : Total volume of true value of one continuous rainfall (mm)
$\Sigma R_S$ : Total volume of estimated value of one continuous rainfall (mm)

Candidate sites of representative rainfall gauging stations were selected based on the rainfall data prepared in the above mentioned ii), by the following procedures:

a) A combination group of random gauging stations selected from the existing ones in each sub-basin was made, and sub-basin average rainfall of those stations was estimated by using "representative coefficient method" with the following formula:
$Rs = \Sigma (Ai \times Ri) + B$
Where, Rs : Estimated value of basin rainfall (mm/day)
Ri : Point rainfall at each station of the group (mm/day)
The parameters, Ai and B, are basin-specific constant values, which vary depending on a combination group of the stations, and those constant values are determined by multiple regression analysis of "a true value of basin average rainfall" and point rainfall at each station of the group.
Further, the following matters were taken into consideration in selecting the candidate sites of the representative stations:
1) Characteristics of spatial and temporal distribution variation of the subject floods selected in the above ii) do not always correspond with possible heavy rainfall in the future.
2) For daily rainfall data, eventuality and complexity of spatial and temporal distribution variation of actual heavy rainfall are averaged at some level.
3) In view of the above 1) and 2), in principle, representative stations should be distributed evenly in each sub-basin.
4) It is necessary to allocate telemetric rainfall stations in consideration of easy and assure operation and maintenance after installation.
5) There have been 39 existing stations equipped with telemetric rainfall gauges in total in the Mejerda River basin, and those stations shall be selected preferentially.

b) An estimate accuracy of basin average rainfall estimated by "representative coefficient method" is generally improved as the number of stations increase. In this analysis, this estimate accuracy shall be represented as the index r: correlation coefficient between true values of basin average rainfall (Ro) and estimated values of basin average rainfall (Rs). Relationship between the number of stations and estimate accuracy are shown in **Figure G2.2.2**.

c) As shown in **Figure G2.2.2**, despite increase of the number of stations, there is a point which remarkably decrease improvement of the estimate accuracy (correlation coefficient: r), which is regarded as an inflection point. This means that improvement of estimate accuracy cannot be expected even if another station is added to the combination group which causes the inflection point. Thus, the combination group which causes this inflection point could be selected as candidate sites of the representative stations under the condition of correlation coefficient: $r \geqq 0.9$.

v) Verification of representativeness

It was verified that the selected stations were appropriate as representative stations for telemetric rainfall gauging stations by confirming that acceptable error is less than 10% for both standard error and total volume error of rainfall, which were calculated by the estimated basin average rainfall of the stations selected in the above iv). The both error values are shown in **Table G2.2.2**. Also, **Figure G2.2.3** represents correlation between true values of basin average rainfall (Ro) and estimated values of basin average rainfall (Rs).

iv) Result of analysis

The result of the analysis indicates that 37 gauging stations in total are required in the whole basin in the Tunisian Territory including existing 23 stations and proposed 14 stations as shown the table below: The exact locations are shown in **Figure 2.2.1**.

**Required Number and ID No. of Telemetric Rainfall Gauging Stations**

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

Source: the Study Team

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

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

*[3]: Station ID No. 53311 represents the Sarrath proposed dam site, and it will also be reviewed in the following clause (2) as a station to be equipped with both rainfall and water level gauges.

*[4]: "Existing" means that there already exist telemetric rainfall gauges.

v) Handling of existing telemetric stations which were not selected

In view of forecasting large scale floods, the above 37 specific rainfall gauges have almost the same level of functions as the case with using all the 144 existing manual gauges. Some existing telemetric gauges were not incorporated into the 37 stations. However, the un-selected existing telemetric gauges are recommended to be continuously used because those gauges might be necessary for forecasting small to middle scale floods and decision for water use control in the dry season.

Besides, the required number of rainfall gauges for forecasting small to middle scale floods shall be examined at the next project stage.

(2) Additional installation of telemetric water level gauges

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

Judging from the above two aspects, additional installation of telemetric water level gauges are recommended as shown below. The exact locations are shown in **Figure G2.2.1**.

**Proposed Additional Installation of Telemetric Water Level Gauging Stations**

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

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

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

In view of coordinated operation of dams, information about reservoir outflow is essential for operation of the dam which is located on the downstream side. The outflow information could be incorporated into the FFWS by means of the following two options.

i) Reservoir outflows based on dam operation records are to be manually input into the telemetry system by the staff at a dam control office.

ii) Reservoir outflows are calculated based on gate openings and change of reservoir water levels. It could be automatically input into the telemetry system.

All reservoir outflow data of dams that could be selected for optimized reservoir operations should be incorporated into the telemetry system.

G2.2.4 Recommended Plan for Data Transmission System

(1) Settlement of GSM telecommunication trouble

The system has sometimes failed to transmit observed data to the call center in DGRE because of GSM telecommunication troubles. In the current test operation, the GSM provider, namely Tunisiana, is trying to settle this problem by installing new antennas or moving existing antennas, and such troubles are being improved step by step.

However, inextricable telecommunication troubles should be covered by some conventional manual transmission means of telephone, facsimile, radio transmission, etc.

It is technically possible to use another provider, Tunisie Telecom, in parallel; however it is inadvisable because of its limited service extent as well as double maintenance cost.

(2) Improvement of AGRINET network

Currently, the telemetry system has not fulfilled its tasks because of limited function of AGRINET. The telemetry system should be effectively utilized through the following improvements:

i) Expansion of the network

A coordinated operation system of dams could be established based on the premise that all dam control offices are able to access AGRINET in order to obtain hydrological information timely. All dam control offices that will be selected for optimized reservoir operations should be added to the network.

ii) Accretion of access speed

The access speed in the network is too slow to be utilized for analysis in the case of a flood event. At least 2.0 Gbps is required for timely analysis.

G2.2.5 Recommended Plan for Analysis System

Even if the information gathering system of hydrological data is improved, the FFWS cannot effectively function without an appropriate analysis system. Thus, it is recommended to establish the following system in order to make hydrology related decisions timely and accurately.

(1) Flood forecasting model/system

The flood forecasting model/system for each area of the basin is recommended to be developed by development term as stated below:

i) Upstream of Sidi Salem Dam

Short term development

For the time being, flood forecasting shall be made by using “river water stage correlation method” based on water level at upstream gauging stations because development of flood runoff analysis models requires substantial time through a trial and error process which is essential for the model development. The development of flood runoff analysis model needs to be carefully coped with because the methods which are to be based on rainfall data include uncertain factors, which may impair forecasting accuracy.

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

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

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

Long term development

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

Currently, GEOSS (Global Earth Observation System of Systems) are being developed under the collaboration and coordination among the concerned research institutes in the world. This system is expected to contribute to the acquisition of rainfall data in any area with no rainfall gauge in the future.

In a related matter, flood analysis systems with using satellite measured rainfall data such as GFAS (Global Flood Alert System) and IFAS (Integrated Flood Analysis System) are also being developed and under test operation.

Detailed applicability of satellite measurement system and analysis system using those data shall be examined in view of its observation time-interval, resolution and accuracy.

ii) Downstream of Sidi Salem Dam

Flood forecasting for the downstream areas shall be made by "river water stage correlation method" based on reservoir outflows from the Sidi Salem Dam and the Siliana Dam, and river water levels in consideration of flood runoff in the downstream sub-catchment areas.

As for only people's evacuation as discussed in Sub-section G2.2.1, this method could provide a necessary lead time though outflows from the Sidi Salem Dam may reach to Slouguia in a very short time.

In addition, in the middle and long term, it will be necessary to develop a flood runoff analysis model as well.

(2) Setting of alert levels in the telemetry system

i) Purpose of alert level setting

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

In the current system, alert and overflow water levels are determined based on the experience. However, in view of the above-mentioned purpose, it is necessary to set step-wise water levels before reaching to the overflow level.

ii) Classification and setting criteria

Classification of water levels and setting criteria of alert levels with their indications are provided as below:

**Alert Water Levels and Setting Basis**

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

Source: Ministry of Land, Infrastructure and Transport, Japan

(3) System of coordinated operation of dams

i) Telemetric hydrological data to be shared for coordinated dam operations

The following telemetric hydrological data shall be shared among respective dam control offices in order to grasp overall coordination of dams.

- Discharge/water level at each gauging station
- Operation status of other dams to be coordinated (including inflow and outflow data)

In this relation, it is also recommended that all dam control offices should access AGRINET as discussed in the above clause (2) in Sub-section G2.2.4.

ii) Necessary lead time for dam operations

It would be necessary to acquire hydrological information at least 24 hours in advance for optimization analysis on reservoir operation.

iii) Fundamental rules for operation

Coordinated operation of dams with a purpose of optimized reservoir operation should be supervised and instructed by the central control office, which would have all necessary information gathered through the telemetry system.

### G2.2.6 Recommended Plan for Warning Dissemination System

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

The dissemination to the residents is discussed in Section G2.3 considering that its primary purpose is evacuation.

### G2.2.7 Cost Estimate

The total cost is estimated at 149,500 Euro considering of the equipment cost as tabulated in **TableG 2.2.3**. This cost estimate in this study is limited to the cost of the additional installation of telemetric gauges and incorporation of dam release discharge data into the existing telemetry system.

# CHAPTER G3 EVACUATION / FLOOD FIGHTING SYSTEM

## G3.1 Identifications and Study of Problems / Issues on Current Evacuation / Flood Fighting System

### G3.1.1 Institutional Arrangements

(1) Legal documents

Institutional arrangements regarding disaster management is based mainly on the following legal documents:

a) Law No.39-1991 on disaster management and organization (June 8, 1991)

The law stipulates 16 articles; 1) definition of disaster, 2) national and regional disaster management plans, 3) national and regional disaster commissions, 4) coordination between the Minister of Interior and the respective Governors, 5) comprehensive statistics of equipments and human resources available for disaster management activities, 6) instruction to implement the national and regional disaster management plans, 7 to 15) requisition of equipments and human resources in times of disaster, and 16) repeal of previous provisions.

b) Decree No.942-1993 on national and regional disaster management plans and the commission (April 26, 1993) and Decree No.2723-2004 on the modification of the Decree No. 942-1993 (December 21, 2004)

These Decrees stipulate 16 articles; 1) means of implementing the national and regional disaster management plans and the commissions, 2) consideration matters in formulating plans, 3) drafting and approval of the plans, 4) orientation of regional plan in national plan, 5) approval of regional plan and submission to National Disaster Commission, 6) intended disaster, 7) specific gradual operations, 8) commencement of implementation, 9) holding of prior meetings with special officers, 10) empowerment of orders, 11) order of working termination, 12) members of National Disaster Commission, 13) meeting of National Disaster Commission, 14) members of Regional Disaster Commission, 15) meeting of Regional Disaster Commission, and 16) implementation of this decree.

(2) Disaster Management Commission

According to the Law No.39-1991 on disaster management and organization, the National and Regional Commissions for disaster management shall be established under the chairmanship of the Minister of Interior and the Governor, respectively.

The Civil Protection assures the functions of permanent secretariat of these commissions and assures the coordination between the different intervening parts.

1) National Disaster Commission

According to the Decree No.942-1993 and No.2723-2004 described above, the National Disaster Commission is the supreme organ of the country for disaster management and is chaired by the Minister of Interior.

The Commission consists of the chairman and 18 representatives selected from the concerned Ministries; however representatives are selected in each case depending on the type of disaster.

2) Regional Disaster Commission

According to the Decree No.942-1993 and No.2723-2004 described above, the Regional Disaster Commission is the supreme organ of the respective governorate for disaster management and is chaired by the Governor.

The Commission consists of the chairman and 17 representatives selected from the regional offices of the concerned Ministries; however representatives are selected in each case depending on the type of disaster.

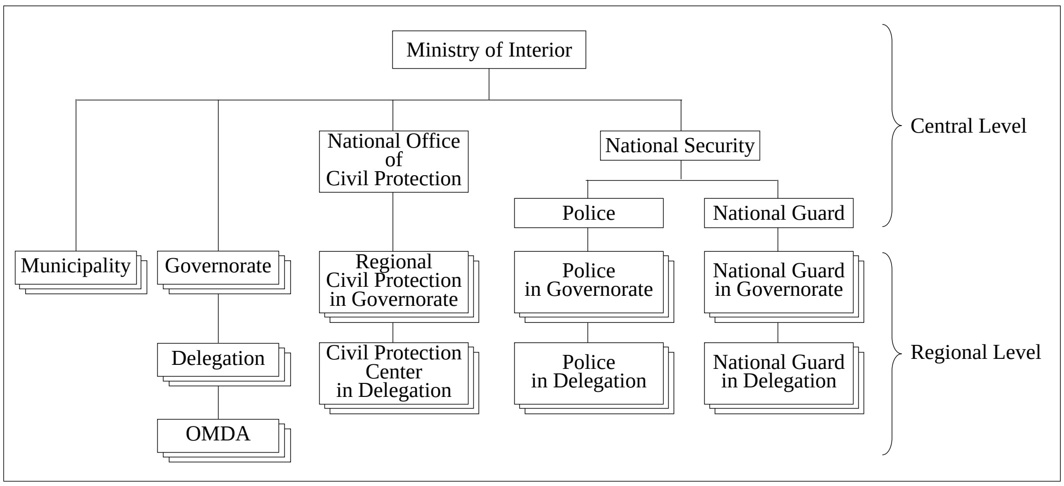
(3) Responsible institutions

1) Civil Protection

The regional Civil Protection office is responsible for evacuation and flood fighting activities in cooperation with the National Guard, the police and the military at the regional level as shown in the photos below:

Source: CRDA Manouba

These agencies except the military belong to the Ministry of Interior as shown in the figure below, and the military belongs to the Ministry of National Defense.




Source: Interviews with MARH

**Agencies Concerned to Flood Fighting**

2) Civil volunteers

Besides the Civil Protection, civil volunteers assist flood fighting activities.

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

(4) Regional disaster management plan

Based on the Law No.39-1991 and the Decree No.942-1993, the plan is drafted by the Regional Disaster Commission in cooperation with the regional Civil Protection. Each regional plan is examined by the National Disaster Commission before being approved by the Governor.

Governorate-specific plans of evacuation / flood fighting system are defined in the regional disaster management plan, which name is ORSEC.

G3.1.2 Status of the Existing Regional Disaster Management Plan

(1) General

The plans formulated in respective Governorates are based on the Guideline[3] so as to standardize the implementation structure and the procedures that will be used in the case of a disaster event, while governorate-specific items are characteristically elaborated.

(2) Composition of plan

The plan is composed of the main part containing common terms applied to all kinds of disasters and four annexes specified for the following disasters:

- The red plan: events engendering a large number of injured people and victims
- The blue plan: floods, drowning and sea pollutions
- The green plan: forest and plantation fires
- The yellow plan: technological or chemical accidents

(3) Update of plan

The blue plan concerning flood disaster is updated before every rainy season in response to natural and/or artificial changes in the field environment that are identified through regular field reconnaissance to be carried out by the regional Civil Protection.

(4) Contents of plan

Through the cooperation with the regional Civil Protection in Manouba Governorate, the plan ORSEC for Manouba Governorate and its appertaining information were disclosed to the JICA Study Team. The plan mainly contains the following:

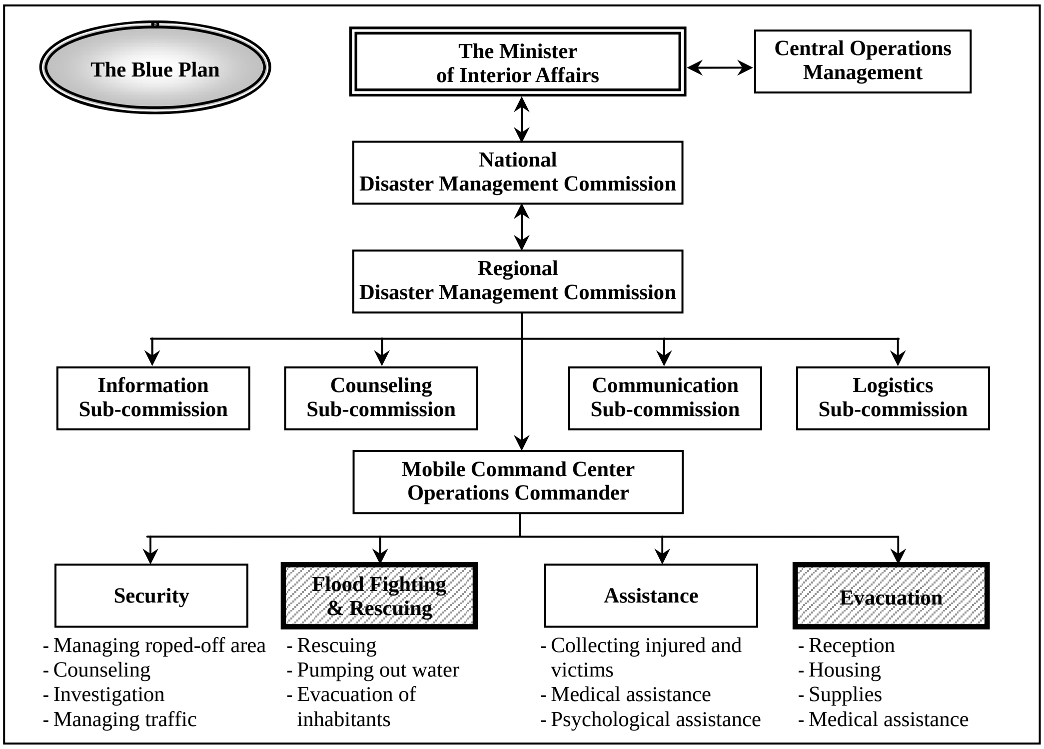
- The legal references
- Organization structure
- Roles and responsibilities for each organization
- Flow chart of coordination, communication and reporting system
- Requisition order of rescue service to be provided by individuals and/or collective

[3] The guideline for the Governors on preparation of regional disaster management and rescuing

- Technical rescue plans and evacuation drill program
- Fiscal plan of the rescue activities
- Various sorts of maps

(5) Organization structure for the Blue Plan

The physical evacuation component of the plan is implemented by four operational units under the instruction of the mobile command center.




Source: The guideline for the Governors on preparation of regional disaster management and rescuing

**Structure of Implementation Units (Blue Plan)**

G3.1.3 Issues in the Current Evacuation / Flood Fighting System

(1) Nondisclosure of disaster management plan and evacuation map

The formulated disaster management plans and evacuation maps are closed in the very limited institutions. Even the members of the National and Regional Disaster Commissions cannot obtain the plan; needless to say, most of the public don't even know its existence. According to the results of flood inundation and damage survey[4], around 80% of the respondents recognize necessity of appropriate evacuation plan for securing their properties.

(2) Imprecise commencement criteria of evacuation and flood fighting activities

In the current system, criteria for mobilization of flood fighting operational units or timing of warning/announcement dissemination to residents are not precisely provided.

[4] The survey was conducted between December 2006 and March 2007 by ECO Ressources International.

(3) Incomplete communication between institutions concerned and residents

According to the results of flood inundation and damage survey, 67% of farmers decided whether to evacuate or not by their own judgment in the past floods because they couldn't receive any flood warning or evacuation announcement in spite of mass media's broadcasting and calling behavior made by the Civil Protection.

In several cases, such reactions might indicate that residents couldn't judge actions to be done because of incomprehensible information rather than incomplete dissemination.

(4) Ineffective use of evacuation maps

Each Regional Commission has prepared an evacuation map as internal information; however, some necessary information is not indicated on the map.

## G3.2 Alternative Plans for Evacuation / Flood Fighting System

### G3.2.1 Recommended Development and Improvement Plan for Evacuation / Flood Fighting

(1) Planning basis

In due consideration of the above-mentioned current status, evacuation / flood fighting system should be reconsidered from the following two viewpoints:

i) In order to decide well-timed commencement of evacuation / flood fighting activities, it is important to clarify precise commencement criteria.
ii) Since understanding and cooperation of the public and their communities are indispensable for evacuation activities, raising of peoples' awareness of disaster mitigation is essential.

This chapter describes proposed development and improvement plans of the existing evacuation and flood fighting system.

(2) Formulation of information sharing system

Sharing of information and recognition among the concerned people including both the governments and the public is essential for evacuation system.

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

- Warning/announcement dissemination method and route
- The nearest or available evacuation spaces in their area
- Key contact address, which will be able to provide assistance to the residents who desire information

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

Besides, in long-term viewpoint, establishment of information sharing system using GIS could contribute to communication between central and local governments as well as information disclosure to the public through website.

(3) Clarification of commencement criteria for required activities

For the purpose of smooth commencement of required activities for evacuation and/or flood fighting, the Governor shall issue evacuation announcements and flood fighting warnings in a stepwise fashion as follows:

i) Classification of evacuation announcements

Announcements shall be classified into three steps, namely 1st) evacuation preparation, 2nd) evacuation advisory, and 3rd) evacuation order, based on water levels at key gauging stations and condition of flood control structures.

ii) Classification of flood fighting warnings

Warnings for flood fighting shall be classified into four steps, namely 1st) standby, 2nd) preparation, 3rd) mobilization, and 4th) continuous caution, based on water levels, including bankful water levels, at key gauging stations.

The criterial water levels at the respective key gauging stations for each step shall be determined based on bankful water levels to be provided by DGRE.

(4) Development of evacuation procedures

It is necessary to develop readily understandable evacuation procedures for both rescuing team and the public from the following three viewpoints:

<u>Assured dissemination method:</u>

- Through mass media under an agreement with media organization
- By any available methods such as a vehicle equipped with a loudspeaker, etc. by efforts of Civil Protection in cooperation with concerned institutions
- Over communication networks of Imada, that is a minimum unit of local community under delegation

<u>Understandable announcements:</u>

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

<u>Systematic evacuation confirmation system:</u>

- Using leadership capacity of the Omda, a head of Imada, who is the most familiar with residents living in his/her Imada
- Checking of evacuees with using name lists at checkpoints installed inside or on the way to the evacuation spaces

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

### G3.2.2 Preparation of Evacuation Map

#### (1) General

An evacuation map covering the settlement area of Jedeida, as a model area, was prepared in this study through the cooperation with Civil Protection Manouba. Evacuation maps for the other objective areas should be prepared by each Governorate in the same manner.

#### (2) Technical approaches

The basic technical approaches applied to this preparation are as follows:

1) Estimation of maximum extent of flood inundation

In this preparation, the result of inundation analysis for the case of 20-year probable flood, which almost corresponds to the flood in January 2003, was used. The analysis was conducted under the condition of "without proposed structures" from the viewpoint of its utilization for the case of a flood event before implementation of the structural measures.

2) Selection of evacuation spaces and evacuation routes

The eligible spaces were selected from the viewpoints of a) public space located out of probable inundation area, b) capacity and facilities of the space, c) distance from probable inundation area, and d) accessibility.

3) Clarification of supplementary information

The supplementary information listed and plotted on the map was selected, which are to be a) communication routes for evacuation announcement, b) medical facilities, and c) local government offices concerned to evacuation / flood fighting activities.

4) Finalization of evacuation map

The draft of evacuation map was finalized on the base topographic map with a scale of 1/25,000 because desirable scale maps, namely 1/10,000 to 1/15,000, were not available in this preparation.

**Figure G3.2.1** shows the evacuation map prepared in this study.

# *Tables*

## Table G2.1.1 List of Telemetry Gauging Stations in Mejerda River Basin

| CRDA | No. | Station Name | Station ID No. | Dam ID No. | Coordinate | | Type | River Name |
|---|---|---|---|---|---|---|---|---|
| | | | | | X_UTM | Y_UTM | | |
| Ariana | 1 | AR-KLT ANDALUS- | 1485352022 | | 601350 | 4104063 | $P$ | --- |
| | 2 | AR-PT BIZERTE-MEJ- | 1485900188 | | 593922 | 4094878 | $H$ | Mejerda |
| | 3 | AR-S/THABET- | 1485667322 | | 592603 | 4084391 | $P$ | --- |
| | 4 | AR-TOBIAS MEJ- | 1485900187 | | 595185 | 4097334 | $HP$ | Mejerda |
| Beja | 5 | BJ-BEJA- | 1485082302 | | 515424 | 4062936 | $P$ | --- |
| | 6 | BJ-EL HERRI-MEJ- | 1485900141 | | 559662 | 4064020 | $HP$ | Mejerda |
| | 7 | BJ-GOUBELAT- | 1485290202 | | 559123 | 4043858 | $P$ | --- |
| | 8 | BJ-GP5 LHR- | 1485802270 | | 565269 | 4053786 | $H$ | Lahmar |
| | 9 | BJ-JBL LAOUEJ-SI- | 1485501635 | | 538469 | 4042093 | $HP$ | Siliana |
| | 10 | BJ-MJZ GP5-MEJ- | 1485900139 | | 554456 | 4055112 | $HP$ | Mejerda |
| | 11 | BJ-MJZ MORADI-MJ | 1485900140 | | 554206 | 4055584 | $H$ | Mejerda |
| | 12 | BJ-PT BEJA-BEJ- | 1485602240 | | 519966 | 4065646 | $H$ | Beja |
| | 13 | BJ-S/SALEM-BGE- | 1485900129 | 54B0101 | 535406 | 4049475 | $HP$ | --- |
| | 14 | BJ-SLOUGHIA-MEJ- | 1485900130 | | 546374 | 4048968 | $HP$ | Mejerda |
| | 15 | BJ-TEBOURSOUK- | 1485755802 | | 522330 | 4034599 | $P$ | --- |
| | 16 | BJ-TESTOUR- | 1485764602 | | 539225 | 4043544 | $P$ | --- |
| | 17 | BJ-KALED AVL-KH | 1485801890 | | 535783 | 4044618 | $H$ | Khalled |
| | 18 | BJ-MKHACHBIA-AVAL | 1485793050 | | 535881 | 4064405 | $H$ | Mekhashiba |
| Jendouba | 19 | JD-BNIMTIR-BGE- | 1485400178 | 53B3502 | 477075 | 4065978 | $HP$ | --- |
| | 20 | JD-BOUSALEM-MEJ- | 1485400180 | | 496974 | 4050563 | $HP$ | Mejerda |
| | 21 | JD-DAR FATMA | no data | | 473204 | 4056375 | $P$ | --- |
| | 22 | JD-GARDIMAOU-MEJ- | 1485400110 | | 449459 | 4033725 | $HP$ | Mejerda |
| | 23 | JD-JENDOUBA- | 1485698801 | | 480808 | 4039439 | $P$ | --- |
| | 24 | JD-JENDOUBA-MEJ- | 1485400160 | | 479198 | 4039531 | $H$ | Mejerda |
| | 25 | JD-KASSEB-BGE- | 1485305029 | 53B0101 | 500427 | 4067868 | $HP$ | --- |
| | 26 | JD-PLAINE RAGHAI- | 1485001160 | | 458855 | 4037351 | $H$ | Raghai |
| | 27 | JD-PT GP17 MLG- | 1485101211 | | 477725 | 4028582 | $HP$ | Mellegue |
| | 28 | JD-PT GP6 MLZ- | 1485301480 | | 461196 | 4035275 | $H$ | Mliz |
| | 29 | JD-S/ABID TSA- | 1485504670 | | no data | no data | $H$ | Tessa |
| | 30 | JD-BOUHERTMA-BGE | 1485400179 | 53B3501 | 481295 | 4058259 | $HP$ | --- |
| El Kef | 31 | KF-HAIDRA SRT- | 1485106125 | | 458425 | 3940535 | $H$ | Sarrat |
| | 32 | KF-K13 MLG- | 1485101210 | | 454661 | 3996946 | $HP$ | Mellegue |
| | 33 | KF-KEF- | 1485361903 | | 474462 | 4003817 | $P$ | --- |
| | 34 | KF-KLT SENAN- | 1485352503 | | 440356 | 3957908 | $P$ | --- |
| | 35 | KF-MELLEGUE-BGE- | 1485101209 | 51B1201 | 473215 | 4018524 | $HP$ | --- |
| | 36 | KF-PT ROUTE RMEL- | 1485104380 | | 467416 | 3996599 | $H$ | Rmel |
| | 37 | KF-PT RTE SARRAT- | 1485100506 | | 460796 | 3962234 | $HP$ | Sarrat |
| | 38 | KF-S/AHMED SLH- | 1485599103 | | 462050 | 3955249 | $P$ | --- |
| | 39 | KF-S/MEDIEN TSA- | 1485201355 | | 495326 | 4017598 | $HP$ | Tessa |
| | 40 | KF-SERS VILLE-TSA- | 1485201330 | | 503341 | 3991048 | $H$ | Tessa |
| | 41 | KF-SKT S/YOUSF- | 1485550003 | | 441929 | 4009730 | $P$ | --- |
| | 42 | KF-SOUANI-BGE- | 1485204109 | no data | 497556 | 4006790 | $HP$ | --- |
| | 43 | KF-ZOUARINE GARE- | 1485827203 | | 491395 | 3986360 | $P$ | --- |
| Manouba | 44 | MN-BJ TOUMI-MEJ- | 1485900147 | | 564901 | 4066252 | $H$ | Mejerda |
| | 45 | MN-CHAFROU- | 1485802580 | | 585708 | 4066434 | $H$ | Chafrou |
| | 46 | MN-JEDEIDA-MEJ- | 1485900170 | | 583249 | 4077940 | $H$ | Mejerda |
| | 47 | MN-TEBOURBA- | 1485753924 | | 575594 | 4076335 | $P$ | --- |
| | 48 | MN-LAROUSIA AVAL- | 1485900150 | | 568915 | 4072662 | $HP$ | Mejerda |
| | 49 | MN-MORNAGUIA | 1484454924 | | 588122 | 4067968 | $P$ | --- |
| Siliana | 50 | SL-KRIB- | 1485377604 | | 512352 | 4019062 | $P$ | --- |
| | 51 | SL-M12 OSAFA-SIL- | 1485504870 | | 538776 | 3979309 | $H$ | Siliana |
| | 52 | SL-PT ROUTE-SIL- | 1485501610 | | 534960 | 3992704 | $H$ | Siliana |
| | 53 | SL-SILIANA- | 1485676304 | | 535244 | 3992016 | $P$ | --- |
| | 54 | SL-SILIANA-BGE- | 1485501609 | 55B1601 | 531479 | 4001000 | $HP$ | --- |
| | 55 | SL-MAKTHAR- | 1485410304 | | 518439 | 3967398 | $P$ | --- |
| | 56 | SL-RMIL-BGE | 1485505089 | 55B5001 | 545066 | 4017607 | $HP$ | --- |
| Kasserine | 57 | KS-TALLA | 1485767809 | | 470375 | 3935599 | $P$ | --- |

Note: Type shows that P=Raindall, H=Water Level, and HP=Rainfall and Water Level.
Source: DGRE

## Table G2.2.1 List of Stations Used for Analysis on Number of Rainfall Gauge

| No. | Sation Name | ID No. | Sub-basin No. | | | | | | | | No. | Sation Name | ID No. | Sub-basin No. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AIN BEYA OUED RHEZALA | 50078 | | | 3 | | | | | | 72 | KOUDIAT INRAT | 53754 | | 2 | | | | | | |
| 2 | AIN DEBBA | 50138 | | | 3 | | | | | | 73 | KRIB FERME COSSEM | 53778 | | | | | | 6 | | |
| 3 | AIN JEMMALA | 50177 | | | | 4 | | | | | 74 | KSAR BOU KHRIS | 53797 | | | | 4 | | | | |
| 4 | AIN GUESIL | 50244 | | | | 4 | | | | | 75 | KSAR BOU KLEIA | 53803 | | 2 | | | | | | |
| 5 | AIN HAMRAYA | 50260 | | | 3 | | | | | | 76 | KSAR HDID | 53810 | | 2 | | | | | | |
| 6 | AIN KERMA 1 | 50276 | | | | | | | 7 | | 77 | KSOUR ECOLE | 53839 | | | | | | 6 | | |
| 7 | AIN MERJA | 50350 | | 2 | | | | | | | 78 | KSAR TYR LES ALLOBROGES | 53875 | 1 | | | | | | | |
| 8 | AIN S'KOUM | 50421 | | | | | | 6 | | | 79 | LABAR ECOLE SERS | 53922 | | | | | | 6 | | |
| 9 | AIN SALLEM | 50422 | | 2 | 3 | | | | | | 80 | LORBEUS CTV | 53964 | | | | | | 6 | | |
| 10 | AIN TABIA | 50467 | | | | | | 6 | | | 81 | MAKTHAR P.F | 54102 | | | | | 5 | | | |
| 11 | AIN TOUNGA SE | 50511 | | | | 4 | | | | | 82 | MEJEZ EL BAB PF | 54292 | 1 | | | | | | | |
| 12 | AIN ZARGA RETENUE | 50522 | | | | | | | | 8 | 83 | MEJEZ EL BAB PV | 54297 | | 2 | | | | | | |
| 13 | AIN ZARGA RUINE ROMAINE | 50523 | | | | | | 6 | | 8 | 84 | MEHRINE CRA | 54345 | 1 | | | | | | | |
| 14 | AIN ZANA | 50535 | | 2 | 3 | | | | | | 85 | MONTARNAUD 1 | 54524 | 1 | | | | | | | |
| 15 | AIN ZEBDA | 50543 | | 2 | | | | | | | 86 | MUNCHAR ECOLE | 54611 | | 2 | | | | | | |
| 16 | AIN ZELIGUA | 50553 | | | | | | 6 | | | 87 | NEBEUR DELEGATION | 54639 | | | | | | | 7 | |
| 17 | AKHOUAT GARE | 50591 | | | | 4 | | | | | 88 | NMAIRIA | 54671 | | | | | 5 | | | |
| 18 | AMDOUN CTV | 50630 | | | 3 | | | | | | 89 | OUED EL LEBEN | 54900 | | 2 | | | | | | |
| 19 | AROUSSIA BARRAGE | 50692 | 1 | | | | | | | | 90 | OUED MLIZ INRAT | 54981 | | 2 | | | | | | |
| 20 | BADROUNA BOUSALEM | 50738 | | 2 | | | | | | | 91 | OUED MELLEGUE K 13 | 54990 | | | | | | | 7 | |
| 21 | BALTA CTV | 50752 | | 2 | | | | | | | 92 | OUED RMIL | 55053 | | | | 4 | | | | |
| 22 | BARRAGE KASSEB | 50764 | | 2 | | | | | | | 93 | OUED TINE | 55080 | | | | 4 | | | | |
| 23 | BARRAGE LAKHMES | 50767 | | | | | 5 | | | | 94 | OUED ZARGA 12 MAI | 55086 | | 2 | | | | | | |
| 24 | BARRAGE SIDI SALEM | 50772 | | | | 4 | | | | | 95 | OUED ZARGA RHAYET | 55087 | | 2 | | | | | | |
| 25 | BATANE ECOLE | 50791 | 1 | | | | | | | | 96 | OUED ZARGA EX FME RURAL | 55089 | | | 3 | | | | | |
| 26 | BATANE OMVVM | 50792 | 1 | | | | | | | | 97 | OUED ZARGA FME DENGUEZLI | 55091 | | 2 | | | | | | |
| 27 | BEAUCE TUNISIENNE | 50799 | | 2 | | | | | | | 98 | OUED ZARGA CTV | 55095 | | 2 | | | | | | |
| 28 | BORJ EL AMRI | 51009 | 1 | | | | | | | | 99 | EL OUATIA HIR EL BEHI | 55135 | 1 | 2 | | | | | | |
| 29 | BORJ EL AIFA | 51103 | | 2 | | | | | | | 100 | PORTO FARINA GHAR EL MELEH | 55193 | 1 | | | | | | | |
| 30 | BORDJ HAMDOUNA | 51133 | | 2 | | | | | | | 101 | RAGHAY SUPERIEUR | 55288 | | 2 | | | | | | |
| 31 | BJ TOUMI STE BARAK | 51190 | 1 | | | | | | | | 102 | REBAIEB | 55335 | 1 | | | | | | | |
| 32 | BEN METIR 2 SM | 51268 | | | 3 | | | | | | 103 | SADINE RESERVE | 55483 | | | | | | | 7 | |
| 33 | BOU HEURTMA BGE | 51403 | | 2 | 3 | | | | | | 104 | SAKIET SIDI YOUSSEF SM | 55502 | | | | | | | 7 | |
| 34 | CHAOUACH | 51552 | 1 | | | | | | | | 105 | SERS AGRICOLE | 55887 | | | | | | 6 | | |
| 35 | CHAOUAT | 51559 | 1 | | | | | | | | 106 | SERS DELEGATION | 55888 | | | | | | 6 | | |
| 36 | CHEMTOU RAOUDET SM | 51608 | | 2 | | | | | | | 107 | SIDI AHMED SALAH CRA | 55991 | | | | | | | | 8 |
| 37 | CHEMTOU FERME | 51609 | | 2 | | | | | | | 108 | SIDI BOU ROUIS SM | 56250 | | | | | | 6 | | |
| 38 | CHERFECH CRGR | 51616 | 1 | | | | | | | | 109 | SIDI BOUROUIS DELEG | 56257 | | | | | | 6 | | |
| 39 | CITE DU MELLEGUE SM | 51672 | | 2 | | | | | 7 | | 110 | SIDI SAHBI ABIDA | 56595 | | | | | | | 7 | |
| 40 | DAOUESS FERME UCP | 51786 | | 2 | | | | | | | 111 | SIDI THABET DOMAINE HARAS | 56670 | 1 | | | | | | | |
| 41 | JANTOURA | 51856 | | | 3 | | | | | | 112 | SIDI THABET OMVVM | 56673 | 1 | | | | | | | |
| 42 | JEBEL KBOUCH | 51934 | | 2 | | | | | | | 113 | SILIANA BARRAGE | 56757 | | | | 4 | 5 | | | |
| 43 | DJEDEIDA CTV | 51967 | 1 | | | | | | | | 114 | SILIANA II SM | 56763 | | | | | 5 | | | |
| 44 | DJERISSA DELEGATION | 52041 | | | | | | | | 8 | 115 | SILIANA AGRICOLE | 56764 | | | | | 5 | | | |
| 45 | DEHMANI MUNICIPALITE | 52510 | | | | | | 6 | | | 116 | SILIANA LAOUJ | 56765 | | | | 4 | | | | |
| 46 | EL ALIA SERS UCP | 52521 | | | | | | 6 | | | 117 | SKHIRA BOU SALEM | 56804 | | 2 | | | | | | |
| 47 | EL GUANTRA | 52545 | | | | | 5 | | | | 118 | SLOUGUIA | 56832 | 1 | | | | | | | |
| 48 | FATH TESSA | 52603 | | | | | | 6 | | | 119 | SODGA | 56906 | | | | | 5 | | | |
| 49 | FEJ KHEMAKHEM | 52619 | 1 | | | | | | | | 120 | SK EL ARBA(JENDOUBA)SE | 56988 | | 2 | | | | | | |
| 50 | FERNANA | 52659 | | | 3 | | | | | | 121 | SK EL ARBA(JENDOUBA)SM | 56990 | | 2 | | | | | | |
| 51 | FEIJA EL SM | 52665 | | 2 | | | | | | | 122 | BOU SALEM DRE | 57018 | | 2 | | | | | | |
| 52 | GAAFOUR DELEG | 52783 | | | | 4 | | | | | 123 | SK EL KHEMIS B.S.CFPA | 57022 | | 2 | | | | | | |
| 53 | GARDIMAOU DRE | 52864 | | 2 | | | | | | | 124 | SOUK ESSEBT | 57030 | | 2 | | | | | | |
| 54 | GHAR EL MELH NOUVEAU SM | 52872 | 1 | | | | | | | | 125 | MORNAGUIA EX SI CYPRIEN | 57122 | 1 | | | | | | | |
| 55 | GHANIMA TESTOUR | 52874 | | | | 4 | | | | | 126 | TAJEROUINE AIN ZOUAGHA | 57328 | | | | | | | 7 | |
| 56 | GOUBELLAT | 52905 | 1 | | | | | | | | 127 | TAJEROUINE Fme D'ETAT | 57332 | | | | | | | 7 | |
| 57 | HAIDRA RE | 53046 | | | | | | | | 8 | 128 | TAJEROUINE AGRICOLE | 57338 | | | | | | | 7 | 8 |
| 58 | HAMMAM BAYADHA SUD | 53057 | | 2 | | | | | | | 129 | TEBOURBA | 57539 | 1 | | | | | | | |
| 59 | EL HERY | 53096 | 1 | | | | | | | | 130 | TEBOURSOUK SM | 57558 | | | | 4 | | | | |
| 60 | HAOUEM | 53097 | | 2 | | | | | | | 131 | TESSA SIDI MEDIEN | 57643 | | 2 | | | | | | |
| 61 | HIR MAZDOUR | 53311 | | | | | | | 7 | 8 | 132 | TESTOUR SM | 57646 | | | | 4 | | | | |
| 62 | HAOUD | 53430 | | | | | | | 7 | | 133 | TALA SM | 57678 | | | | | | | | 8 |
| 63 | JAMA DRE | 53446 | | | | 4 | 5 | | | | 134 | THIBAR SM | 57690 | | 2 | | | | | | |
| 64 | KALAA KHASBA DELEGATION | 53508 | | | | | | | | 8 | 135 | TOUNGAR CRA | 57731 | 1 | | | | | | | |
| 65 | KALAAT ANDALOUS | 53520 | 1 | | | | | | | | 136 | TOUIREF CTV | 57742 | | | | | | | 7 | |
| 66 | KALAAT ESSENAM DELEGATION | 53525 | | | | | | | 7 | | 137 | TOUKEBER | 57752 | 1 | | | | | | | |
| 67 | KHARROUBA | 53554 | | | | 4 | | | | | 138 | UTIQUE OMVVM | 57966 | 1 | | | | | | | |
| 68 | KEF EN NESOUR | 53603 | | 2 | | | | | | | 139 | ZAAFRANE UCP | 58059 | | 2 | | | | | | |
| 69 | KEF.B.I.R.H | 53605 | | | | | | | 7 | | 140 | ZEBIDA UCP ENNAJAT | 58090 | | | | | | | 7 | |
| 70 | KEF HELIOPOLIS | 53612 | | | | | | | 7 | | 141 | ZAOUEM SM | 58158 | | 2 | | | | | | |
| 71 | KEF CMA | 53619 | | | | | | | 7 | | 142 | ZOUARINE GARE | 58272 | | | | | | 6 | | |

Source: DGRE

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

**Table G2.2.2 Error of Estimated Daily Rainfall**

| Sub-basin No. | Period of Subject Flood | Number of Samples | Standard Error | Total Volume Error |
|---|---|---|---|---|
| 1 | May 22-27, 2000 | 24 | 0.35% | 9.15% |
| | Jan 8-13, 2003 | 24 | 0.68% | 2.30% |
| | Jan 22-27, 2003 | 24 | 2.09% | 8.55% |
| | Dec 8-13, 2004 | 24 | 0.32% | 2.17% |
| | | Average | 0.86% | 5.54% |
| 2 | May 22-27, 2000 | 24 | 1.22% | 3.25% |
| | Jan 8-13, 2003 | 24 | 1.59% | 0.66% |
| | Jan 22-27, 2003 | 24 | 3.61% | 4.11% |
| | Dec 8-13, 2004 | 24 | 0.62% | 9.94% |
| | | Average | 1.76% | 4.49% |
| 3 | May 22-27, 2000 | 24 | 1.73% | 7.33% |
| | Jan 8-13, 2003 | 24 | 3.19% | 4.90% |
| | Jan 22-27, 2003 | 24 | 2.17% | 6.26% |
| | Dec 8-13, 2004 | 24 | 0.43% | 4.02% |
| | | Average | 1.88% | 5.63% |
| 4 | May 22-27, 2000 | 24 | 1.53% | 4.78% |
| | Jan 8-13, 2003 | 24 | 0.50% | 2.56% |
| | Jan 22-27, 2003 | 24 | 0.88% | 0.38% |
| | Dec 8-13, 2004 | 24 | 0.46% | 2.37% |
| | | Average | 0.84% | 2.52% |
| 5 | May 22-27, 2000 | 24 | 0.34% | 8.52% |
| | Jan 8-13, 2003 | 24 | 0.24% | 0.65% |
| | Jan 22-27, 2003 | 24 | 0.20% | 3.01% |
| | Dec 8-13, 2004 | 24 | 0.18% | 7.93% |
| | | Average | 0.24% | 5.03% |
| 6 | May 22-27, 2000 | 24 | 2.50% | 6.87% |
| | Jan 8-13, 2003 | 24 | 2.00% | 6.71% |
| | Jan 22-27, 2003 | 24 | 1.27% | 0.92% |
| | Dec 8-13, 2004 | 24 | 0.91% | 0.34% |
| | | Average | 1.67% | 3.71% |
| 7 | May 22-27, 2000 | 24 | 0.24% | 0.67% |
| | Jan 8-13, 2003 | 24 | 1.43% | 2.67% |
| | Jan 22-27, 2003 | 24 | 1.05% | 4.68% |
| | Dec 8-13, 2004 | 24 | 1.42% | 0.28% |
| | | Average | 1.04% | 2.07% |
| 8 | May 22-27, 2000 | 24 | 0.36% | 1.90% |
| | Jan 8-13, 2003 | 24 | 0.74% | 1.21% |
| | Jan 22-27, 2003 | 24 | 1.30% | 5.71% |
| | Dec 8-13, 2004 | 24 | 1.09% | 1.09% |
| | | Average | 0.87% | 2.48% |

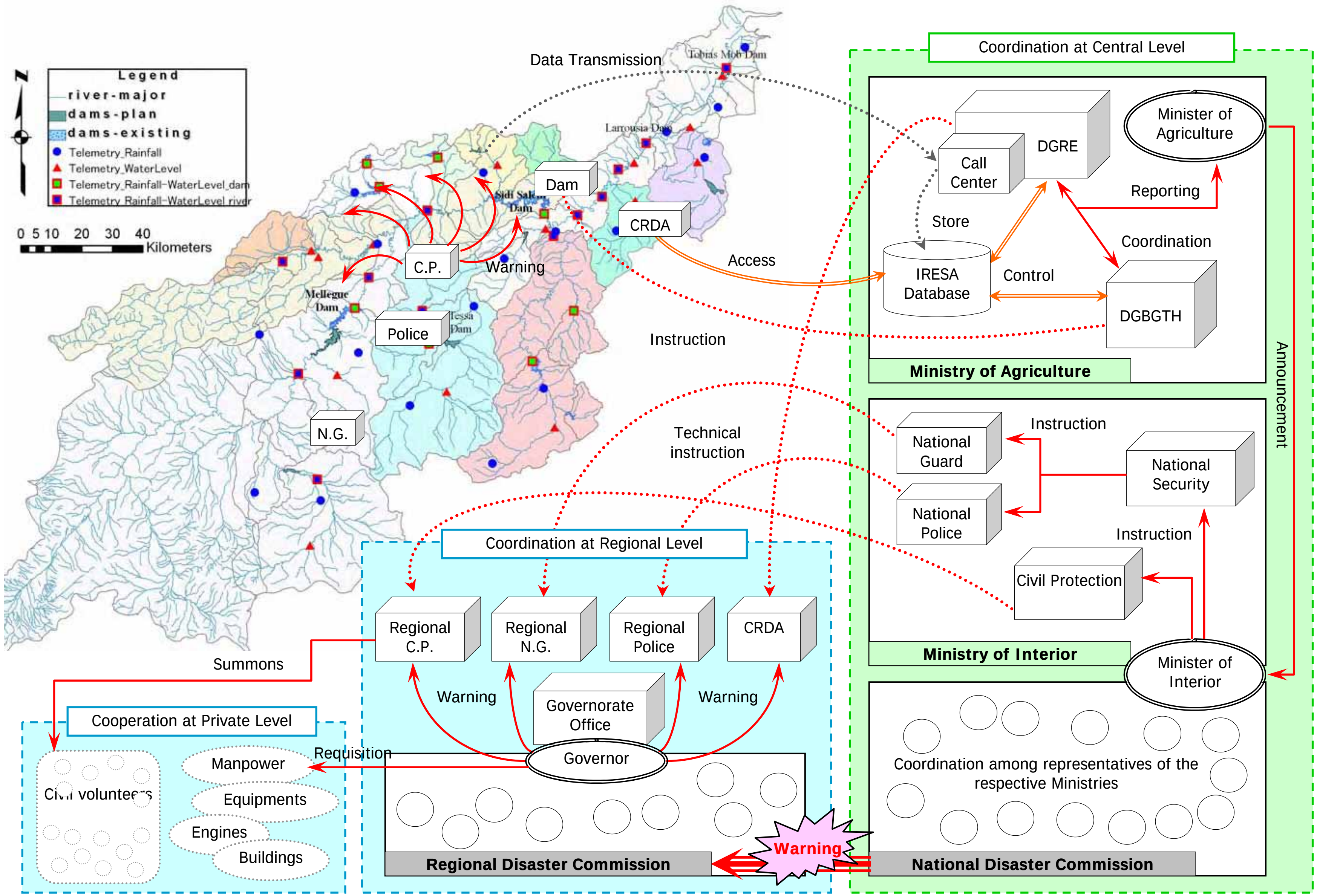
## Table G2.2.3 Cost Estimate for Improvement of FFWS in the Mejerda River Basin

| No. | Item | Unit Price | Quantity | Amount (EUR) *[1] |
|---|---|---|---|---|
| I | Installation of Telemetric Rainfall Gauge | | | |
| | Rainfall Gauging Station | 5,000 EUR/station | 13 stations | 65,000 |
| II | Installation of Telemetric Water Level Gauge | | | |
| | Water Level Gauging Station | 6,500 EUR/station | 2 stations | 13,000 |
| III | Installation of Telemetric Rainfall and Water Level Gauge*[4] | | | |
| | Rainfall and Water Level Gauging Station | 7,000 EUR/station | 2 stations | 14,000 |
| IV *[2] | Incorporation of Dam Release Discharge Data into the Telemetry System | | | |
| | Dams to Be Incorporated | 6,500 EUR/station | 7 dams | 45,500 |
| | 1. Sidi Salem Dam | 1,000 EUR/gate | 3 gates | 3,000 |
| | 2. Mellegue Dam | 1,000 EUR/gate | 3 gates | 3,000 |
| | 3. Bou Heurtma Dam | 1,000 EUR/gate | 1 gate *[3] | 1,000 |
| | 4. Siliana Dam | 1,000 EUR/gate | 2 gates *[3] | 2,000 |
| | 5. Mellegue 2 Dam (planned) | 1,000 EUR/gate | 1 gate *[4] | 1,000 |
| | 6. Sarrath Dam (planned) | 1,000 EUR/gate | 1 gate *[3] | 1,000 |
| | 7. Tessa Dam (planned) | 1,000 EUR/gate | 1 gate *[3] | 1,000 |
| | Total | | | 149,500 |

Source: C2MS (the company which installed the existing telemetry system)

Notes:
1. The above cost does not include maintenance and communication cost, which are estimated at about EUR1,250 /station/year.
2. Item No.IV represents the case of an automatic calculation based on gate opening heights and change of reservoir water levels.
3. In the case of spillway without any gate, the numbers of spillway are counted in calculating the item No.IV.
4. Sarrath and Tessa Dam sites

# *Figures*




Source: Interviews with MARH

Figure G2.1.1 Overall FFWS in the Mejerda River Basin

**Mejerda River Upstream of Sidi Salem Dam**

| | Ghardimaou | Jendouba | Bou Salem |
|---|---|---|---|
| Jendouba | 72 / 10 / 13 | | |
| Bou Salem | 112 / 17 / 22 | 40 / 6 / 9 | |
| Sidi Salem Dam | 167 / 30 / 38 | 95 / 20 / 25 | 55 / 14 / 16 |

**Tributaries Upstream of Sidi Salem Dam**

| | Mellegue Dam | Sidi Medien | Bou Heurtma Dam |
|---|---|---|---|
| K13 | 45 / 4 / 5 | | |
| Bou Salem | 71 / 10 / 12 | 32 / 7 / 9 | 31 / 7 / 9 |
| Sidi Salem Dam | 98 / 23 / 28 | 87 / 20 / 25 | 85 / 21 / 25 |

**Mejerda River Downstream of Sidi Salem Dam**

| | Sidi Salem Dam | Slouguia | Mejez El Bab Pont GP5 | Mejez El Bab Pont Andalous | El Herri | Borj Toumi | Laroussia Dam | El Battane | Jedeida | Pt de Bizerte GP8 |
|---|---|---|---|---|---|---|---|---|---|---|
| Slouguia | 22 / 4 / 6 | | | | | | | | | |
| Mejez El Bab Pont GP5 | 38 / 8 / 11 | 19 / 4 / 6 | | | | | | | | |
| Mejez El Bab Pont Andalous | 39 / 9 / 11 | 20 / 4 / 6 | 1 / 0:30 / 0:30 | | | | | | | |
| El Herri | 62 / 14 / 18 | 43 / 9 / 12 | 24 / 5 / 7 | 23 / 5 / 7 | | | | | | |
| Borj Toumi | 74 / 17 / 22 | 55 / 12 / 16 | 36 / 8 / 11 | 35 / 8 / 10 | 12 / 3 / 4 | | | | | |
| Laroussia Dam | 83 / 18 / 25 | 66 / 14 / 20 | 47 / 10 / 14 | 46 / 10 / 14 | 23 / 5 / 7 | 11 / 2:30 / 3:30 | | | | |
| El Battane | 97 / 23 / 29 | 78 / 17 / 23 | 59 / 13 / 17 | 58 / 13 / 17 | 35 / 7 / 10 | 23 / 5 / 7 | 12 / 3 / 4 | | | |
| Jedeida | 106 / 26 / 33 | 89 / 20 / 26 | 70 / 15 / 20 | 69 / 15 / 20 | 46 / 10 / 14 | 34 / 7 / 10 | 23 / 5 / 8 | 11 / 2:30 / 3:30 | | |
| Pt de Bizerte GP8 | 132 / 31 / 44 | 116 / 26 / 34 | 97 / 22 / 28 | 96 / 22 / 28 | 73 / 16 / 21 | 61 / 13 / 18 | 50 / 11 / 16 | 38 / 8 / 11 | 28 / 6 / 8 | |
| Tobias Dam | 135 / 32 / 42 | 119 / 27 / 35 | 100 / 23 / 29 | 99 / 23 / 29 | 76 / 17 / 22 | 64 / 14 / 19 | 53 / 12 / 16 | 41 / 9 / 12 | 31 / 7 / 10 | 3 / 1 / 1 |

**Tributaries Downstream of Sidi Salem Dam**

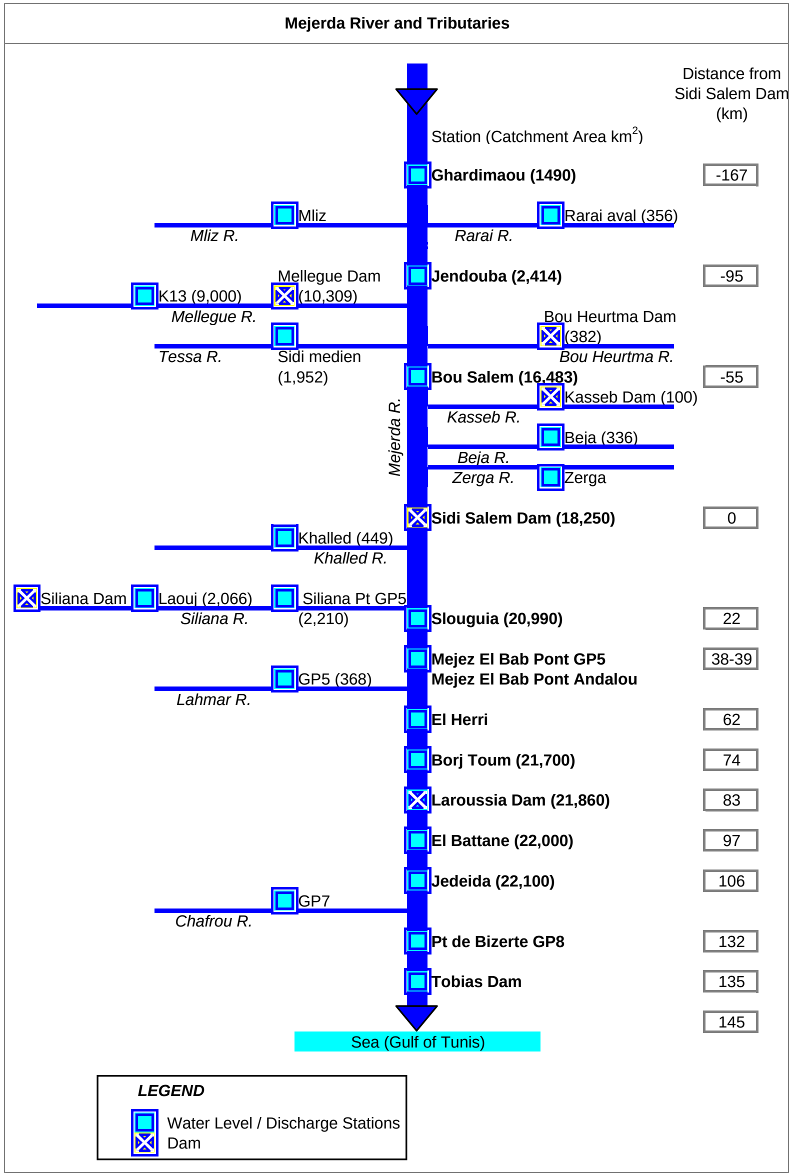
| | Khalled | Siliana Dam | Siliana Laouj | Siliana Pt GP5 |
|---|---|---|---|---|
| Slouguia | 12 / 3 / 4 | 80 / 18 / 22 | 28 / 7 / 8 | 9 / 2 / 3 |

**Tributaries Downstream of Sidi Salem Dam**

| | Lahmar GP5 |
|---|---|
| El Herri | 30 / 6 / 8 |

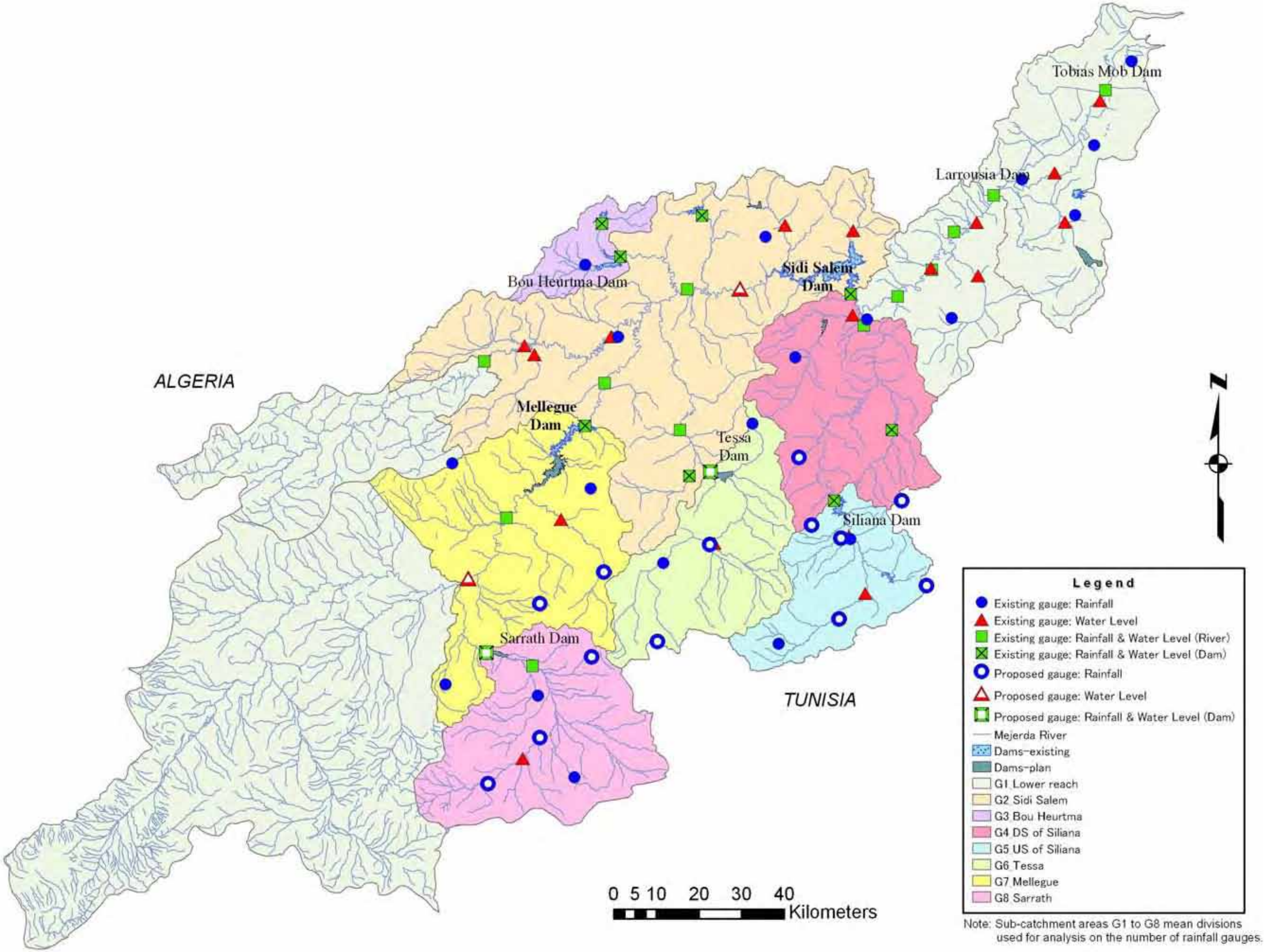
***LEGEND***

| | *Sidi Salem Dam* | |
|---|---|---|
| *Slouguia* | *18 km* | Distance between Slouguia and Sidi Salem Dam (km) |
| | *4 h* | Minimum propagation time (hr) |
| | *6 h* | Maximum propagation time (hr) |




Source: GDRE

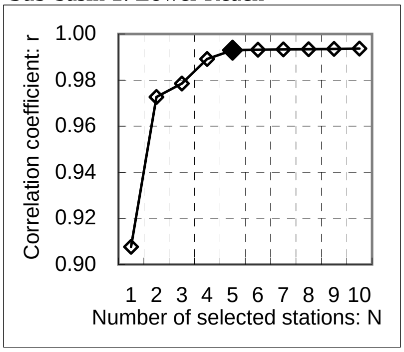
**Figure G2.1.2 Propagation Time for Mejerda River Basin**




Source: the Study Team, and DGRE

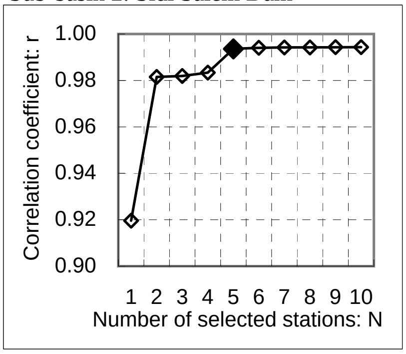
**Figure G2.2.1 Proposed Additional Installation of Telemetric Gauging Stations**

Sub-basin 1: Lower Reach



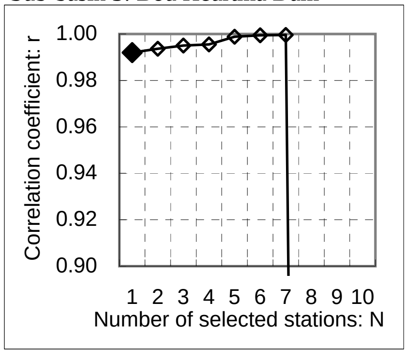

Required number of stations: 5

Sub-basin 2: Sidi Salem Dam



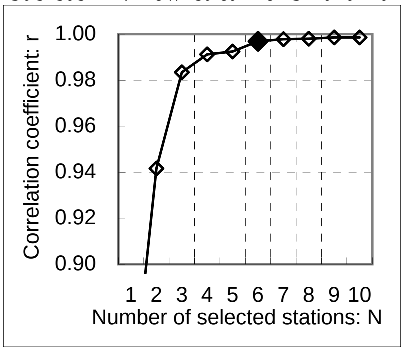

Required number of stations: 5

Sub-basin 3: Bou Heurtma Dam



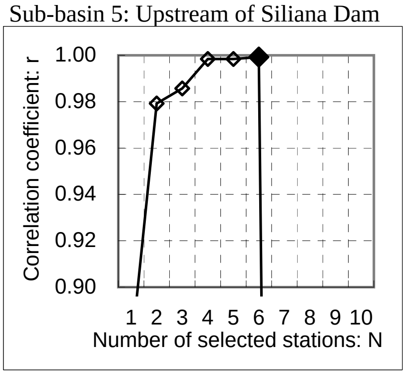

Required number of stations: 1

Sub-basin 4: Downstream of Siliana Dam



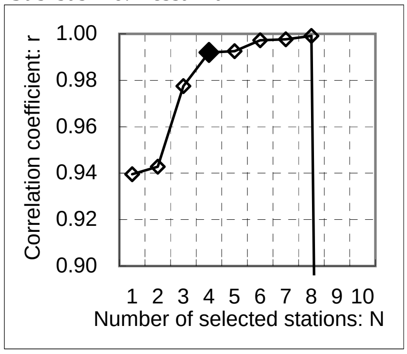

Required number of stations: 6

Sub-basin 5: Upstream of Siliana Dam



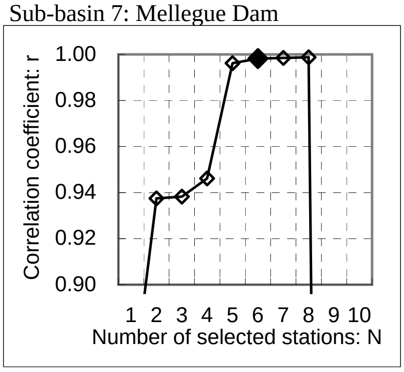

Required number of stations: 6

Sub-basin 6: Tessa Dam



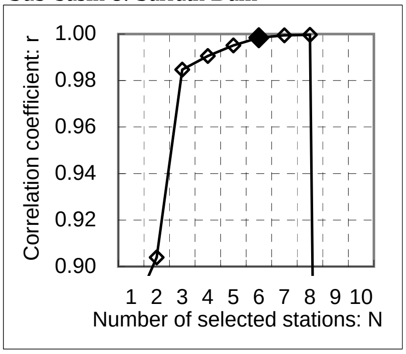

Required number of stations: 4

Sub-basin 7: Mellegue Dam




Required number of stations: 6

Sub-basin 8: Sarrath Dam

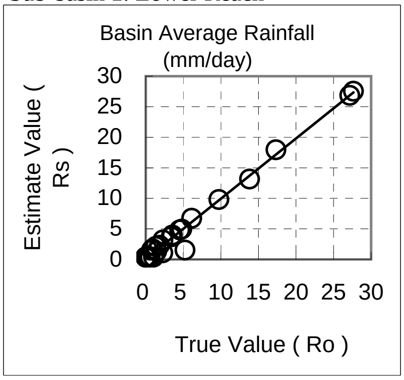



Required number of stations: 6

Source: the Study Team

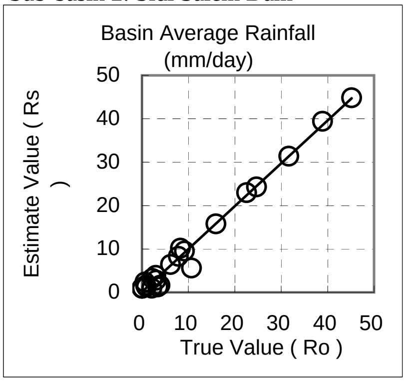
**Figure G2.2.2 Relationship between the Number of Selected Stations and Correlation Coefficient**

Sub-basin 1: Lower Reach



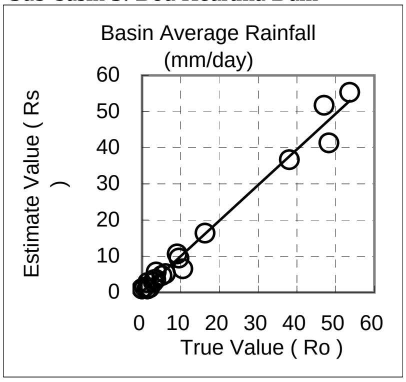

Correlation coefficient = 0.993

Sub-basin 2: Sidi Salem Dam



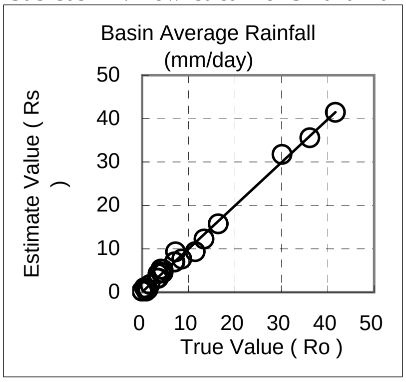

Correlation coefficient = 0.994

Sub-basin 3: Bou Heurtma Dam



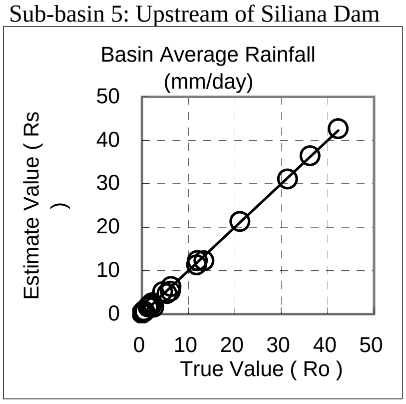

Correlation coefficient = 0.992

Sub-basin 4: Downstream of Siliana Dam



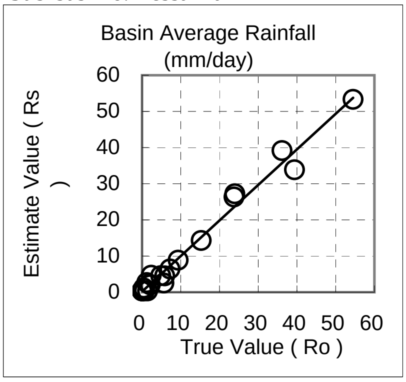

Correlation coefficient = 0.997

Sub-basin 5: Upstream of Siliana Dam



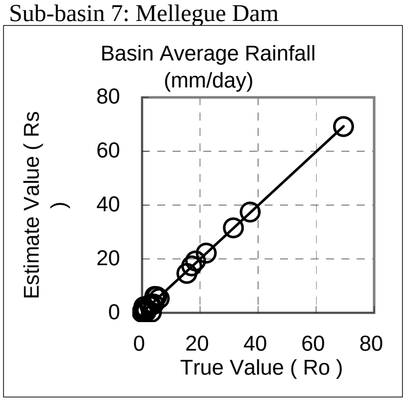

Correlation coefficient = 0.999

Sub-basin 6: Tessa Dam



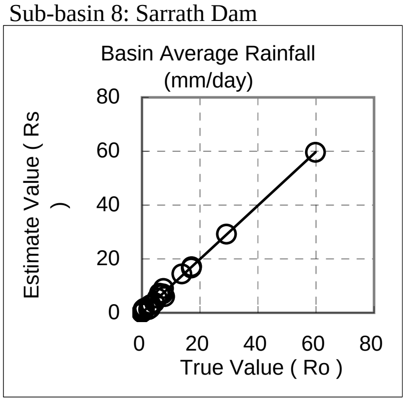

Correlation coefficient = 0.992

Sub-basin 7: Mellegue Dam




Correlation coefficient = 0.998

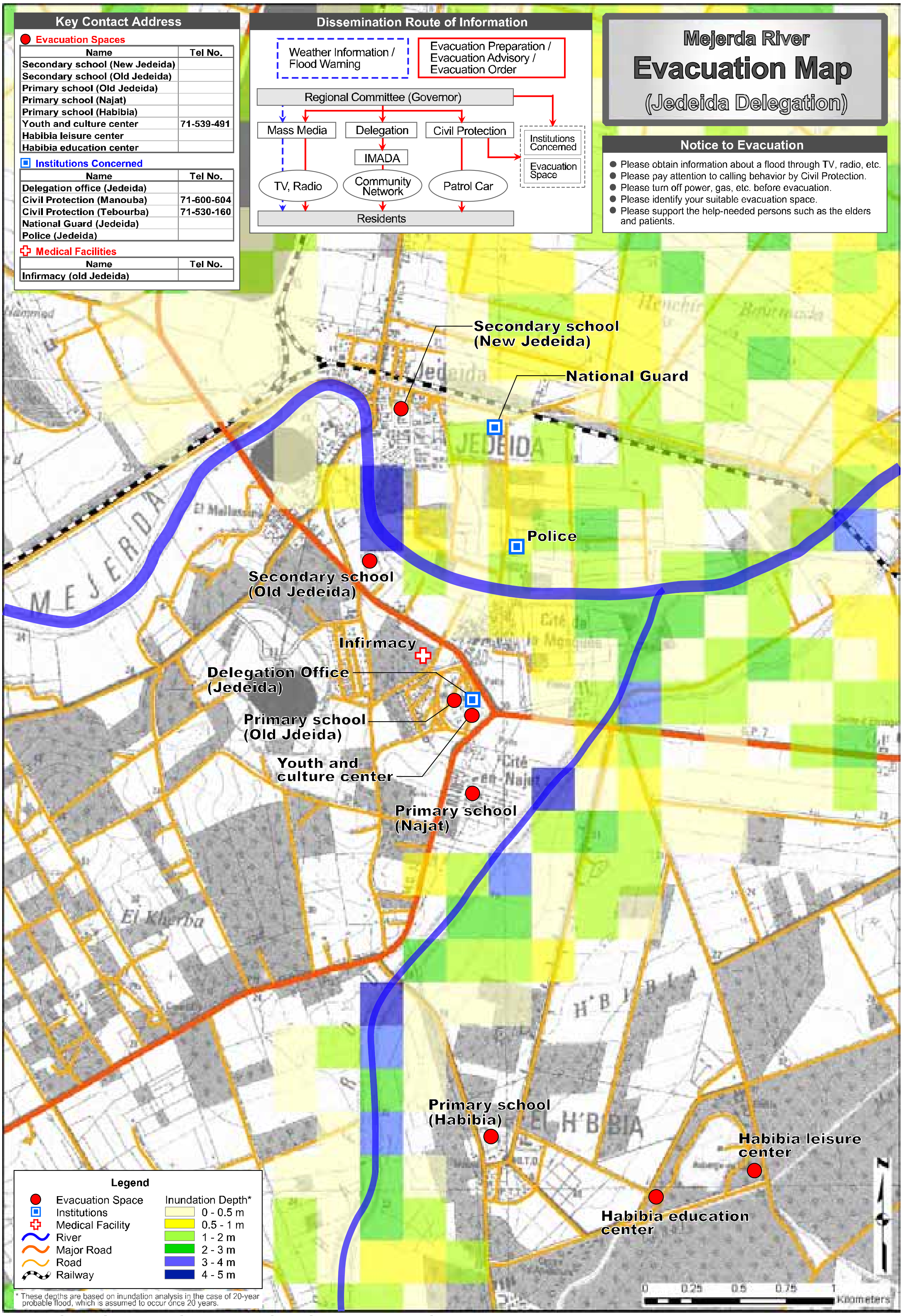
Sub-basin 8: Sarrath Dam




Correlation coefficient = 0.998

Source: the Study Team

**Figure G2.2.3 Correlation between True Values (Ro) and Estimated Values (Rs) of Basin Average Rainfall**




Source: the Study Team, and interview with Civil Protection Manouba

**Figure G3.2.1 Evacuation Map for Jedeida Delegation**