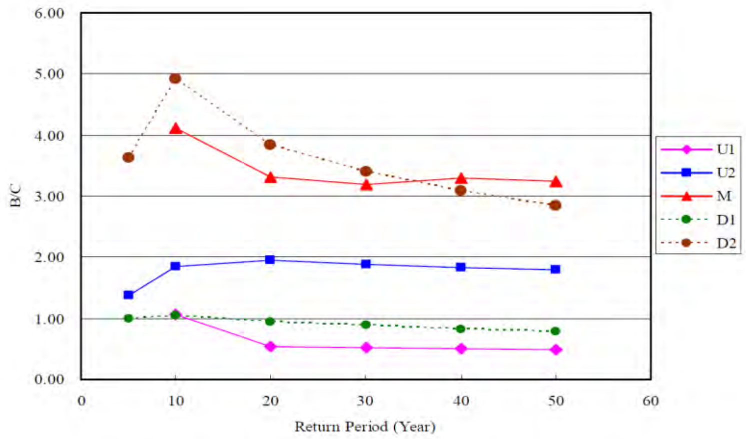
Chapter 4. River Improvement Plan

4.1 Basic Conditions for River Improvement Plan

4.1.1 Flood Safety Levels

The target safety level for flood controls will follow the Master Plan. The benefit-cost ratio is calculated by flood control safety level in each section within the Master Plan, taking the safety level with the highest ratio.

The figure below gives the relation between benefit-cost ratio and flood safety levels for each section. From the following study results, the target flood safety level for Section D2 is a 10th-year flood. It is worth noting here that preparing Section D2 for a 50-year flood could also be cost-effective.

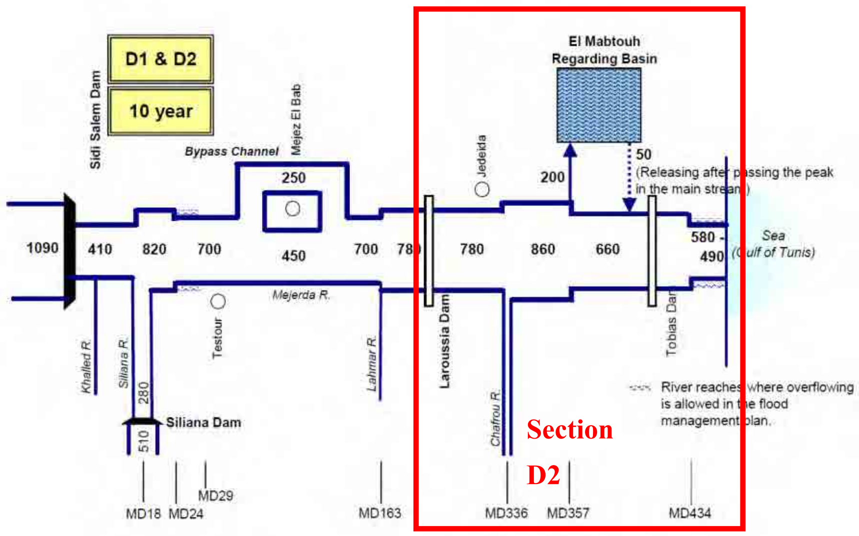


Source: Master Plan Study

Figure 4-1: Main site hydrograph

4.1.2 Structural measures

The 10th-year probability in the design flood discharge distribution in the Master Plan is outlined below. For Section D2, this means structural measures based on a combination of river channel improvements and a retarding basin. Structural measures for this study are also a combination of river channel improvements and retarding basins.



Source: Master Plan Study

Figure 4-2: Design discharge distribution in Master Plan

4.2 Base Discharge

Discharge calculations have been addressed separately in the Mejerda River Basin Climate Change Impact Assessment in Tunisia (hereinafter the MRCCIA). This study will use the discharge calculations studied in the MRCCIA to determine base discharge and design flood discharge.

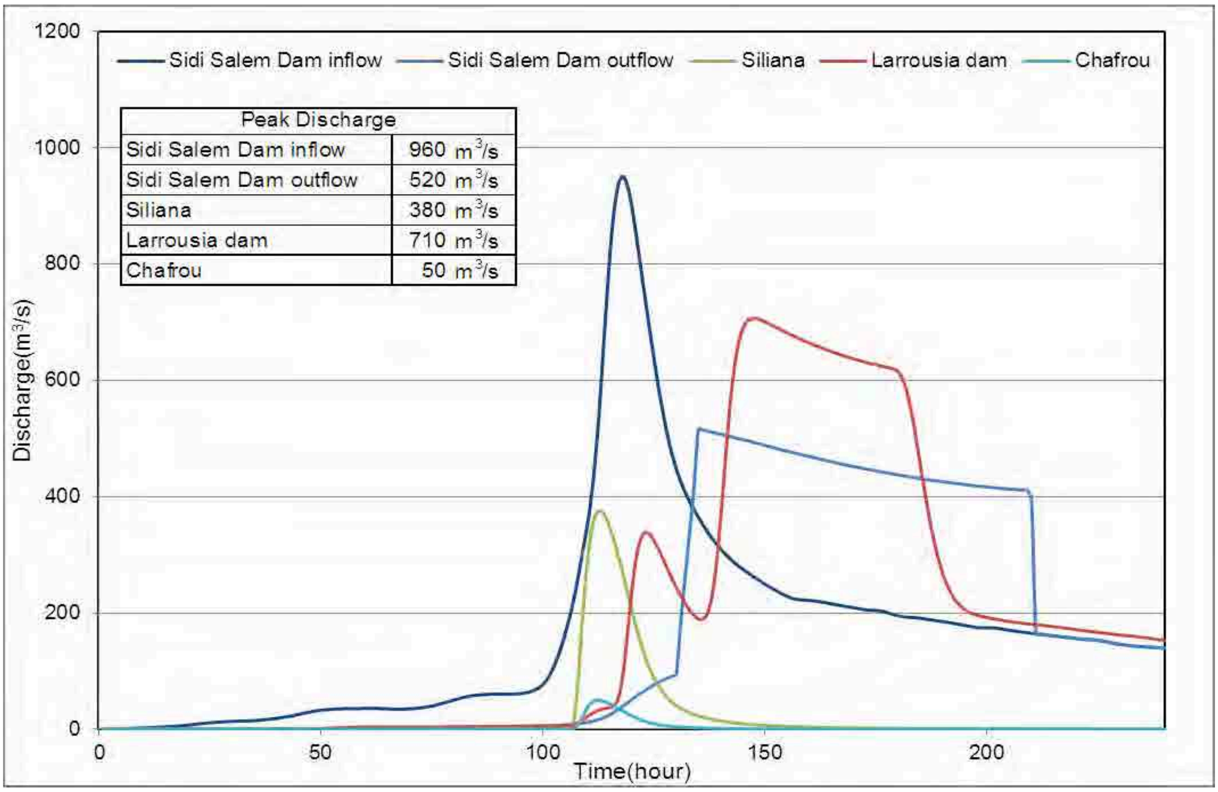
The hydrograph and base discharge distribution for the major sites as obtained in the MRCCIA is given below. Peak discharge for the Laroussia Dam site is 710 m3 per second, but we have set base discharge in Section D2, the target section of this study, to 800 m3 per second to account for residual basin runoff downstream of Laroussia Dam (including Chafrou River runoff).

In addition, water discharge amount at Sidi Salem Dam is calculated by assuming the operation below;

・Flood Control Start Level: 116.0m

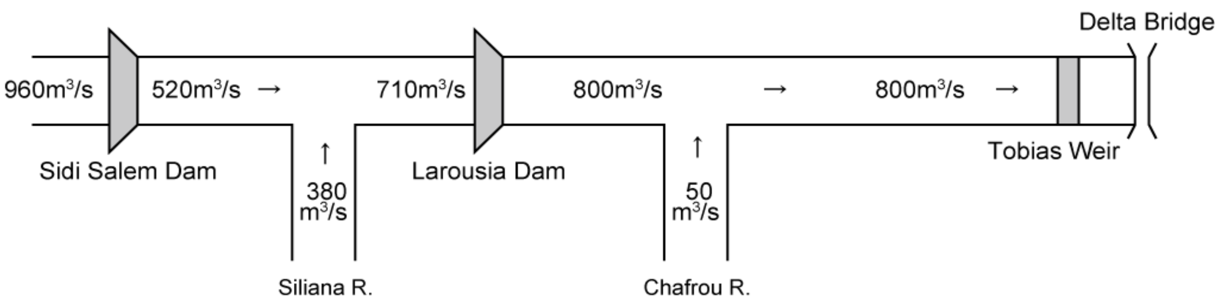
・The gate will be opened at 0.9m/h and fully opened after 6 hours.

・When water level is low, the gate will fully be opened steady basis until 115.0m, full capacity.



Source: JICA Survey Team

Figure 4-3: Main site hydrograph



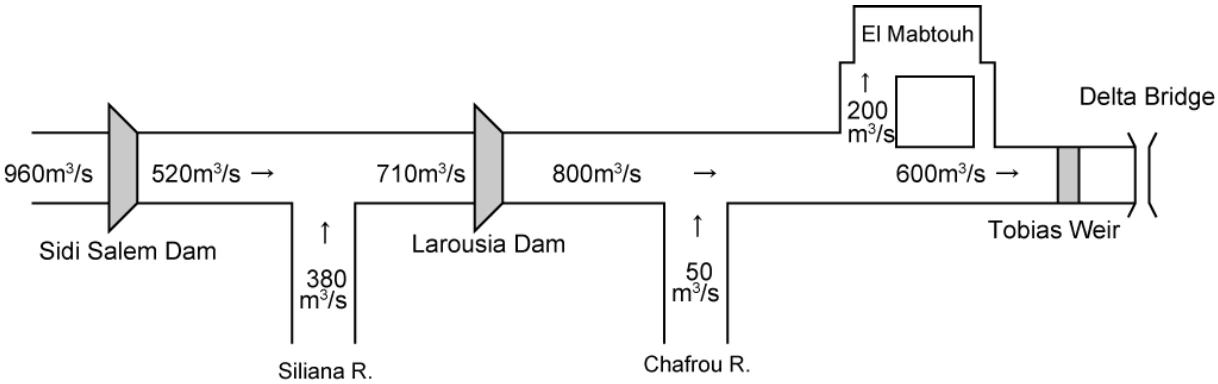
Source: JICA Survey Team

Figure 4-4: Base Discharge Distribution Chart

4.3 Design Flood Discharge

Design discharge is a combination of river improvements and the El Mabtouh basin based on the Master Plan.

Given the capacity of the El Mabtouh wetlands, the amount distributed into the El Mabtouh basin was set to 200 m^3 per second according to the Master Plan. Below is a distribution hydrograph for design flood discharge.



Source: JICA Survey Team

Figure 4-5: Design Flood Discharge Distribution Hydrograph

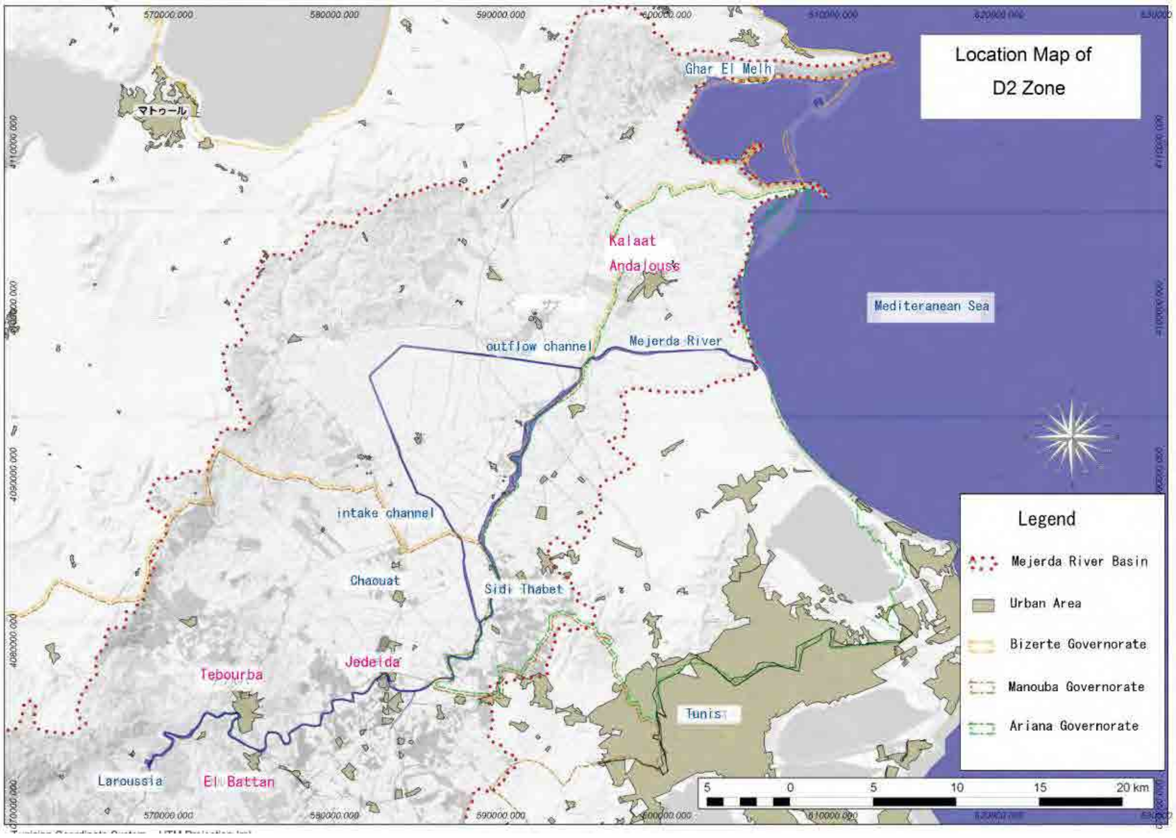
4.4 Channel Characteristics

4.4.1 Channel Cross Sections and Longitudinal Sections

This is a study of Zone D2, the section from the Laroussia Dam to the downstream end of the Mejerda River. The survey data used to understand channel characteristics for this study are found in the table below. As the survey line positions were not perpendicular to the channel normal in some places in the 2011 cross-sectional survey data, this study will use the 2007 measurement data.

Table 4-1: Channel Survey Data

	Section	Measurement Year	Source	Length	Cross Sections
1	Mejerda River (from Laroussia Dam to lower Mejerda River basin)	2007	Master Plan	64.974 km	199



Source: JICA Survey Team

Figure 4-6: Study Section (D2)

4.4.2 Understanding the Runoff Analysis

We will understand the current flow capacity of the study section. The conditions for hydrological calculation used to determine flow capacity are given in the table below.

Table 4-2: Conditions for Hydrological Calculations

No	Item	Condition
1	Calculation Method	Non-uniform flow
2	Section	Mejerda River (Downstream end to Laroussia Dam, 64.974 km)
3	Channel	Channel in current state (as of 2007)
4	Flow	W = 6 cases of 20-120% for 10th-year (800 m^3/sec.)
5	Roughness Coefficient	0.04
6	Starting Water Level	0.77 m
7	Structures	11 bridge piles

(1) Study Section

The section for the runoff analysis will be from the downstream end of the Mejerda River to the Laroussia Dam (0.0 to 64.974 kilometers).

(2) Channel

Targeting the channel in its current state, we will use the channel cross-sections from 2007 when creating the Master Plan.

(3) Flow

Based on the design scale of a 10th-year probability, we used flow of 20-120%.

(4) Roughness Coefficient

The model cross sections given on the following page are divided into the riverbed and the portion with flourishing tamarisk, as set using a composite roughness. The roughness for each model cross section is given as follows. Roughness is set to n = 0.030 for the riverbed and n = 0.060 for the portion with flourishing tamarisk.

・49.809 km: n = 0.040 ・35.521 km: n = 0.040
・22.521 km: n = 0.039 ・7.633 km: n = 0.037

As the state of tamarisk growth for the entire section is visible and there are no big differences in composite roughness between the model cross sections, n = 0.040 will be used for all sections.

The roughness coefficients above are also considered relevant because inundation points were able to be reproduced as part of calculations to reproduce inundation conditions from the 2003 flood, detailed below.

(5) Starting Water Level

Starting water level will be set to 0.77 meters, the design high water level for the downstream end of the Mejerda River as set in the Master Plan.

A design longitudinal section from the Master Plan is given in Figure 4.7 below.

(6) Structures

We will take into consideration any structures which may obstruct the flow area during the runoff analysis. Specifications for such structures are given in the table below.

Table 4-3 Structure Specifications

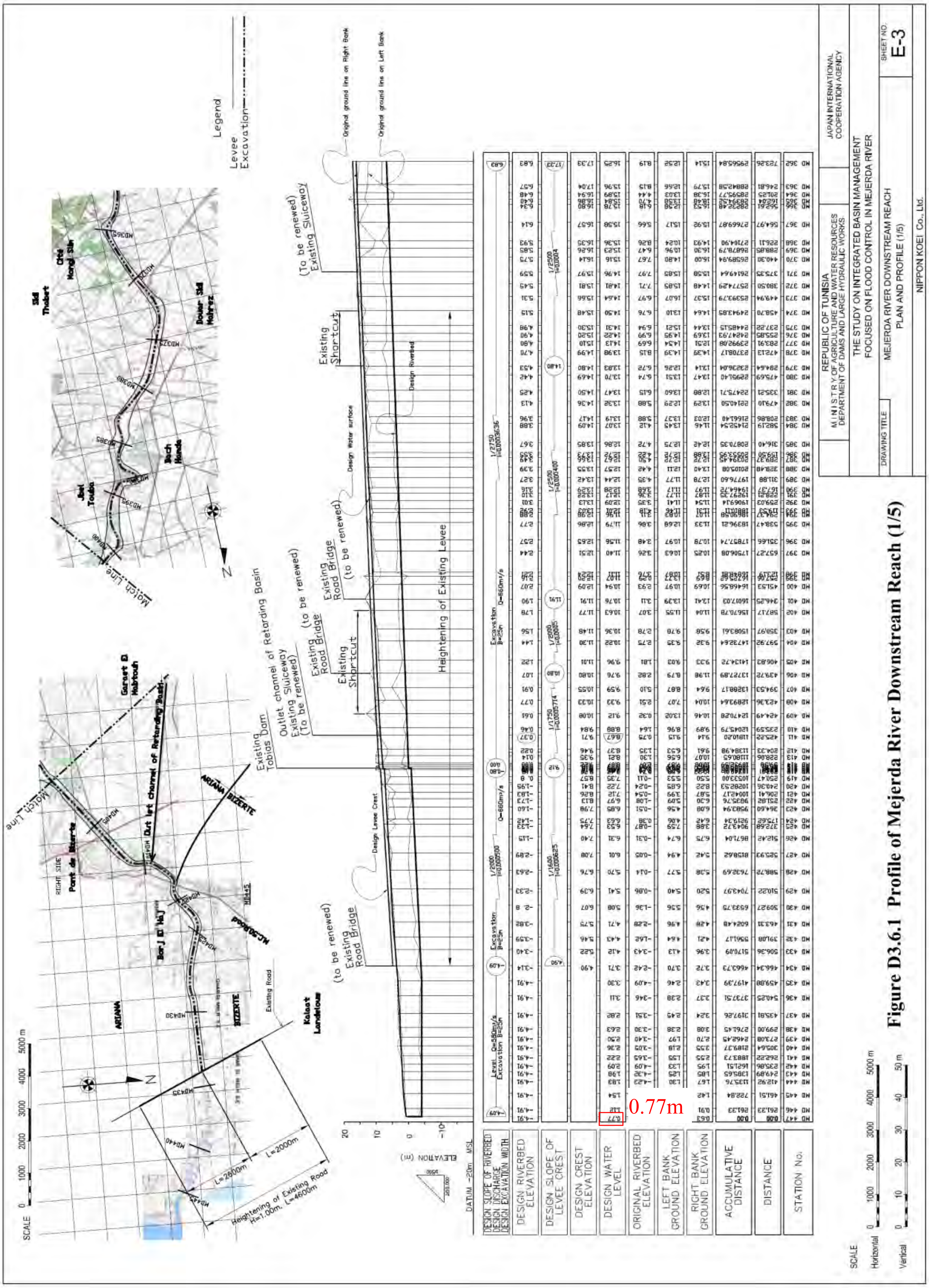
No	Structure Name	Distance from Mouth	Pier Width	Piers
1	El Battane Weir bridge	53.111	2.24	17
2	GP7 road Jedieda	41.926	1.2	4
3	Jedeida old bridge	41.091	6	3
4	Jedeida new bridge	41.071	1	2
5	A4 Highway	16.017	2	5
6	GP8 road	13.728	0.6	10
7	Tobias dam old bridge	10.836	0.5	4
8	Tobias dam new bridge	10.828	0.8	2
9	Delta bridge	4.664	0.37	3
10	Jedeida old railway bridge	37.848	2.278	1
11	Jedeida new railway bridge	37.834	1.013	2

Source: JICA Survey Team

(7) Designing Channel Cross Section from Delta Bridge to River Mouth

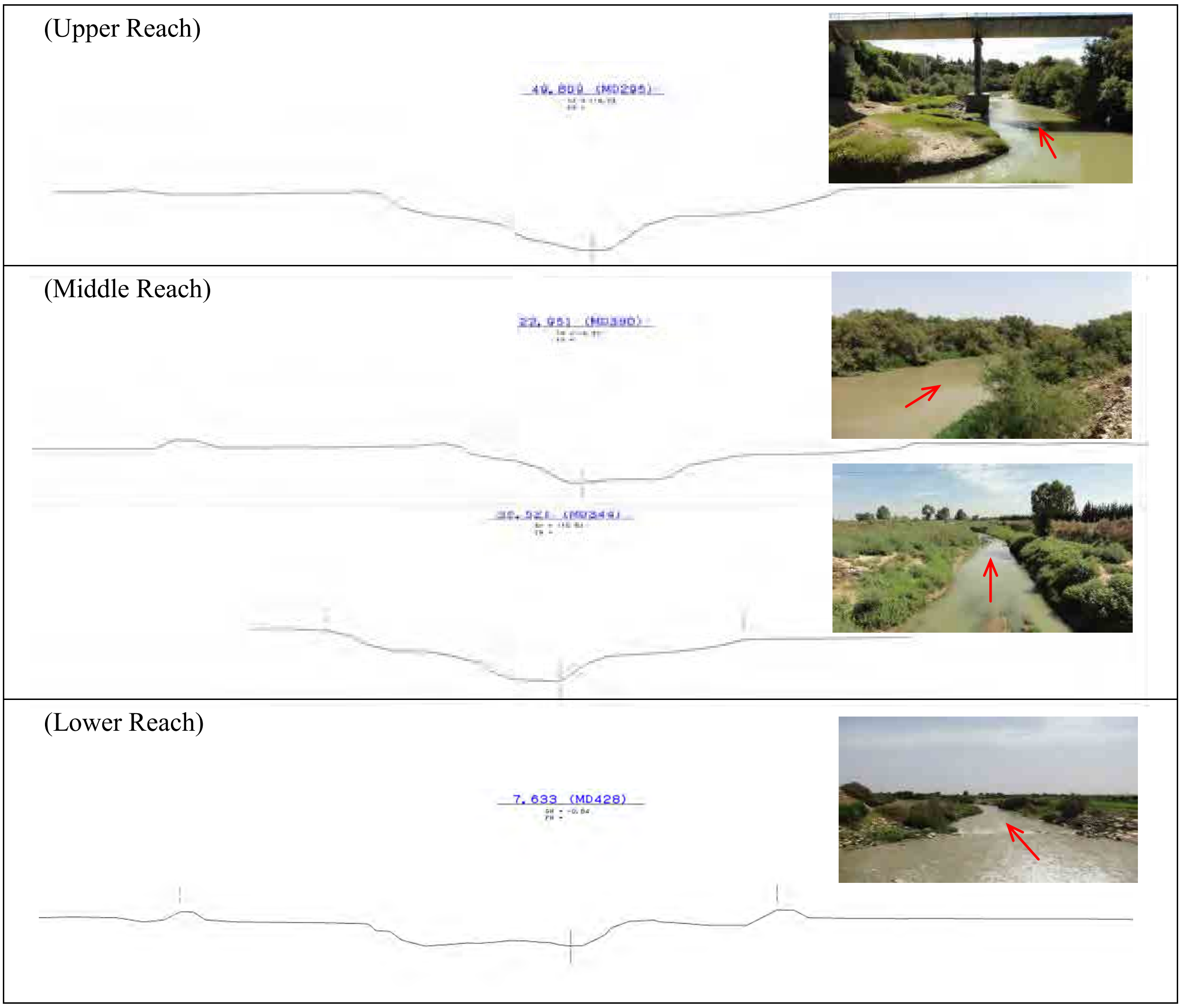
The channel cross section from the delta bridge to the river mouth is small, so it was designed with inundation in mind. Given the local topography, the area designed as an inundation area is 300 meters from the river channel to the left and right banks.

Calculations of current flow capacity are as shown on Figure 4.10. Ten-year flood flow rates are possible upstream of the El Bataan Weir, but most of the sections downstream of the weir lack the capacity for design flood discharge. Some of the insufficient sections have flow capacity as low as 100 m^3 per second. The current flood safety level as determined from the current Mejerda River flow capacity is a two-year flood level.



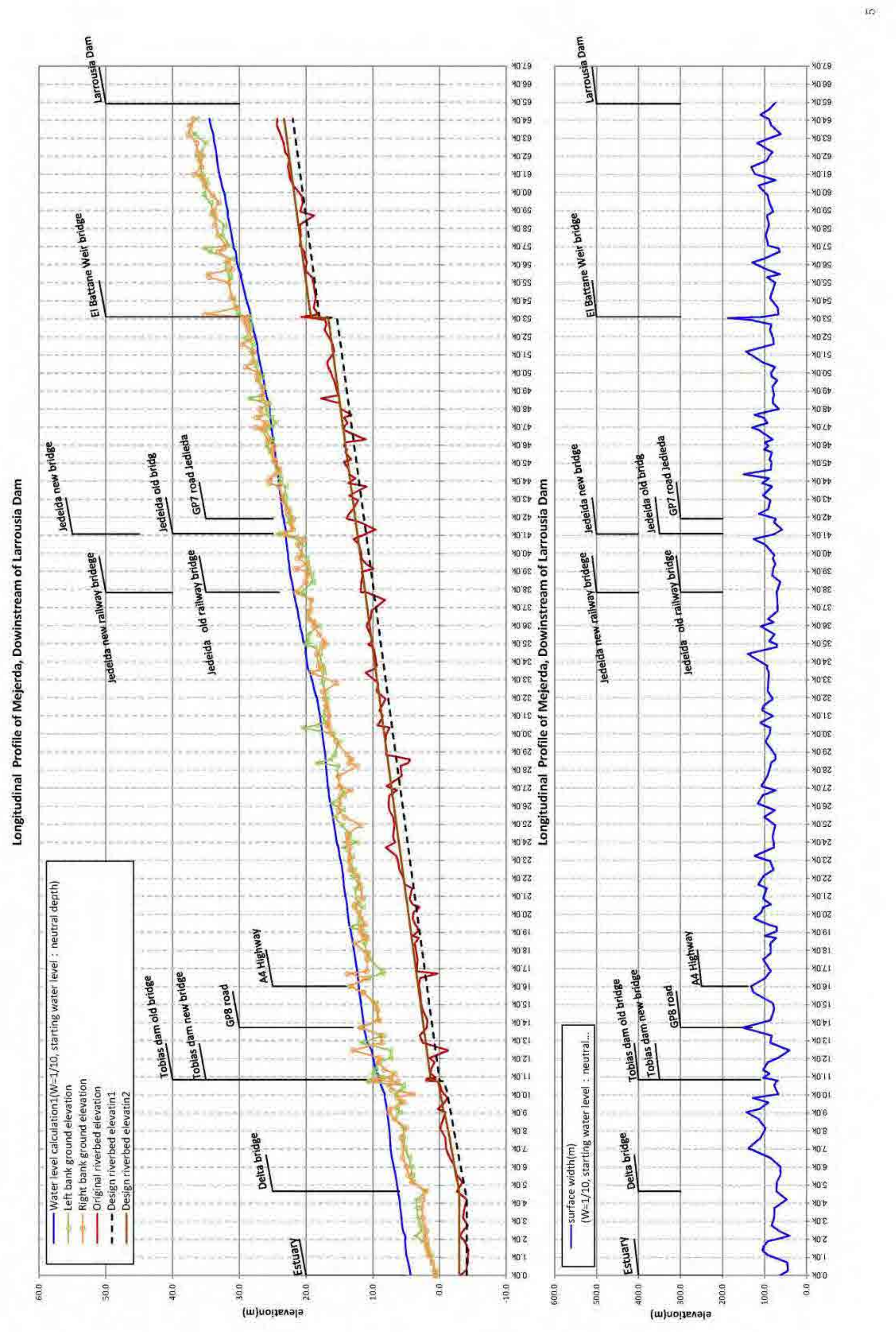
Source: Master Plan Study

Figure 4-7: Longitudinal Section Planned in Master Plan



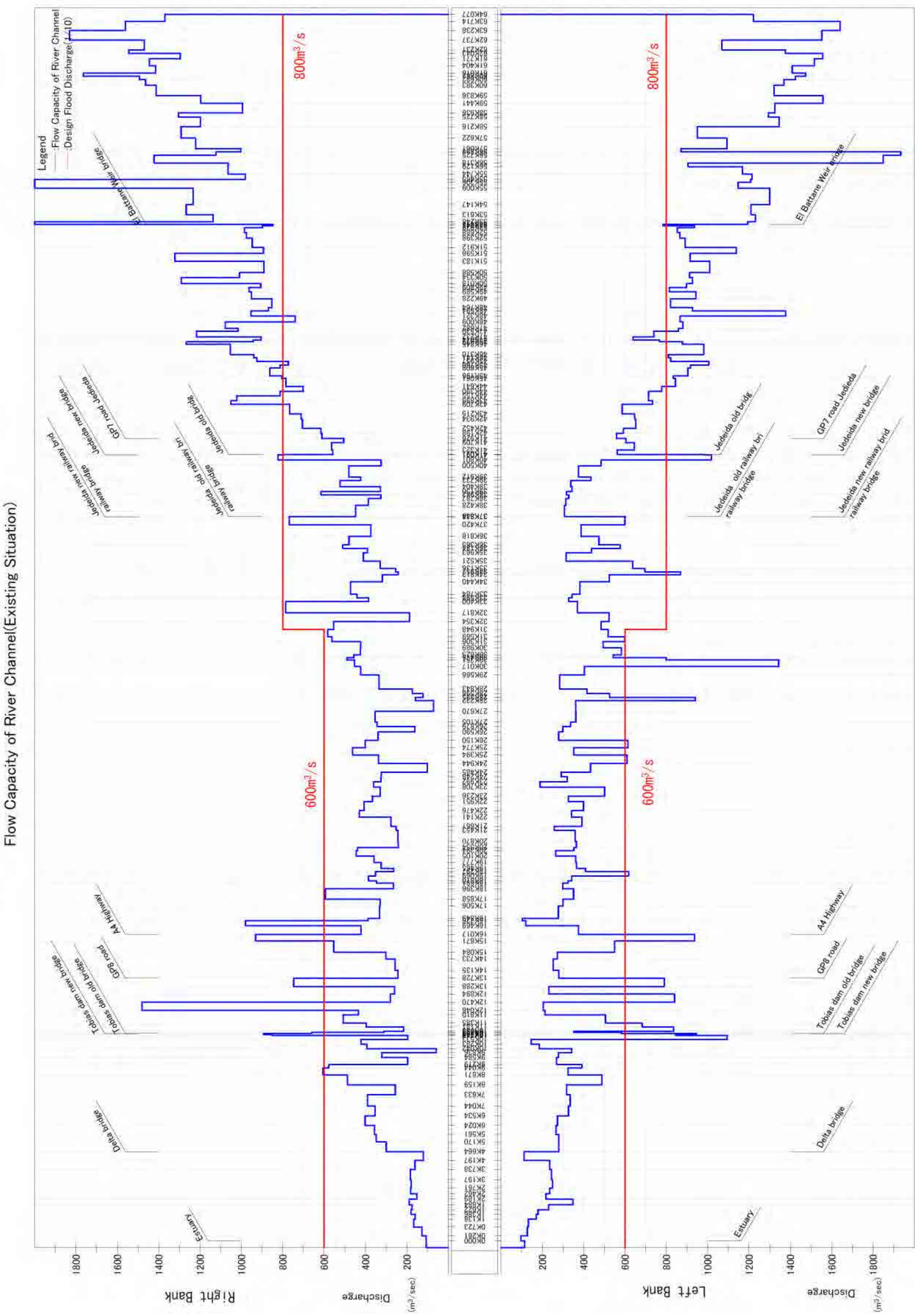
Source: JICA Survey Team

Figure 4-8: Model Cross Sections



Source: JICA Survey Team

Figure 4-9: Current Longitudinal Sections



Source: JICA Survey Team

Figure 4-10: Water Level Calculations from Current Longitudinal Sections and Cross Sections

4.5 Channel planning

4.5.1 River Improvements for Mejerda River

We compared proposals for banking and excavating the design channel. The basic approaches for both proposals are as given below.

・**Case 1: Banking**

We considered an embankment with a 1:2 gradient and crown width of four meters in order to account for an allowance height of one meter for banking the current cross section.

・**Case 2: Excavating**

Aims were made to keep the channel embedded to the extent possible, including allowance height. Allowance height was one meter, gradient was 1:2 and riverbed gradient was 1/2,600, based on the current deepest riverbed point. In order to leave the water route, a lower limit of two to five meters above the design riverbed was set for excavation.

The lower limit for excavation was set at 2.0 meters from the design riverbed in the lower basin and at 5.0+ meters from the design riverbed in the upper basin with a straight line connecting the two serving as the excavation lower limit line since the channel in the upper basin is deeper and has considerable flow capacity compared to that in the lower basin. The gradient of this excavation lower limit line is roughly 1/2,000.

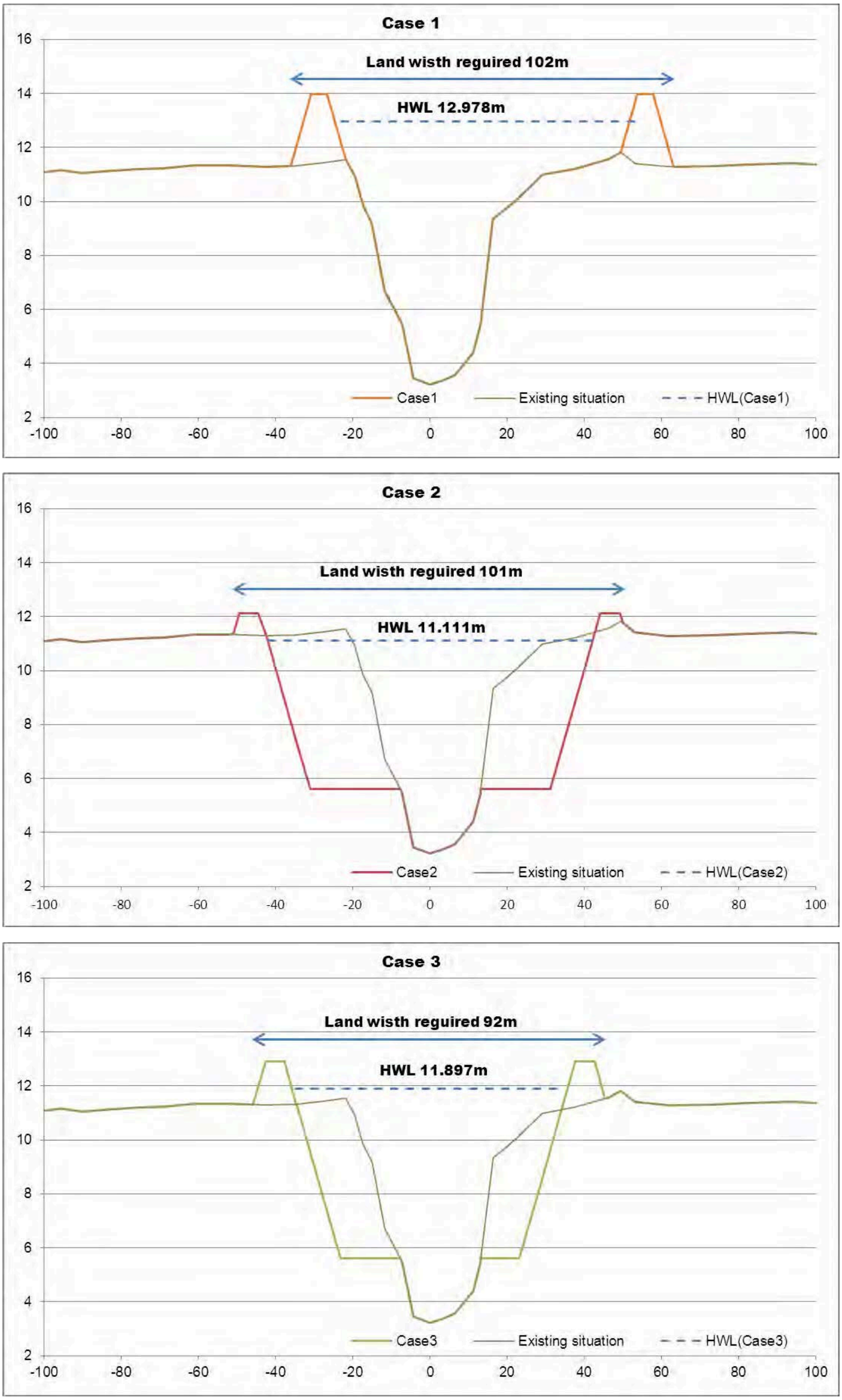
・**Case 3: Banking and Excavating**

Based on the excavating plan, this proposal would perform banking with the allowance height of one meter to reduce the amount of excavation.

The following pages show the design channel cross section and profile of flow for a typical cross section. Case 1 produces water levels 1.5 to 3.3 meters (average: 2.4 meters) higher than Case 2. In terms of land required, Case 3 is preferable. Cases 1 and 3 would require either removing or relocating the old Jedeida Bridge, and historical structure.

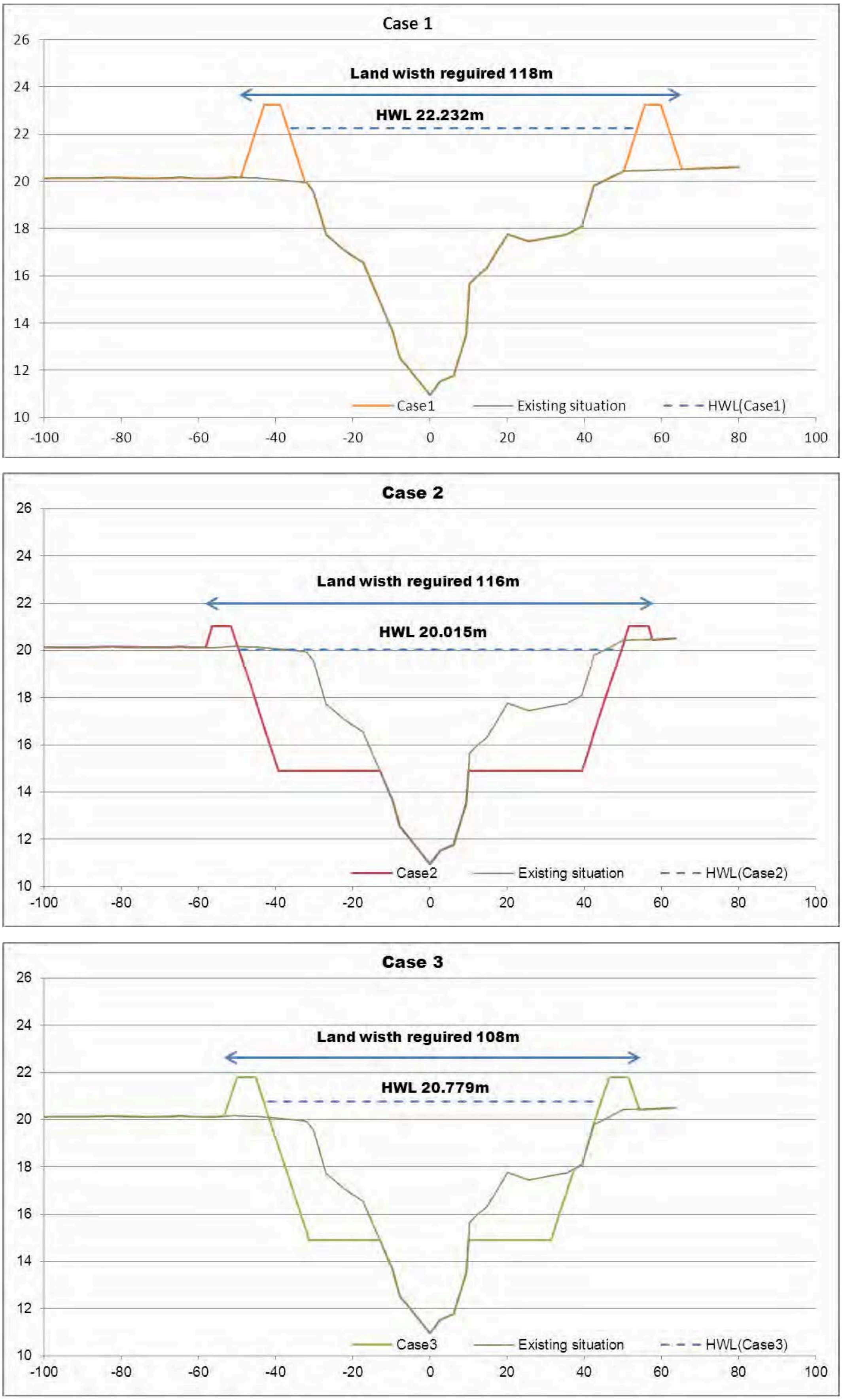
Item	Case 1: Banking	Case 2: Excavating	Case 3: Banking and Excavating
Land Required	Large	Large	Small
Impact on historical structures	Old Jedeida bridge must be removed or relocated	None	Old Jedeida bridge must be removed or relocated
Impact on internal waters	Large	Almost none	Some
Fitness for larger floods brought on by climate change	Low	High	Mid

Upon consulting with the Tunisia side based on the above results, they confirmed that we would adopt Case 2 and excavate due to the impact on historical structures and internal waters. The standard cross and longitudinal sections of flow for each case on typical cross sections are shown below.



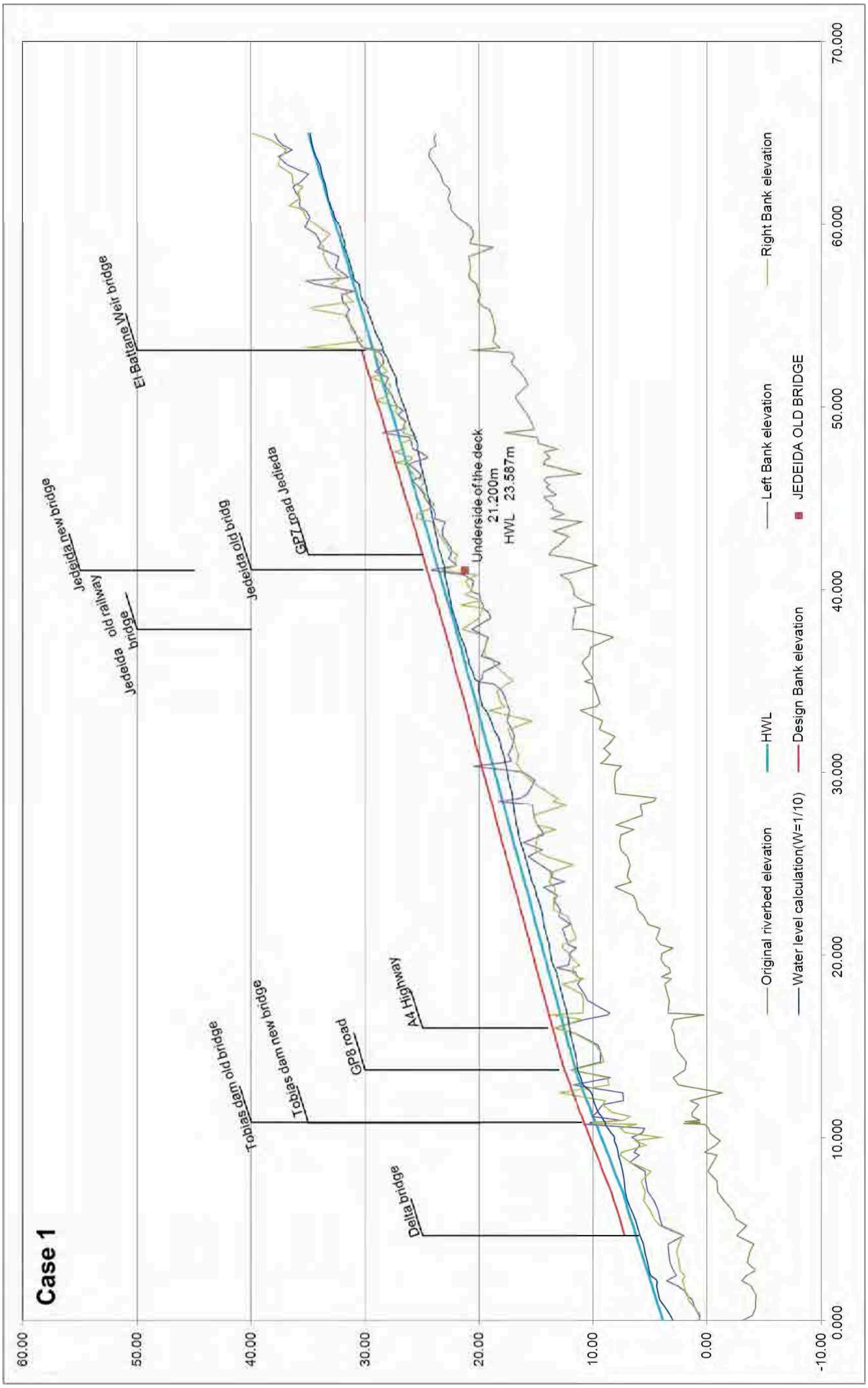
Source: JICA Survey Team

Figure 4-11: 20.105 km, comparison of design cross sections



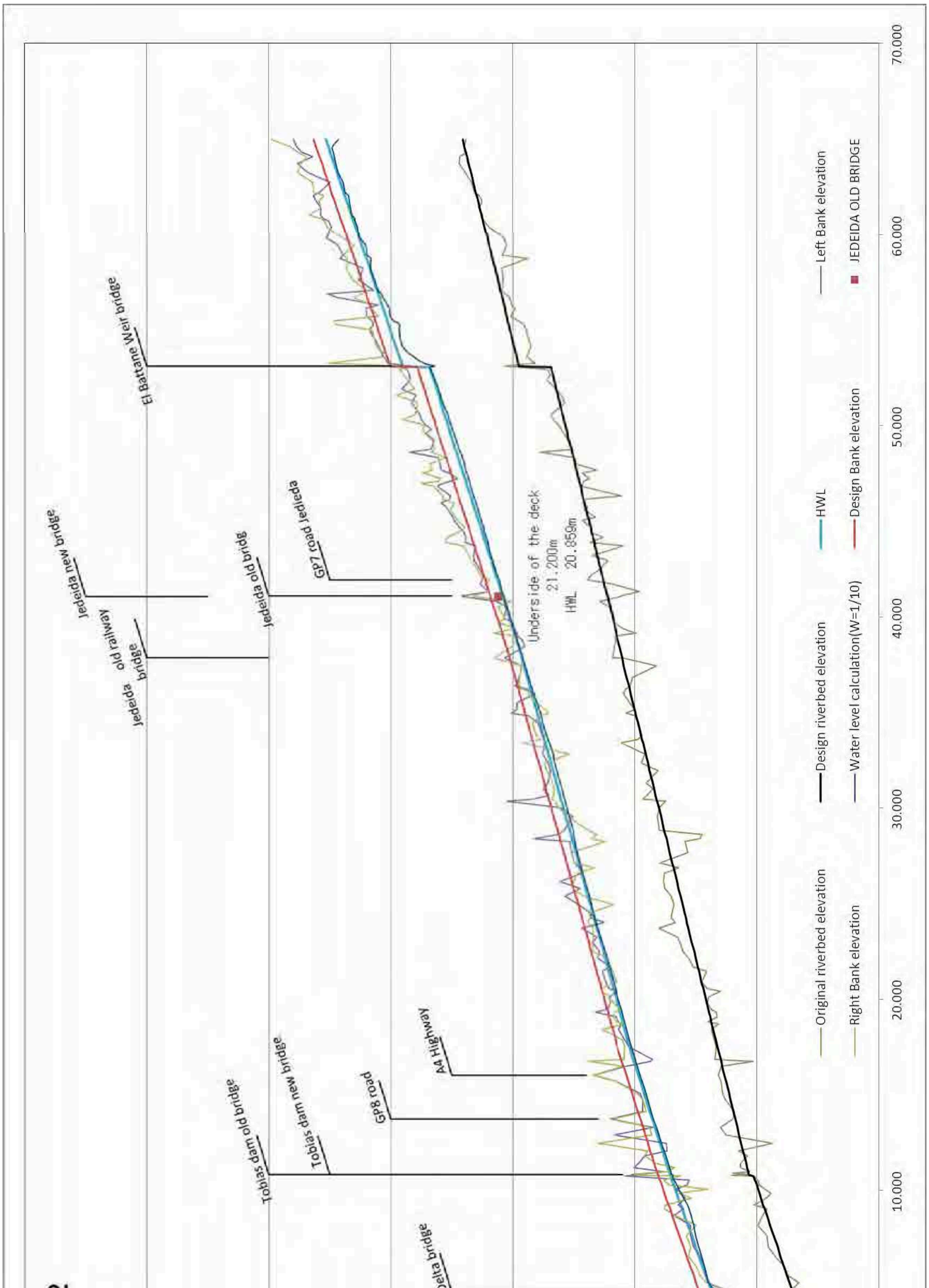
Source: JICA Survey Team

Figure 4-12: 39.404 km, comparison of design cross sections



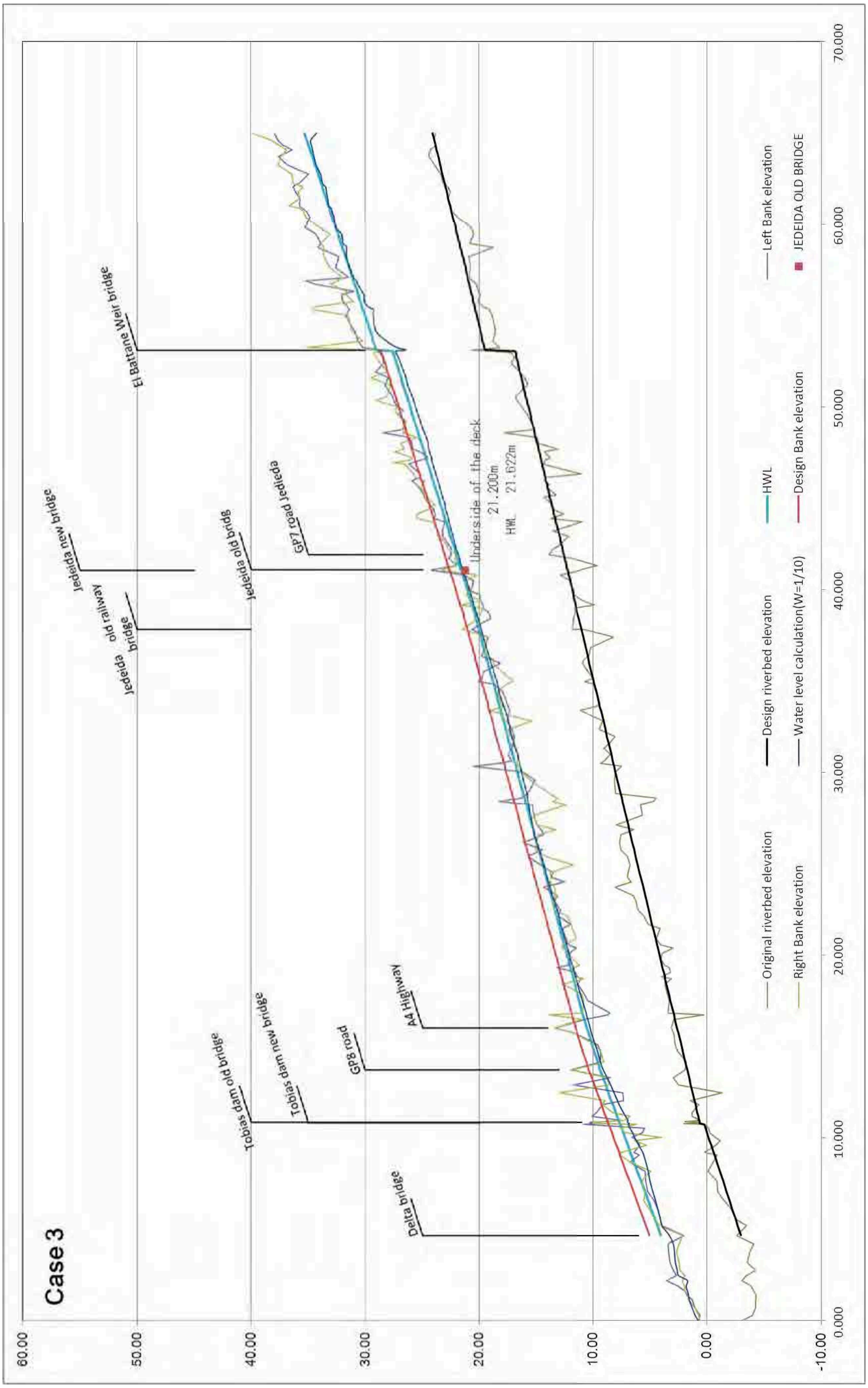
Source: JICA Survey Team

Figure 4-13: Longitudinal Section for Case 1, Banking



Source: JICA Survey Team

Figure 4-14: Longitudinal Section for Case 2, Excavating



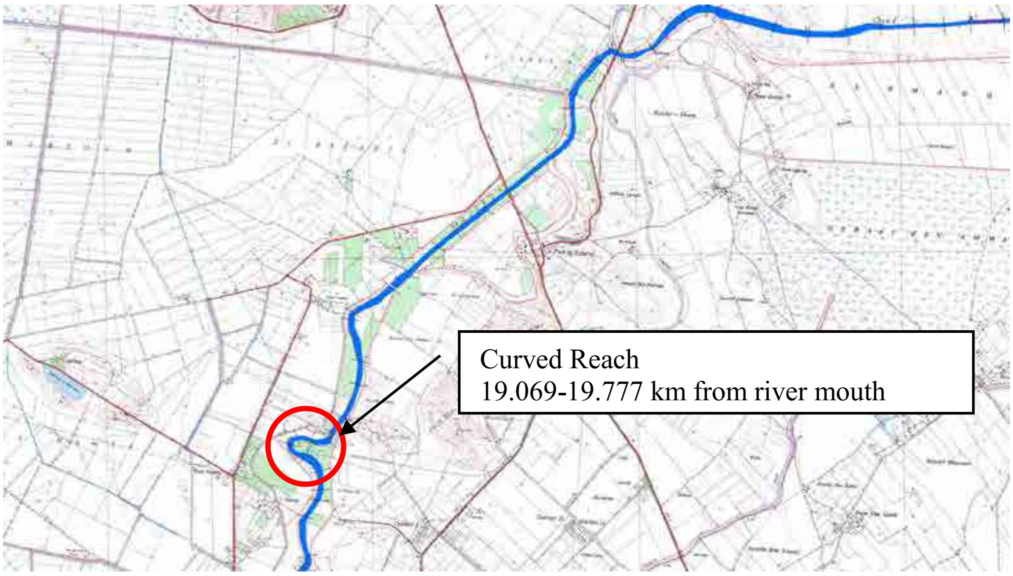
Source: JICA Survey Team

Figure 4-15: Longitudinal Section for Case 3, Excavating and Banking

4.5.2 Cutoff for Curved Reach

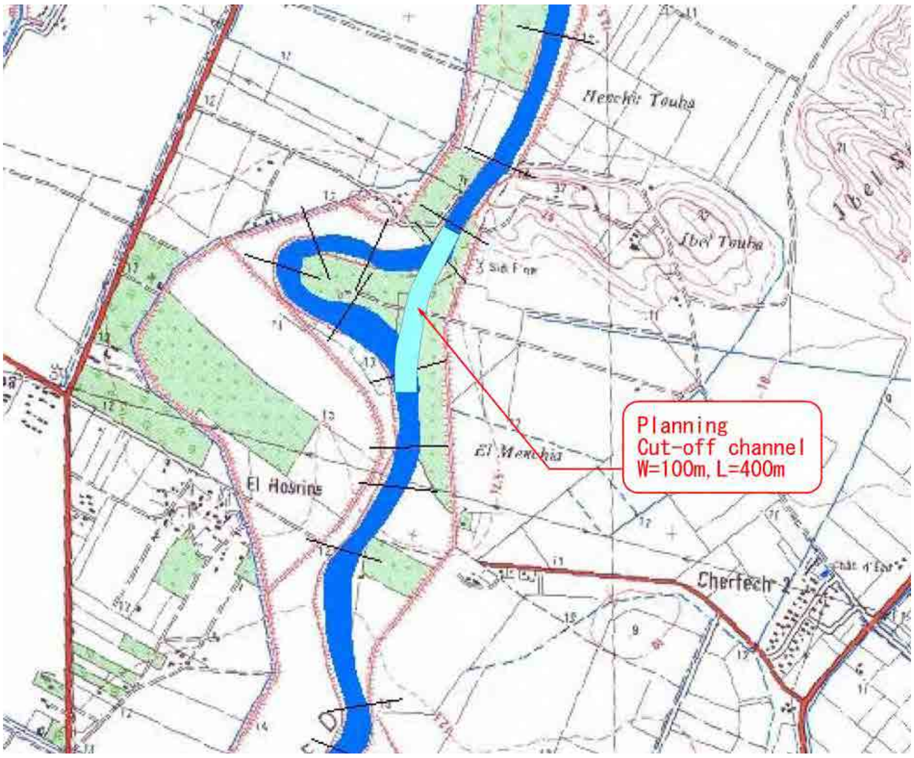
We have proposed a cutoff for the curved reach shown in the figure below using general improvement methods. This cutoff is meant to stabilize the channel and reduce upstream channel water levels.

The Tunisia side wanted to improve the river without making a cutoff, voicing concerns that it would increase land acquisition costs, cause unexpected bank erosion and other unwanted environmental impacts. Thus, this study will not make a cutoff at the curved reach.



Source: JICA Survey Team

Figure 4-16: Location of Curved Reach



Source: JICA Survey Team

Figure 4-17: Proposed cutoff channel

4.5.3 Chafrou River

Tributaries will be used as backwater dikes based on the Master Plan.

As the runoff analysis methods are the same for the main river and tributaries in this study, we will perform the hydrological calculations with the following two boundary conditions, setting both water levels as the comprehensive high water levels.

・Boundary condition 1

Tributary flow: design flood discharge of 50 m^3 per second

Main river water level: 16.9 meters during tributary flood discharge

・Boundary condition 2

Tributary flow: 1 m^3 per second flow during main river design flood discharge

Main river water level: Main River design high water level: 19.8 meters

Conditions for hydrological calculations are given in the table below:

Table 4-4: Conditions for Hydrological Calculations

No	Item	Condition
1	Calculation Method	Non-uniform flow
2	Section	Chafrou River (from confluence with Mejerda River to 4.944 km)
3	Channel	Channel in current state (as of 2011)
4	Flow	W = 10th-year discharge (50 m^3/sec.) and 1 m^3/sec.
5	Roughness Coefficient	0.04
6	Starting Water Level	Condition 2: Mejerda River high water level: 19.8 m Condition 1: Mejerda River water level with Chafrou River at peak: 16.9 m

(1) Study Section

The section for the runoff analysis will be from confluence with the Mejerda River to the 4.944-kilometer point.

(2) Channel

Targeting the channel in its current state, we will use the channel cross sections from 2011.

(3) Flow

We used the design scale of a 10th-year discharge (50 m^3 per second) and the main river discharge during design discharge (one m^3 per second).

(4) Roughness Coefficient

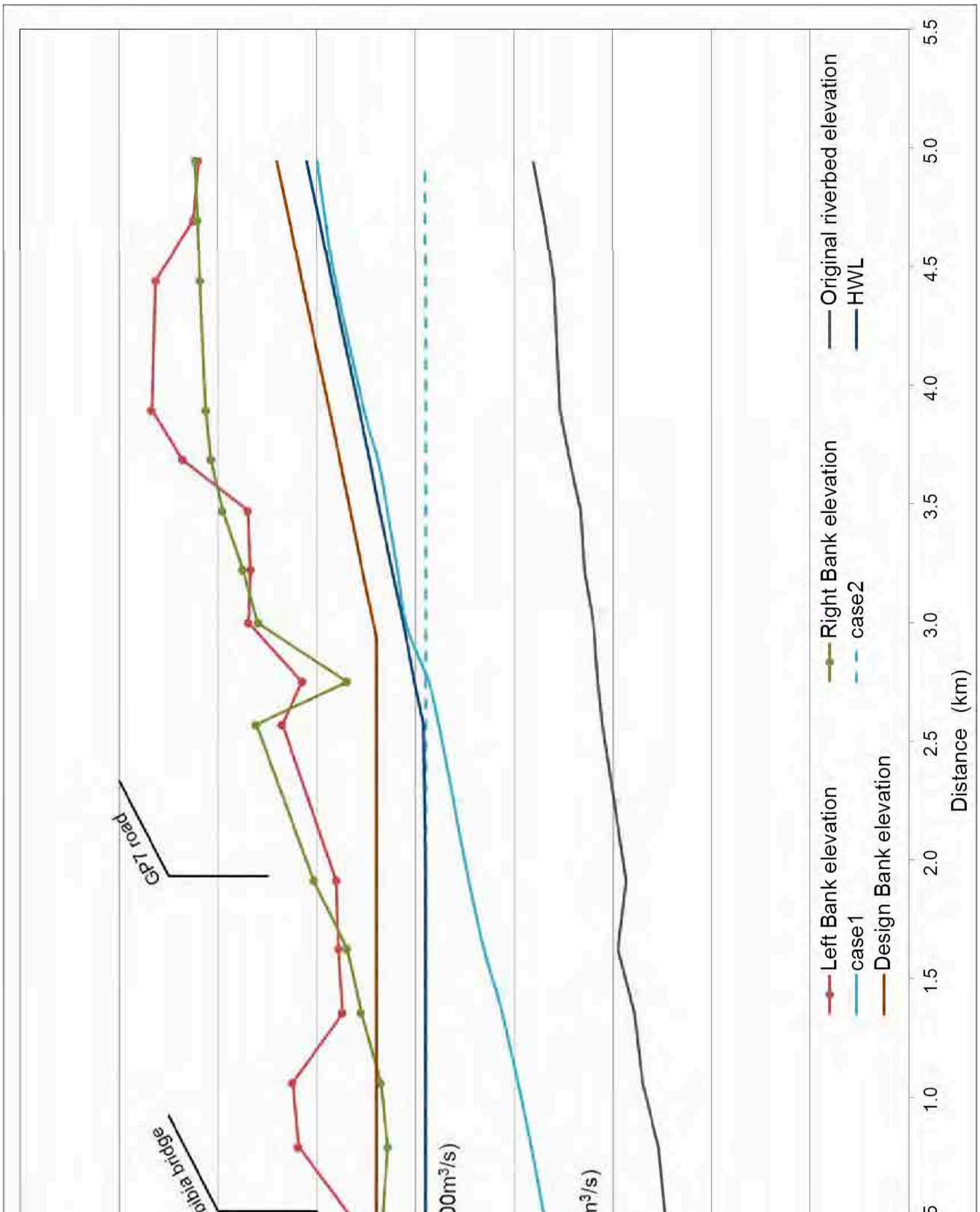
The coefficient was made as the same value of that of main Mejerda River.

(5) Starting Water Level

We used the main river water level during tributary flood discharge (16.6 meters) and the main river design high water level (19.8 meters).

The non-uniform flow calculations and set designs for the back dike are given on the following page. The right bank of the Chafrou River must be raised slightly.

The Chafrou River is the only major tributary in Section D2, but it contains sluice gates and/or sluiceways in nine places. These sluice gates and sluiceways will be improved.



Source: JICA Survey Team

Figure 4-18: Non-uniform flow calculations for Chafrou River and back dike settings

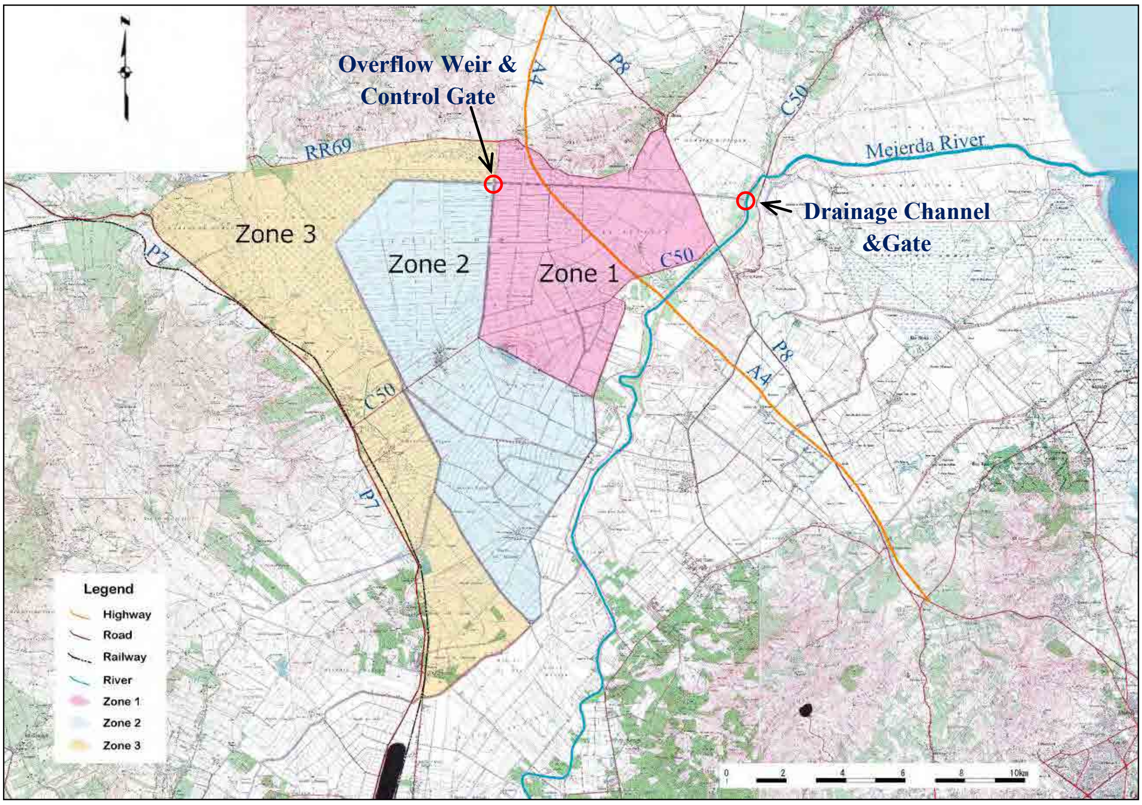
4.6 El Mabtouh Retarding Basin Plan

The El Mabtouh wetlands are the proposed site for a retarding basin in the Master Plan. This area offers topographic advantages for a retarding basin: it is lower than the surrounding area, with hills stretching from the north to northwest.

Part of the El Mabtouh wetlands has been used as a retarding basin for natural flooding from the Mejerda River, with several hydraulic control structures in place. However, the structures are damaged, and some are completely abandoned.

In terms of its function as a retarding basin, the existing El Mabtouh wetlands are divided into three zones as given below. The usage rules for each zone are given below.

・Flooding order: Zone 3 → Zone 2 → Zone 1
・Drainage order: Zone 1 → Zone 2 → Zone 3



Source: JICA Survey Team

Figure 4-19: Existing zones in El Mabtouh plains

As Tunisia is using long-term management for the zone divisions and operational rules for the El Mabtouh wetlands retarding basin, they have requested that these not be changed. They have also indicated that they will not recognize embankments which divide the current zones.

In planning for the El Mabtouh retarding basin, we kept with the current zone divisions and operational rules in accordance with Tunisia side requests.

We plan to make effective use of the current channel route to have water branch out from the Mejerda River at the 32.35-kilometer point and discharge into the Mejerda River at the 11.81-kilometer point.

Following the Master Plan, water will discharge into the retarding basin at 200 m^3 per second. Water at that point in the Mejerda River will be slowed from its rate of 800 m^3 per second down to 600 using a side weir for the diversion facilities.

We will repair the existing channel to the retarding basin after diversion, but plan to reconstruct a new inflow channel from the diversion point to the same existing channel.

Considering the ground elevation, riverbed height of the existing channel and design high water level, we took the overflow depth at design flow of the fixed inlet overflow weir to be 1.0 meter.

The equation below gives more than 150 meters as the required width for overflow depth of 1.0 meter.

$$Q/Q_0 = \cos\left(155 - 38 \times \log_{10}(1/I)\right)$$

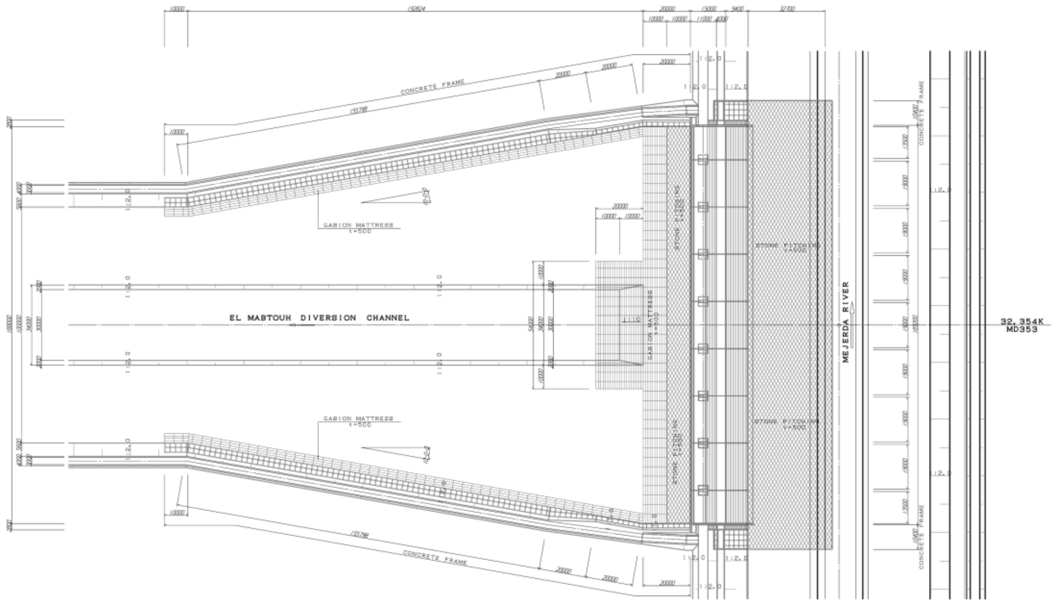
Where Q0 = main flood flow (m^3/sec.)

$$Q_0 = 0.35 \times h_1\sqrt{2gh_1} \times B$$

h1 = flood depth (m), B = flood width

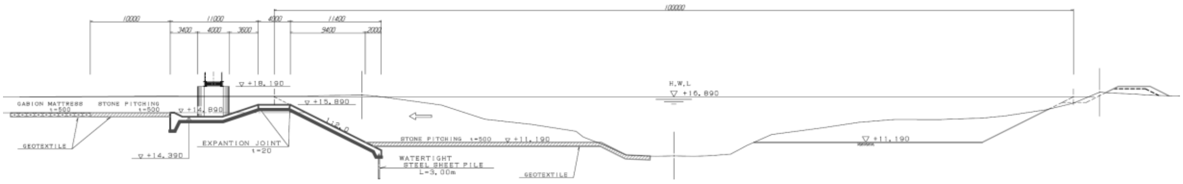
Q = side flood flow (m^3/sec.)

I = Riverbed grade



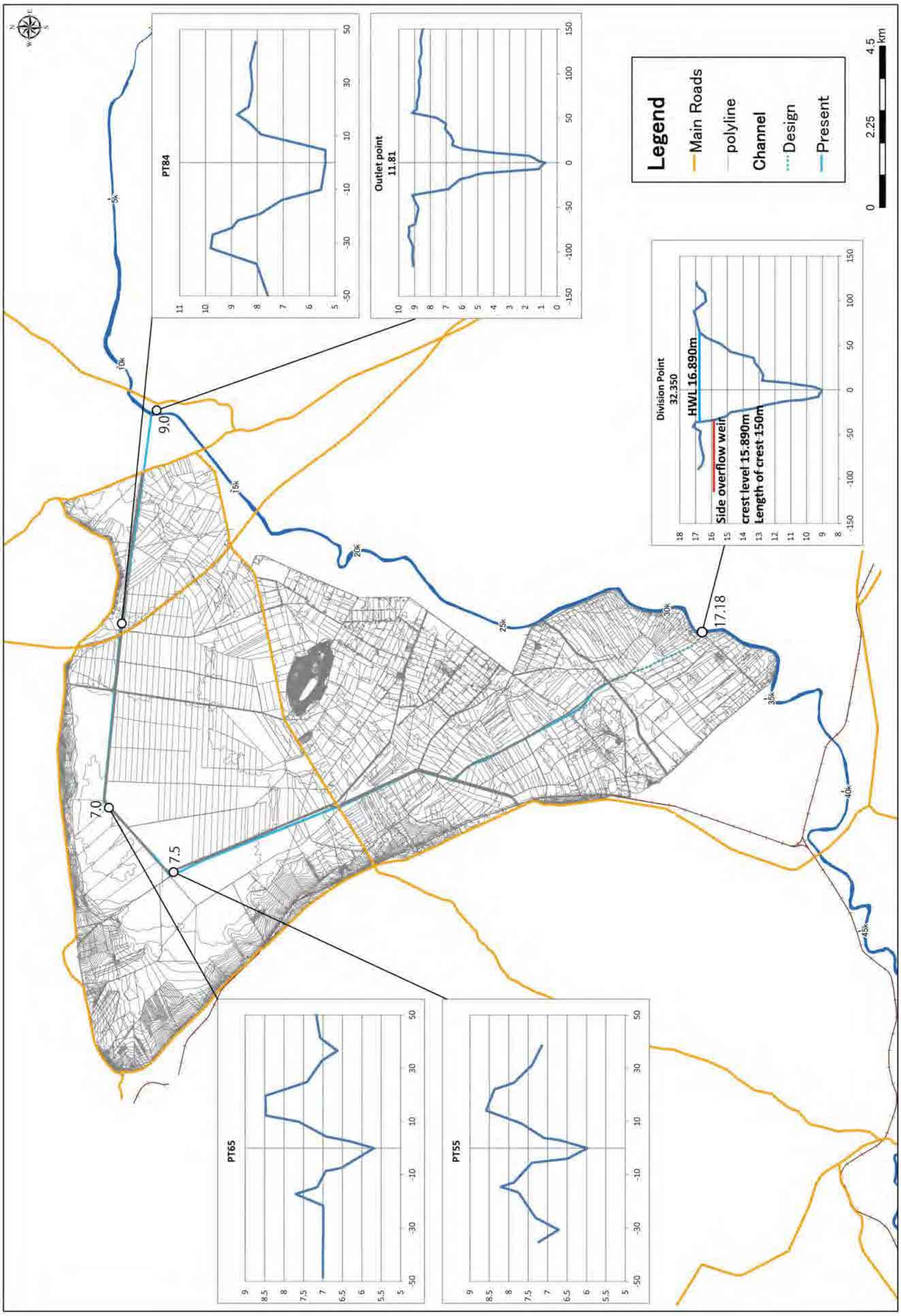
Source: JICA Survey Team

Figure 4-20: Plane figure of overflow weir



Source: JICA Survey Team

Figure 4-21: Cross section of overflow point



Source: JICA Survey Team

Figure 4-22: Whole view of El Mabtouh retarding basin

4.7 Inundation Analysis

4.7.1 Inundation Model

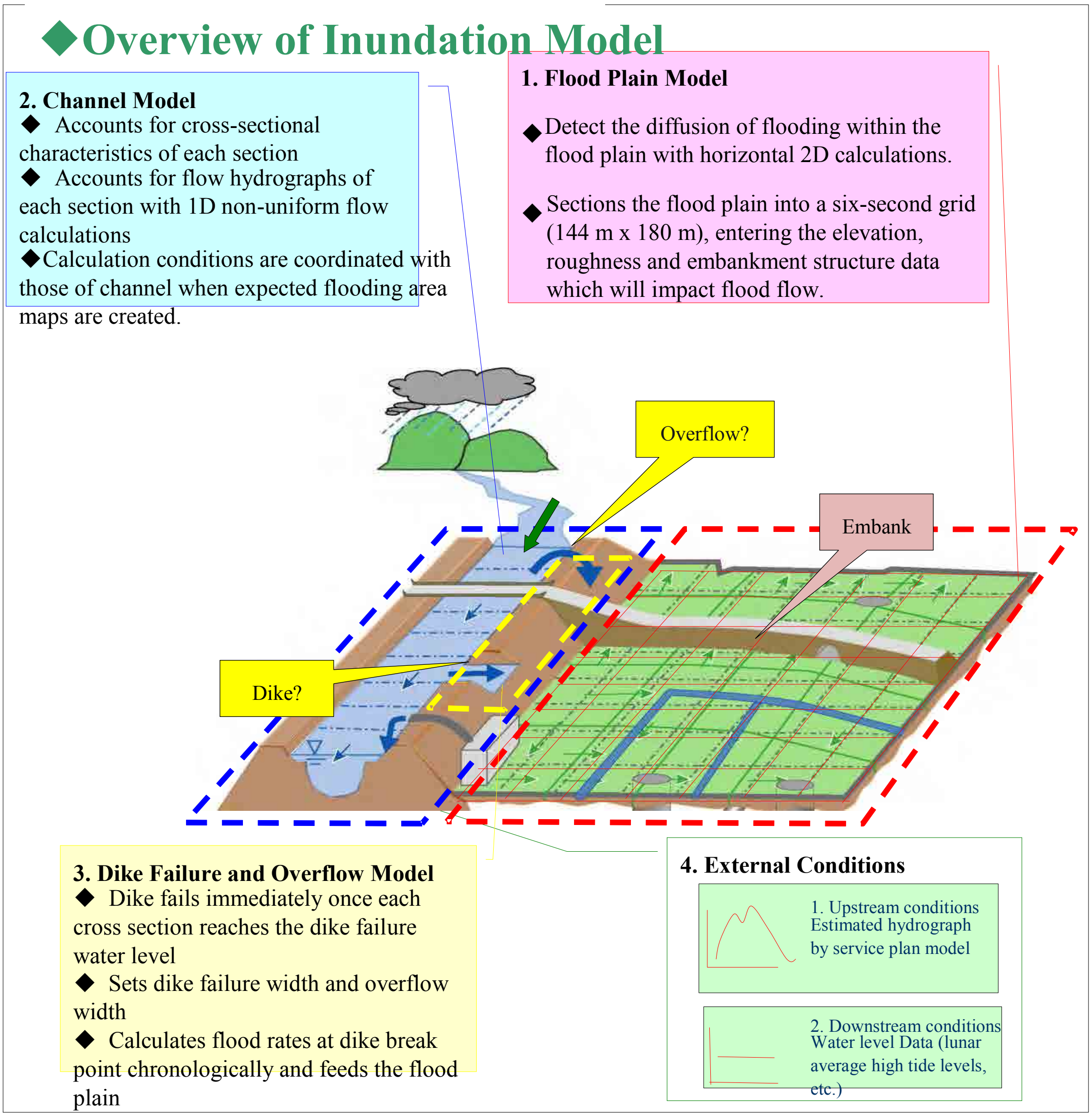
Generally, one of the following three models is used for inundation analysis.

Given the gentle gradient of the flood plain and need to account for internal waters, we will use a horizontal two-dimensional unsteady flow model in this study.

Table 4-5: Inundation Models

Model Name	1D Unsteady Flow Model	Pond Model	Horizontal 2D Unsteady Flow Model
Concept for setting flood boundaries	Flood boundaries set by utilizing flood plain as part of the channel and calculating channel internal water level at peak flow for flooding.	The flood plain and channel are separated, treating the flood plain as a closed uniform area, referred to as a "pond." Flood levels in the pond are all uniform. Flood boundaries are set based on the relation between the inflow rate of inundation from channel to flood plain and the topographic characteristics of the flood plain (water level, capacity and area).	Flood boundaries are set by treating the flood plain and channel as separate and analyzing the behavior of the water flooding into the flood plain from the channel with a two-dimensional fluid motion.
Image			
Model Characteristics	Can be applied to discharged inundation, in which flood waters discharge from the channel into the flood plain. However, with the characteristics of this model, the inundation analysis area is treated as not diked.	Can be applied to non-spreading inundation, in which flooding can be prevented from spreading due to blockage from mountains, plateaus, embankments or other areas of higher elevation. Flood waters within the closed area have a uniform water level with no surface grade or flow rate. A series of banks in the flood plain, however, may require a model with multiple ponds, using the banks to divide the back pond areas.	Can basically be applied to any form of inundation. In addition to maximum flood area and flood depth, this model can also reproduce inundation rates and time changes. As this model generally gives more exact calculations, it is also frequently used for creating maps of expected flood areas. Given the model characteristics, however, precision of the inundation analysis is limited by the model grid size.

An overview of the horizontal two-dimensional unsteady flow model is given on the following page.



Source: JICA Survey Team

Figure 4-23: Overview of Horizontal Two-Dimensional Unsteady Flow Model

4.7.2 Creating the Inundation Model

(1) Creating Topographic Data

1) Revising topographic data

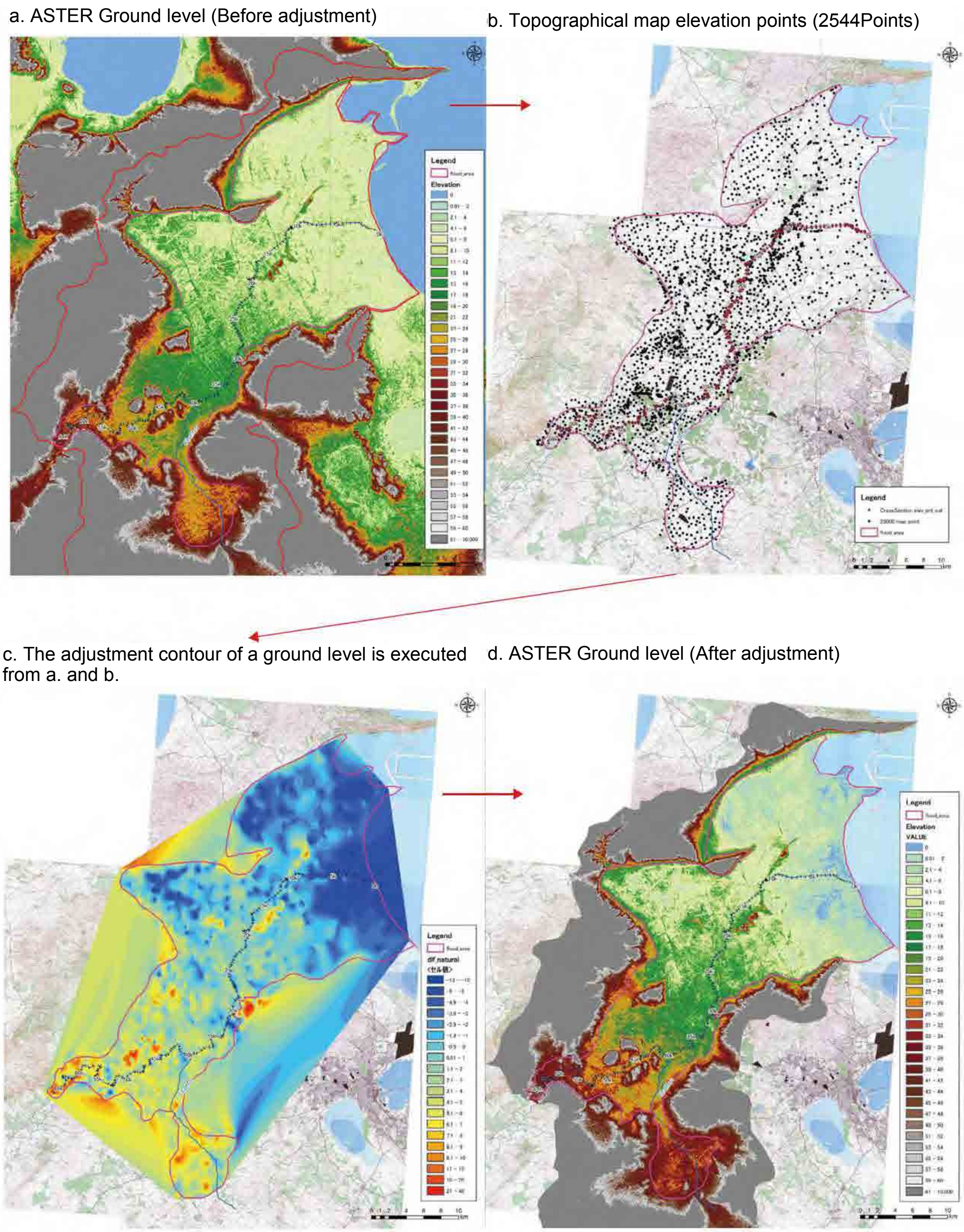
We modeled topographic data for the flood plain using a two-dimensional model. The topographic data used to create the flood plain model is given in the table below.

We revised topographic data based off three-dimensional full global data (Aster Gdem with 30-meter mesh). We calculated ground height differentials using endpoint elevations extracted from a 1:25,000 scale topographic map and riverbank endpoints extracted from cross sections of the Mejerda River.

An image of the revised topographic data follows below.

Table 4-6: Topographic Data

	Data Type	Data	Pixel Interval	Creating Agency	Use
1	Full 3D global data (Aster Gdem)	Mesh	1 second (approx. 30 m)	METI/NASA	Terrain model creation
2	1 topographic map, 1:25,000 scale	2,544 endpoints	See figure	MARHP (Ministry of Agriculture, Water Resources and Fisheries), 2007	Terrain model revision
3	400-meter sections of Mejerda River from Laroussia Dam to lower Mejerda River	345 endpoints	See figure	M/P	Terrain model revision

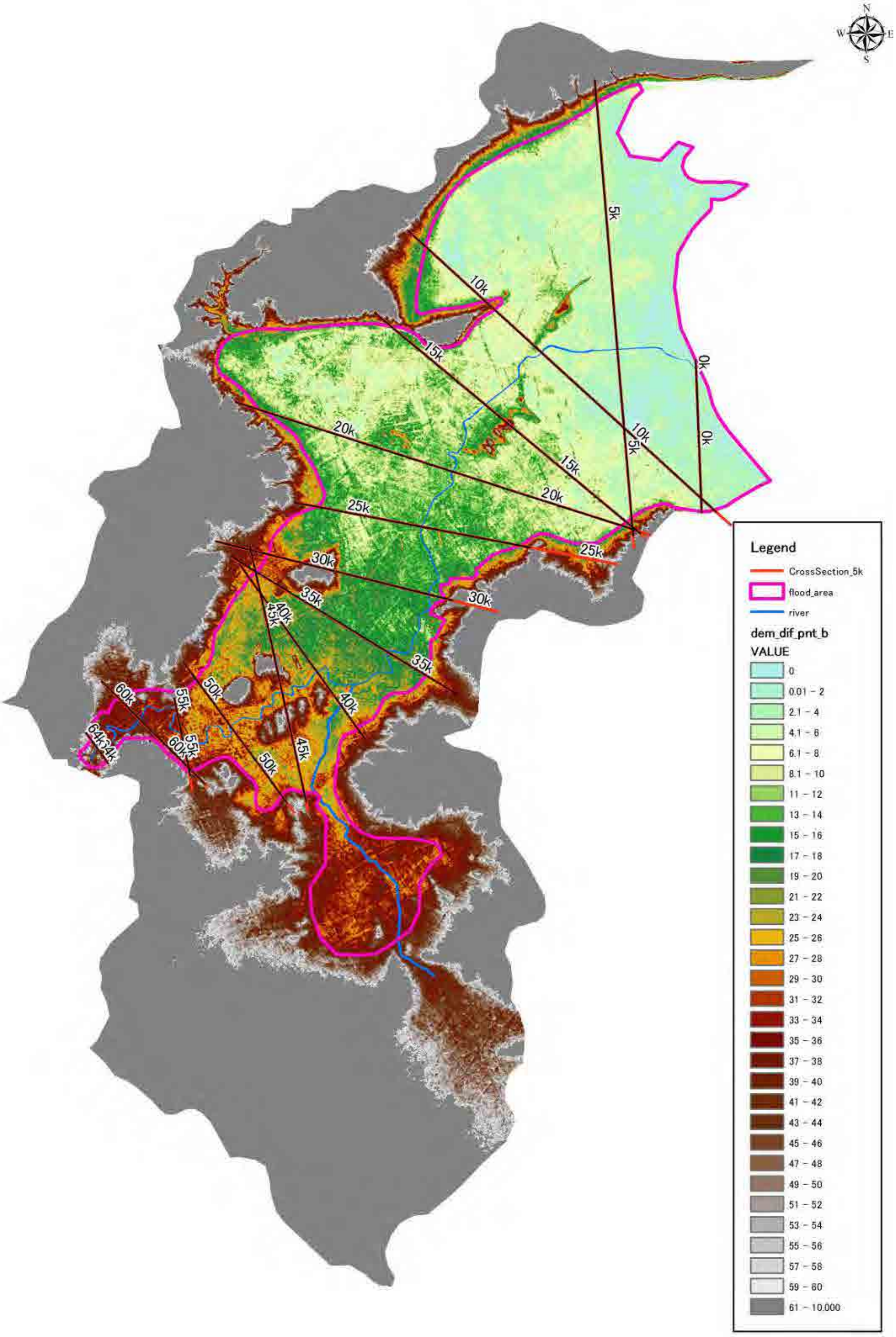


Source: JICA Survey Team

Figure 4-24: Image of topographic data revisions

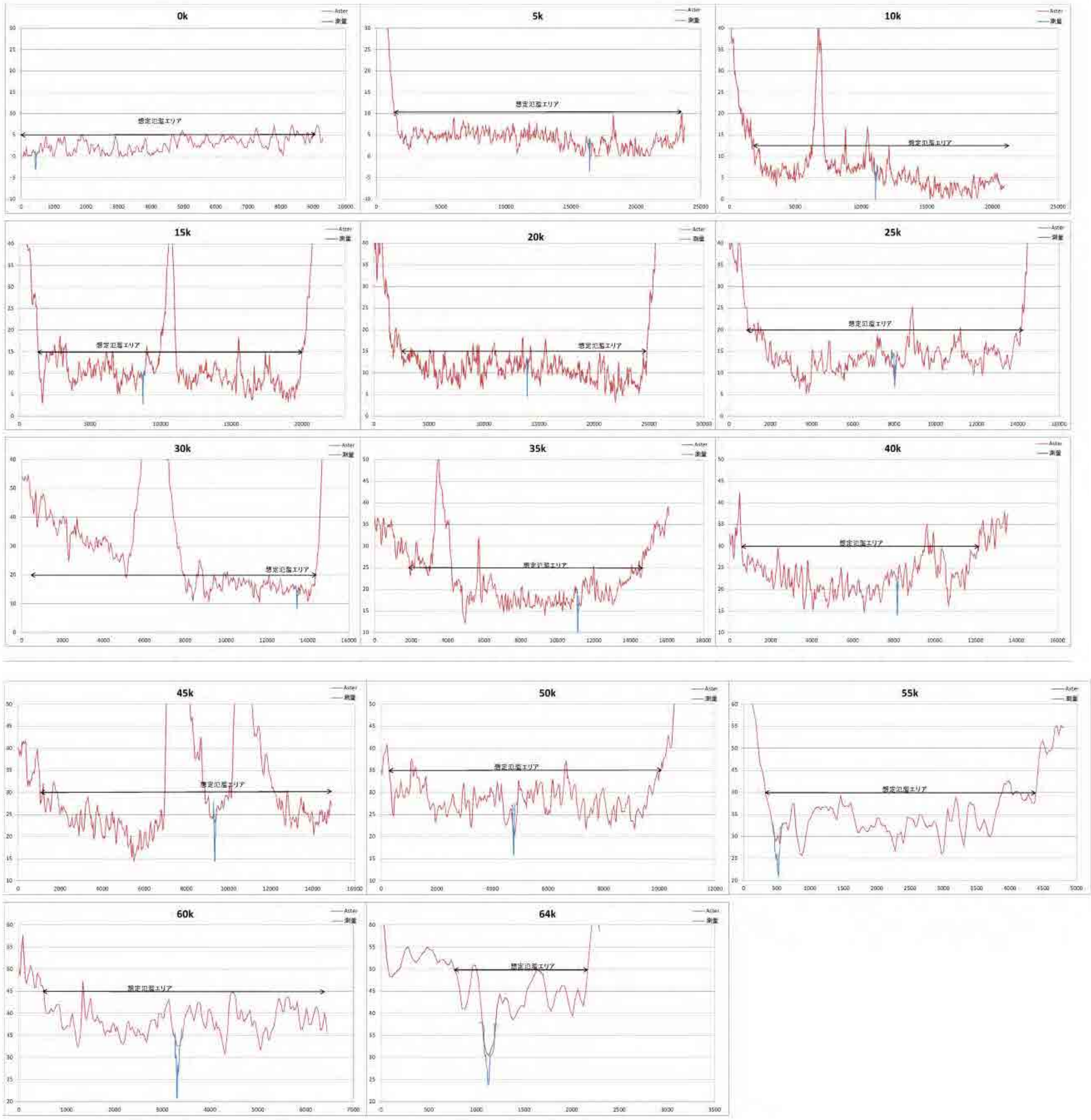
2) Setting the Expected Inundation Area

The expected inundation area will be set based on the topographic data created. As shown in the figure below, we have created a cross section of the flood plain and set an expected inundation area based on the current dike height.



Source: JICA Survey Team

Figure 4-25: Flood plain cross section creation points



Source: JICA Survey Team

Figure 4-26: Flood plain cross sections

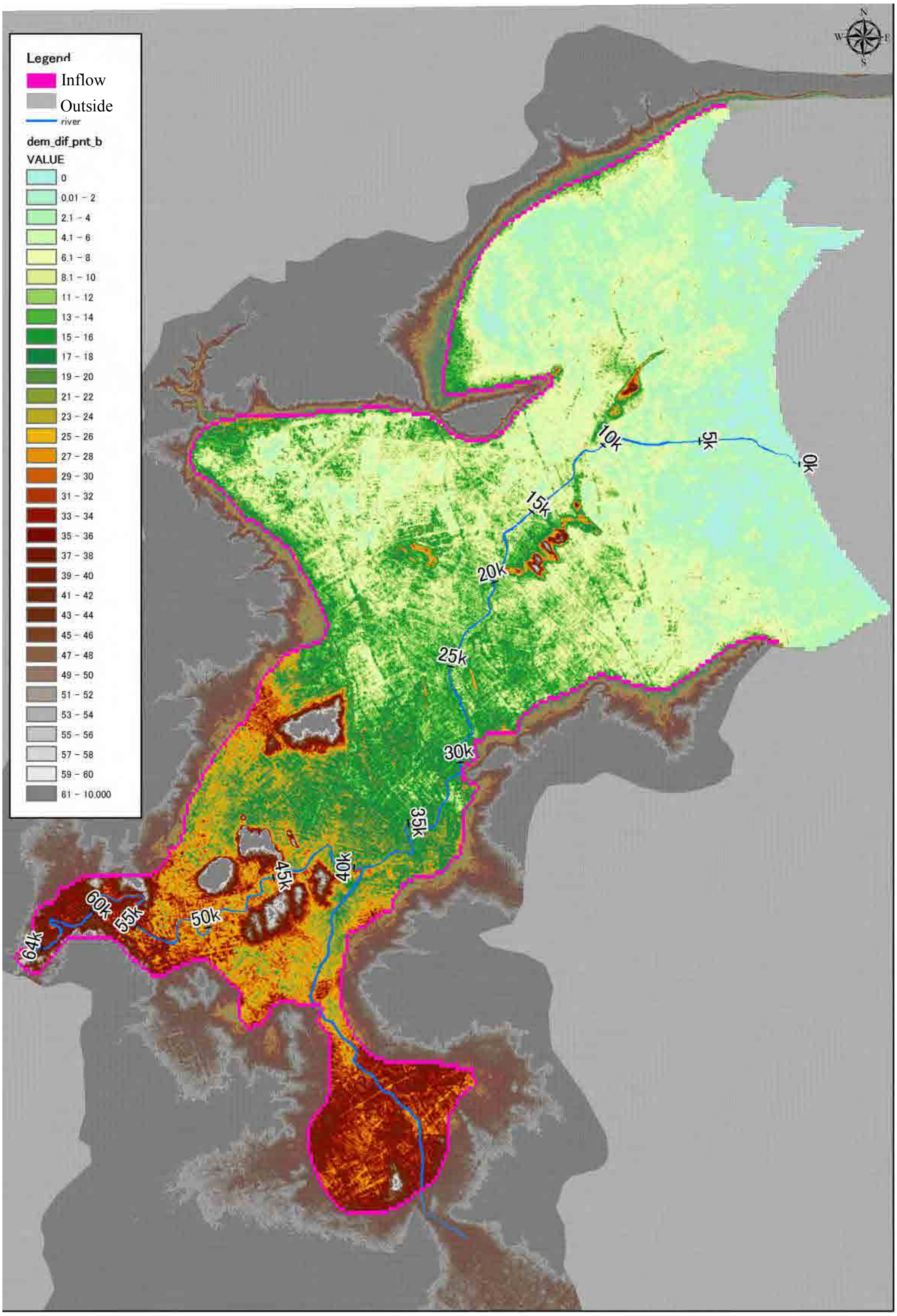
3) Creating grid ground height

As the Aster Gdem ground height data to be used is made on a one-second grid (24- by 30-meter), we went with a six-second (144- by 180-meter) configuration for the modeling grid.

Below is a ground height mesh grid which averages revised full three-dimensional global data (Aster Gdem, 30-meter mesh) into a 150-meter mesh.

Table 4-7 Mesh grid creation specifications

	Item	Description	
1	Original topographic data	Full 3D global data (Aster Gdem)	Size: 1 second (24 x 30 m)
2	Calculation grid	150 m mesh	Size: 6 seconds (144 x 80 m)
3	Grid squares	Total: 325 x 425 = 138,125 Flood plain: 27,858	
4	Coordinate system	Geodetic survey system: French Clarke 1880 (ClarkelGN) Projection: UTM Zone 32	



Source: JICA Survey Team

Figure 4-27: Average grid ground height

(2) Flood plain roughness

We solved for the roughness coefficient for the flood plain by taking the weighted average of area by land usage for the base roughness coefficient of non-buildings. We will also use the composite equivalence roughness coefficient given below, derived from a building density based on building occupancy rates.

Base roughness coefficient:

$$n_0{}^2 = \frac{n_1{}^2 \cdot A_1 + n_2{}^2 \cdot A_2 + n_3{}^2 \cdot A_3}{A_1 + A_2 + A_3}$$

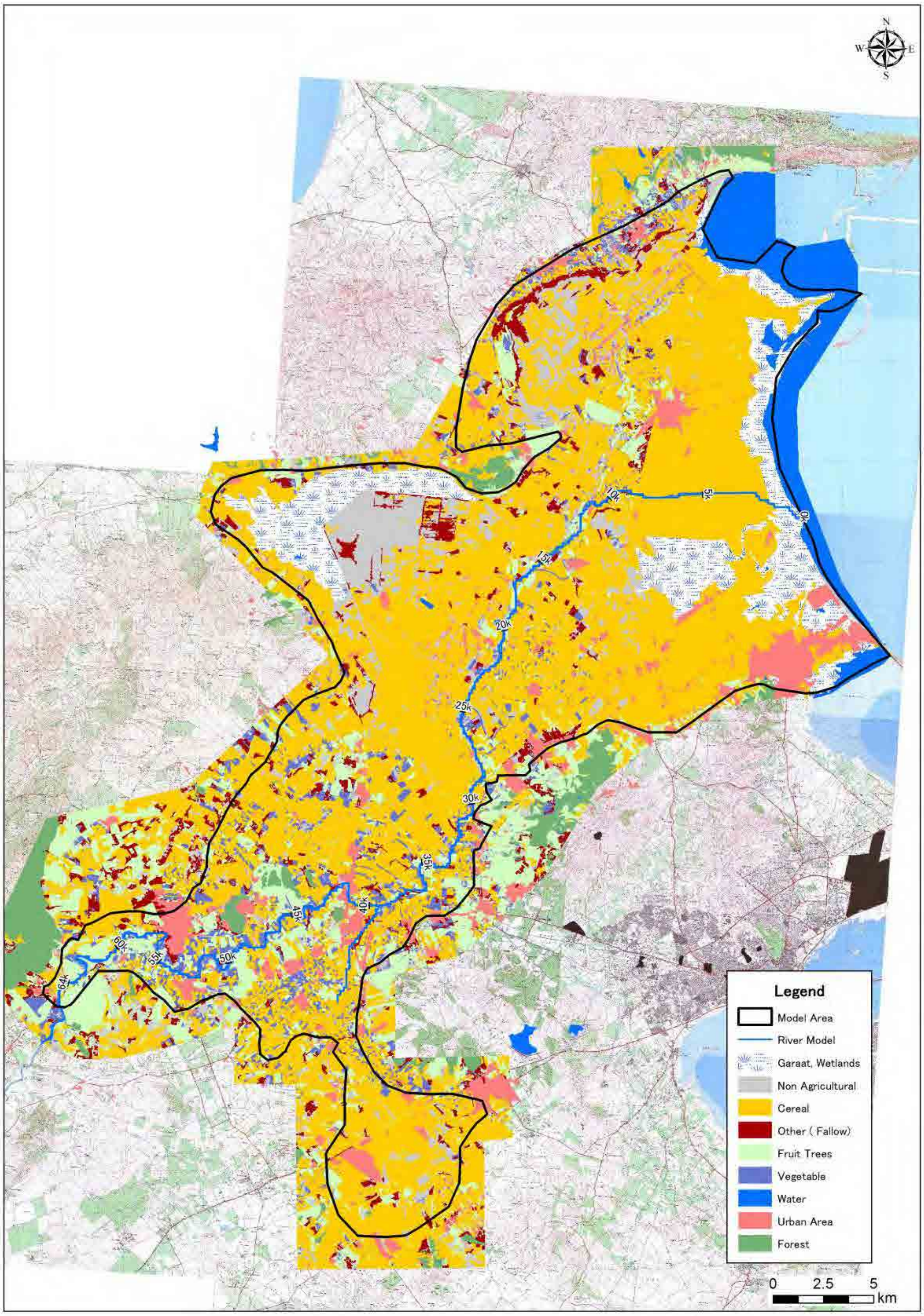
Where A1 = farmland area (rice and crop fields), n1 = 0.060; A2 = road surface area, n2 = 0.047, A3 = other area, n3 = 0.050

Roughness coefficient, accounting for building density:

$$n^2 = n_0{}^2 + 0.020 \times \frac{\theta}{100 - \theta} \times h^{4/3}$$

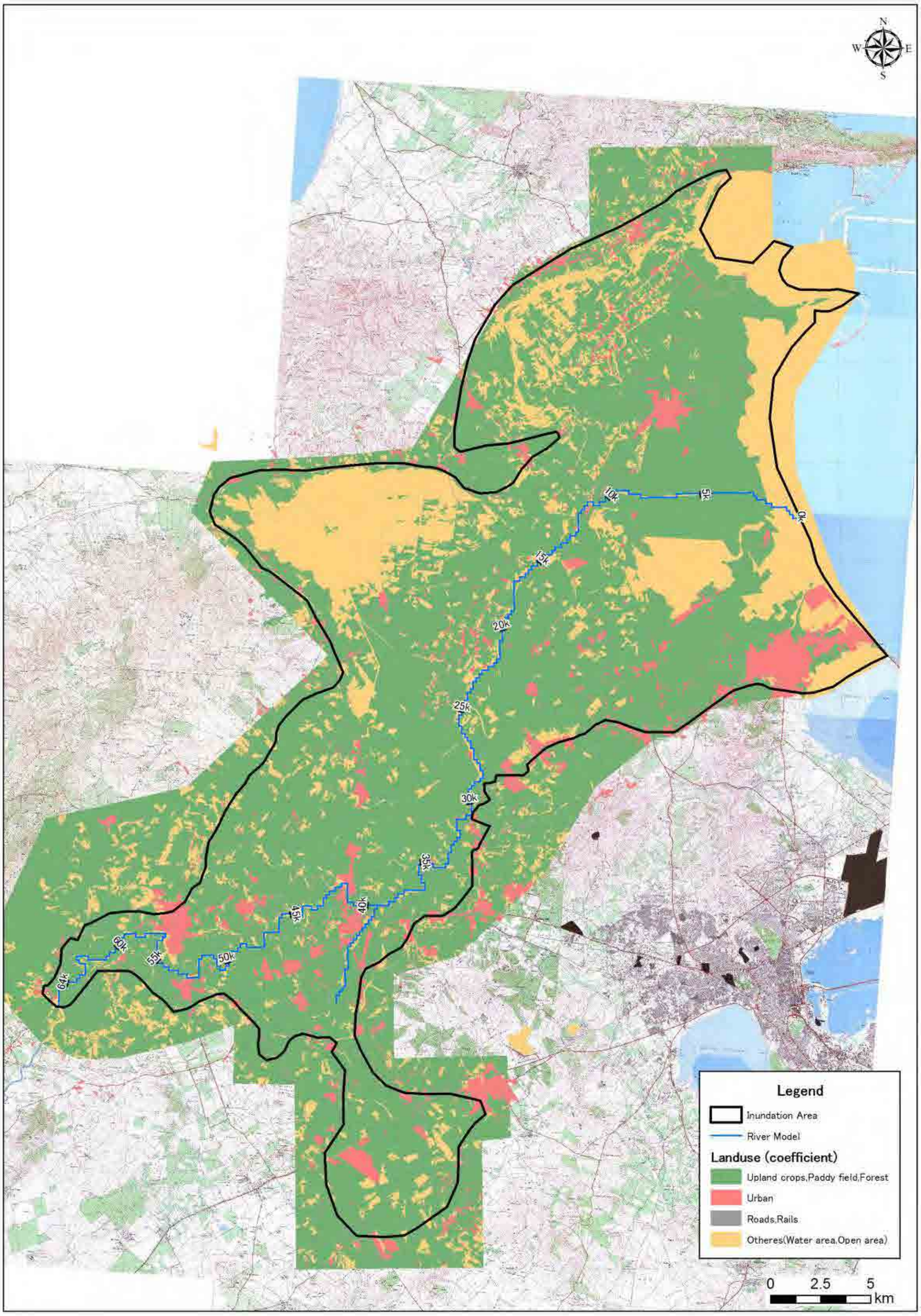
Where θ = building occupancy rates and h = grid water depth

In setting the roughness coefficient, we reclassified the land use map shown below into four classes. For building occupancy rates, we set the grid share by eye based on satellite imagery.



Source: JICA Survey Team

Figure 4-28: Land use map



Source: JICA Survey Team

Figure 4-29: Land use partition map (roughness coefficient settings)

Table 4-8: Legend for setting building occupancy rates

10%			60%		
20%			70%		
30%			80%		
40%			90%		
50%					

Source: JICA Survey Team

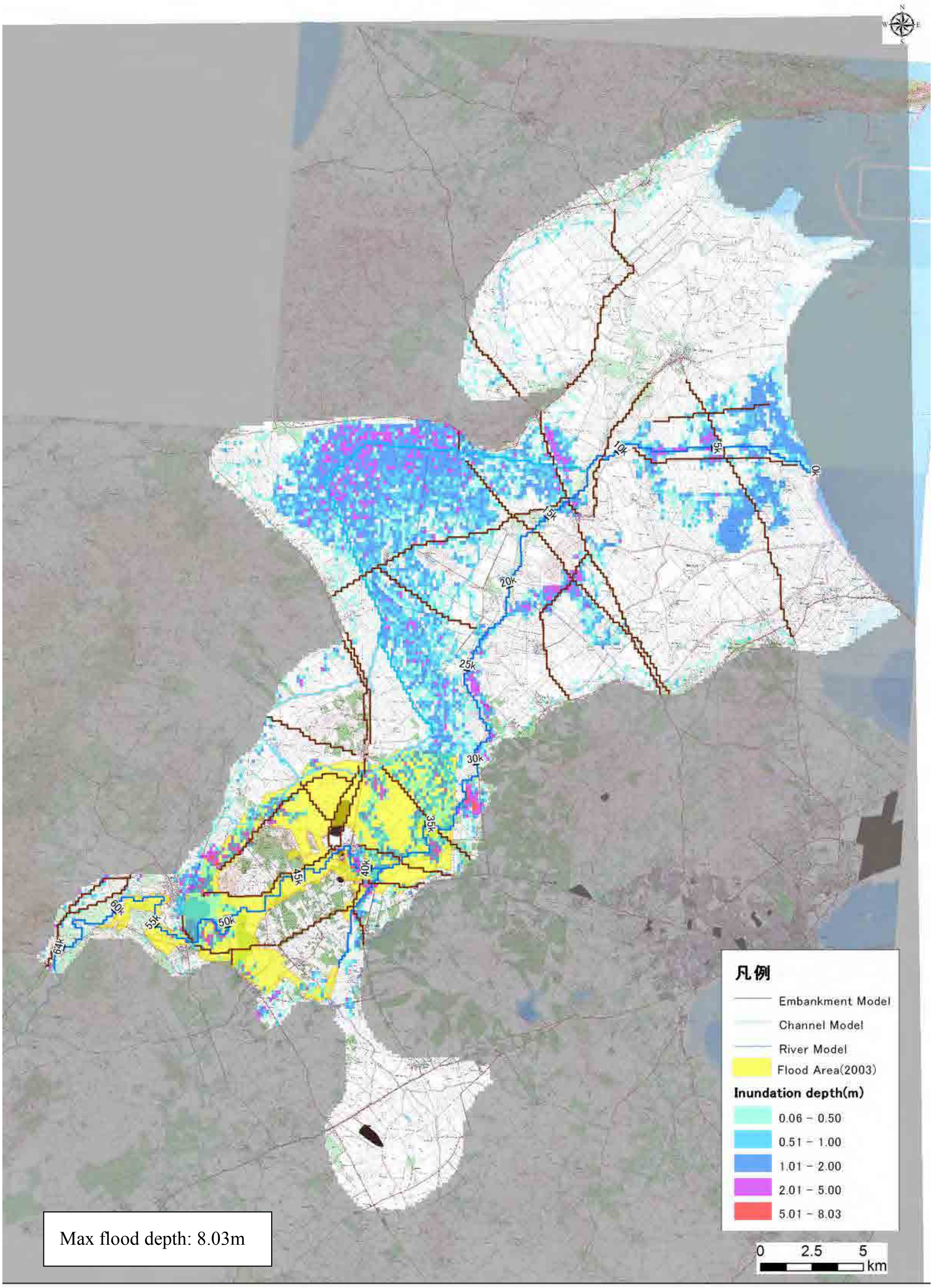
4.7.3 Reproducing flooding from 2003

Using the created inundation model, we made calculations to reproduce flooding from 2003, the largest flooding year in recent years.

A map overlaying actual flooding and inundation analysis results is given on the next page. Only results from around El Bataan to around Jedeida have been sorted for actual flooding data. A look at the calculations shows that the flow route of inundation overlaps with actual flooding. We were able to reproduce the current state of the middle course and lower sections not sorted which currently discharge into the El Mabtouh wetlands along the channel and accumulate in the retarding basin. We thus chose to use this model for the inundation model. The conditions for inundation analysis calculations are given in the table below.

Item		Condition	Notes
External Conditions	Design Scale	2003 results	
	Flow Hydrograph	Taken from Slouguia observatory	
	Rainfall Waveform	2003 flood	
	Rainfall	Taken from 3 observatories downstream of Laroussia Dam	
Channel Model	Calculation Method	One-dimensional non-uniform flow	
	Scope	Lower Mejerda River to Larrousia Dam, 64.974 km	
	Calculation Pitch	Roughly 300-500 m	
	Section to be Used	2007 measurement cross section Current channel	
	Downstream Water Level	T.P.0.77m (fixed)	
	Roughness Coefficient	0.040	
Inundation Model	Flooding Format	Diffused	
	Calculation Method	Two-dimensional non-uniform flow	
	Ground Height	Created from full 3D global data	
	Roughness Coefficient	Farmland: 0.060, Roads: 0.047, Other: 0.050	
	Building Occupancy Rate	Created from aerial photography	
	Inundation	Determined with one-dimensional non-uniform	

	Conditions		flow Inundation coefficient: set accounting for side overflow from official sources Inundation height: current dike height or design dike height Inundation sections: all	
	Dike Failure Conditions		None set	
	Effective Rainfall	**f1**	Paddy fields: 0, Mountains: 0.15, Fields: 0.25, Towns: 0.6-0.9	
		Rsa	Paddy fields: 50, Mountains: 300, Fields: 150, Towns: 55	
		fsa	Paddy fields: 1, Mountains: 0.6, Fields: 1, Towns: 1	



Source: JICA Survey Team

Figure 4-30: Calculated reproduction of 2003 flooding

4.7.4 Comparison of Internal Water Inundation of Banking and Excavating Proposal Sections

Due to its insufficient flow capacity, channel excavation, widening, banking or other means are necessary to ensure the needed sectional area for the Mejerda River. As all sections of the Mejerda River are embedded, banking could incite internal water damage.

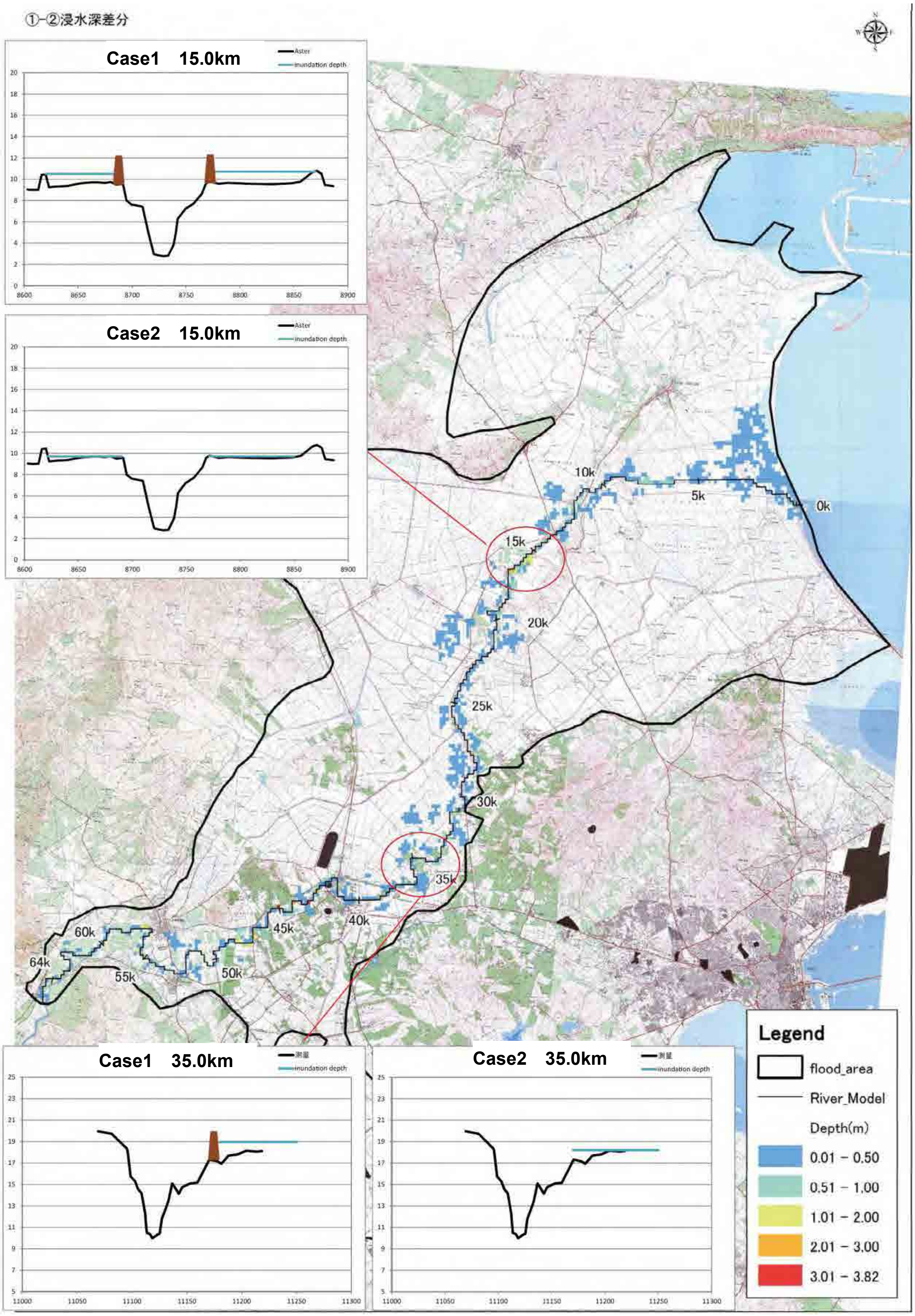
Therefore, we verified validity of the channel plan by comparing flooding conditions of cross sections from the banking proposal (Case 1 above) and embanking proposal (Case 2 above).

Conditions for inundation analysis calculations are given in the table below.

Table 4-9: Calculation Conditions

Item		Condition	Notes
External Conditions	Design Scale	5 times 10th-year discharge	
	Flow Hydrograph	None	
	Rainfall Waveform	Centralized	
	Rainfall	5 times 10th-year discharge: 526.1 mm/48hrs.	W=1/10 105.2 mm/48hrs.
Channel Conditions	Scope	Lower Mejerda River to Larrousia Dam, 64.974 km	
	Calculation Pitch	Roughly 300-500 m	
	Section to be Used	2007 measurement cross section Case 1: Banking proposal section, Case 2: Excavating proposal section	
	Downstream Water Level	T.P.0.77m (fixed)	
	Roughness Coefficient	0.040	
Flood Plain Conditions	Flooding Format	Diffused	
	Calculation Method	Two-dimensional non-uniform flow	
	Flood Plain Model	1. Ground height: Avg. ground height from aforementioned 150 m grid 2. Roughness Coefficient: Crop fields and wastelands – uniformly 0.06 3. Building occupancy rate: 40-80%, cities only	
	Channels	Not considered	
	Inundation Conditions	Considered return from flood plains for embedded channels, ignoring inundation from channel	
	Effective Rainfall	f1: Crop fields, 0.15 Rsa: 0	Flood plain assumed to be damp

Comparisons results are given on the next page. The colored portions in the comparison results are the range in which banking would incite internal water damage. Water depth is given by color. The results verify that installing a two-meter bank with the banking proposal would incite internal water damage. Therefore, it has once again become clear that the expense to account for internal water would be greater with the banking proposal than it would be with the excavation proposal.



Source: JICA Survey Team

Figure 4-31: Comparison of internal water inundation

4.7.5 Inundation Analysis Results by Probability Scale

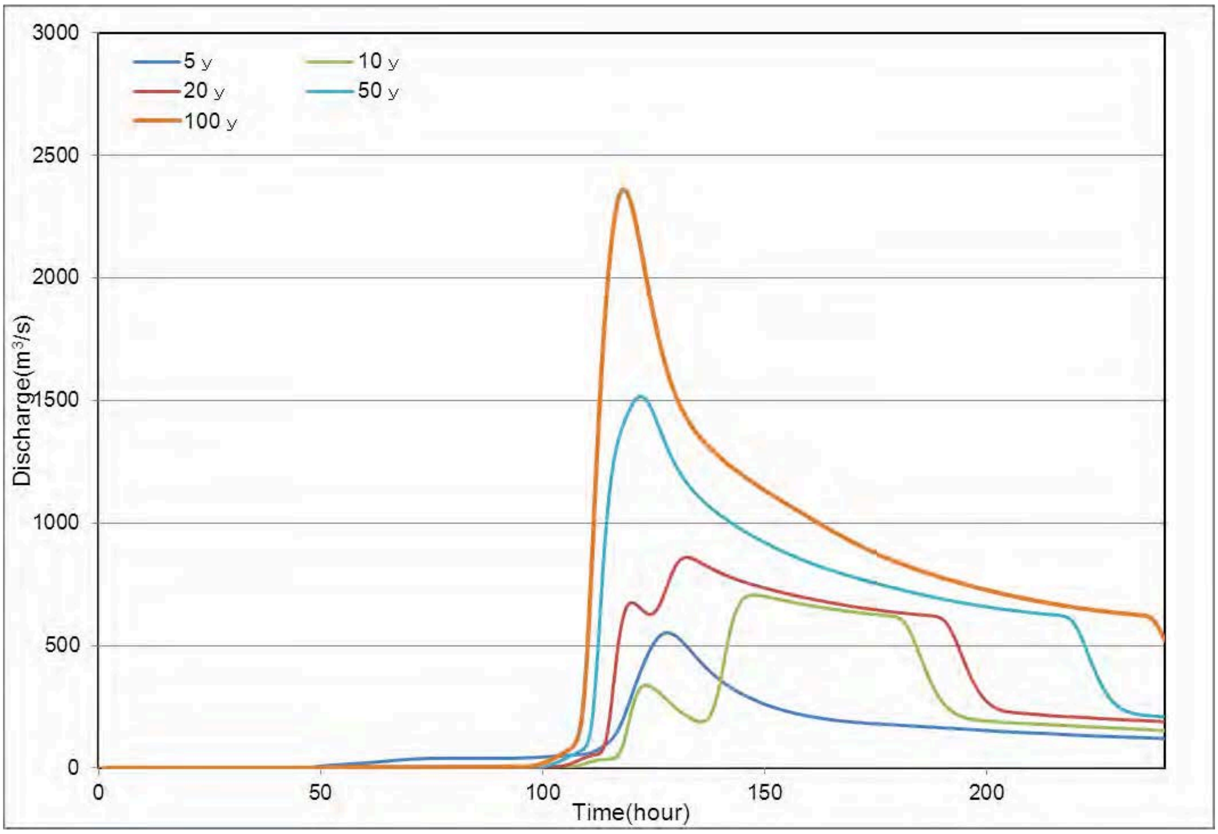
We ran inundation analyses by rainfall probability for both the current channel and design channel. The conditions for inundation analysis calculations are as given below.

Table 4-10: Calculation Conditions

Item		Condition	Notes
External Conditions	Design Scale	Current channel: 1/5 1/10 1/20 1/50 1/100 Design channel: 1/10 1/20 1/50 1/100	
	Flow Hydrograph	Flow by probability scale at Laroussia Dam	
	Rainfall Waveform	Centralized	
	Rainfall	From 3 observatories downstream of Laroussia Dam, by probability scale	
Channel Model	Calculation Method	One-dimensional non-uniform flow	
	Scope	Lower Mejerda River to Larrousia Dam, 64.974 km	
	Calculation Pitch	Roughly 300-500 m	
	Section to be Used	2007 measurement cross section Current channel and design channel	
	Downstream Water Level	T.P.0.77m (fixed)	
	Roughness Coefficient	0.040	
Inundation Model	Flooding Format	Diffused	
	Calculation Method	Two-dimensional non-uniform flow	
	Ground Height	Created from 360˚ 3D global data	
	Roughness Coefficient	Farmland: 0.060, Roads: 0.047, Other: 0.050	
	Building Occupancy Rate	Created from aerial photography	
	Inundation Conditions	Determined with one-dimensional non-uniform flow Inundation coefficient: set accounting for side overflow from official sources Inundation height: current dike height and design dike height Inundation sections: all	

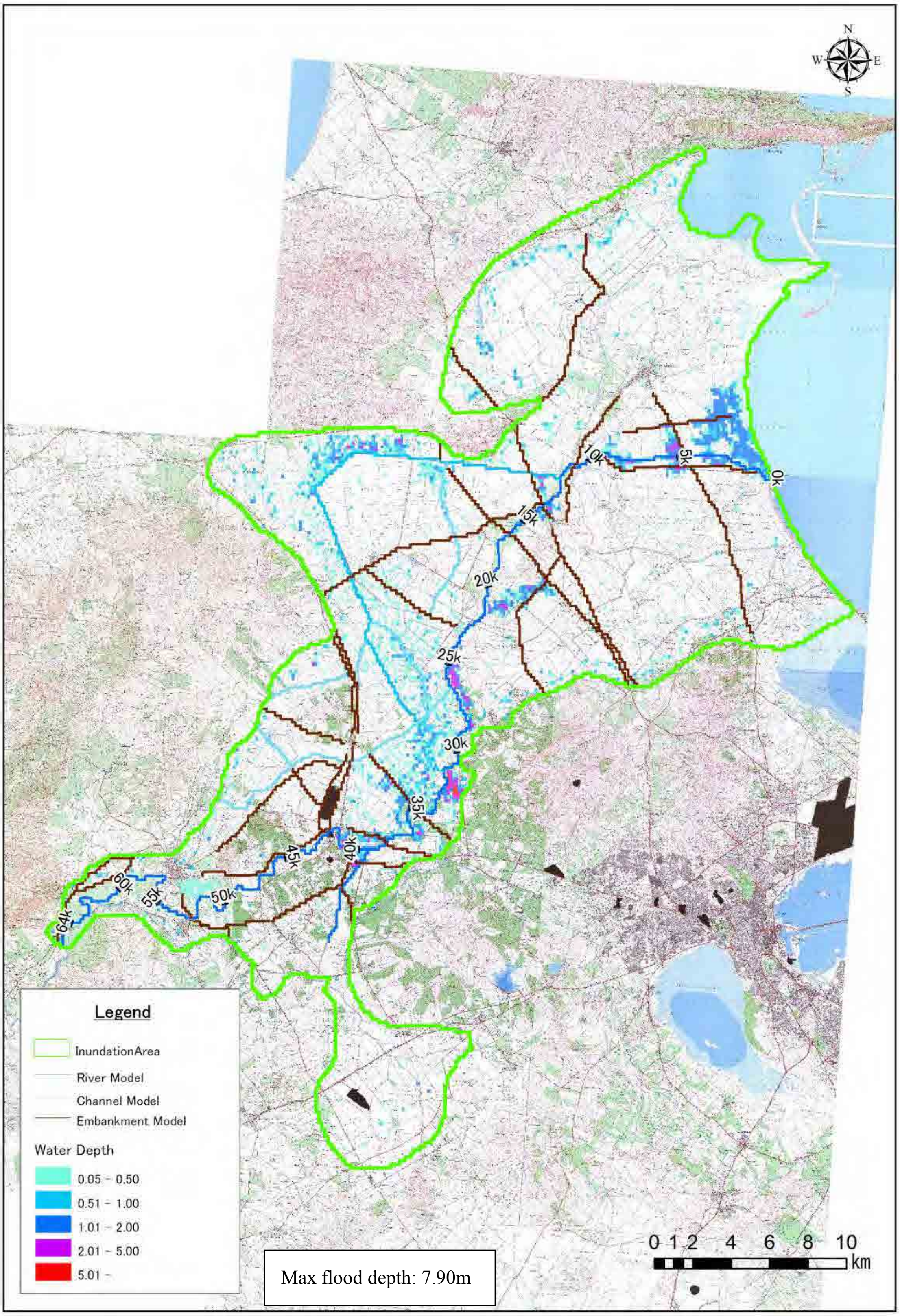
	Dike Failure Conditions		None set	
	Effective Rainfall	**f1**	Paddy fields: 0, Mountains: 0.15, Fields: 0.25, Towns: 0.6-0.9	
		Rsa	Paddy fields: 50, Mountains: 300, Fields: 150, Towns: 55	
		fsa	Paddy fields: 1, Mountains: 0.6, Fields: 1, Towns: 1	

From the next page on are the hydrographs and inundation analysis results by probability. Based on the flood analysis result, it is needless to say that flooding due to external water by 1/10 years which is the design size at design river channel was not occurred and flooding until 1/20 years was not occurred under the assumption of no washout even if the water level is risen up to dike levee crown. Also, flooding area is limited by diversion to retarding basin at 1/50 and 1/100 years. Meantime, immersion depth is increased at unimproved section in downstream but flooding area remained virtually unchanged.



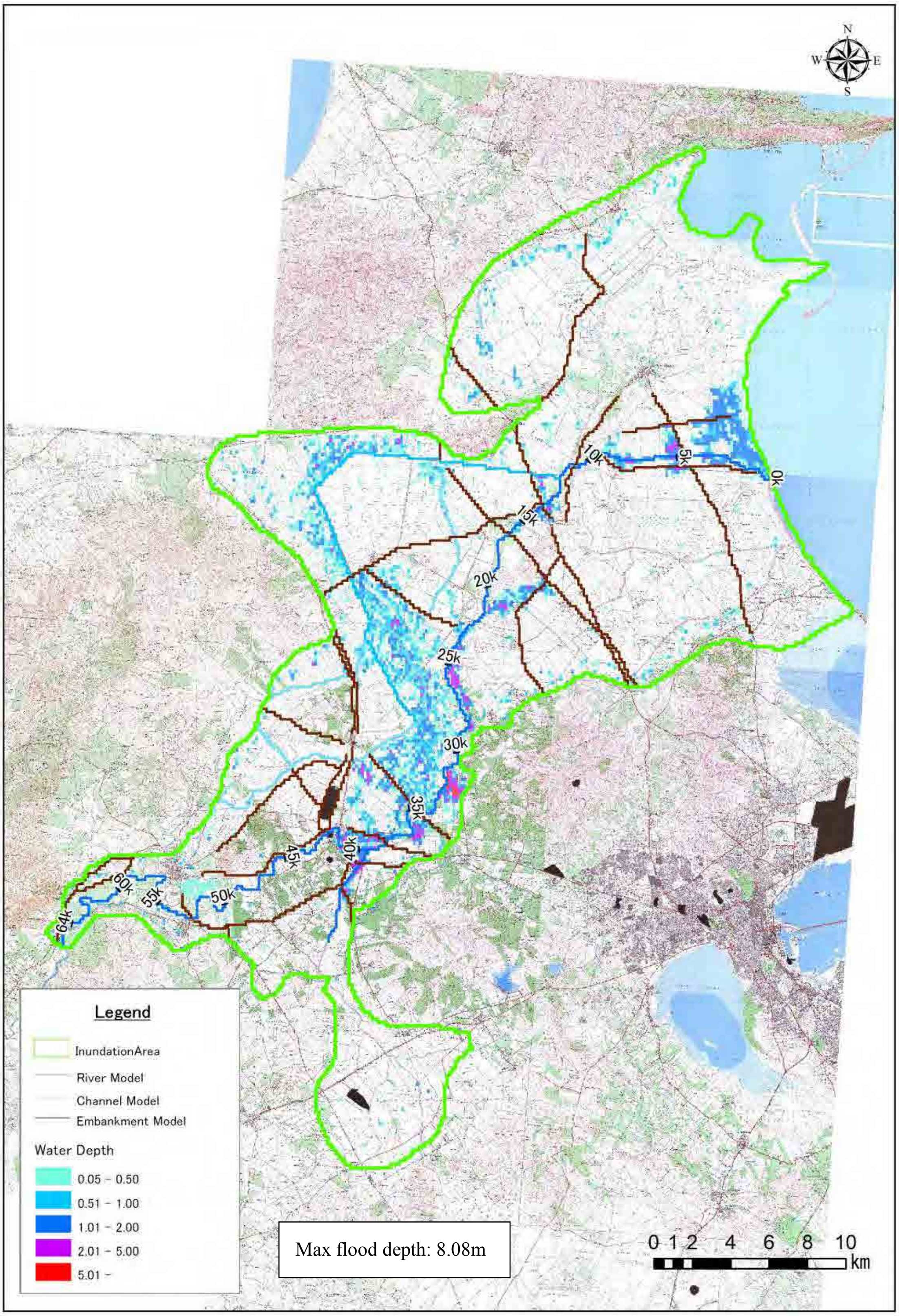
Source: JICA Survey Team

Figure 4-32: Hydrographs by probability scale



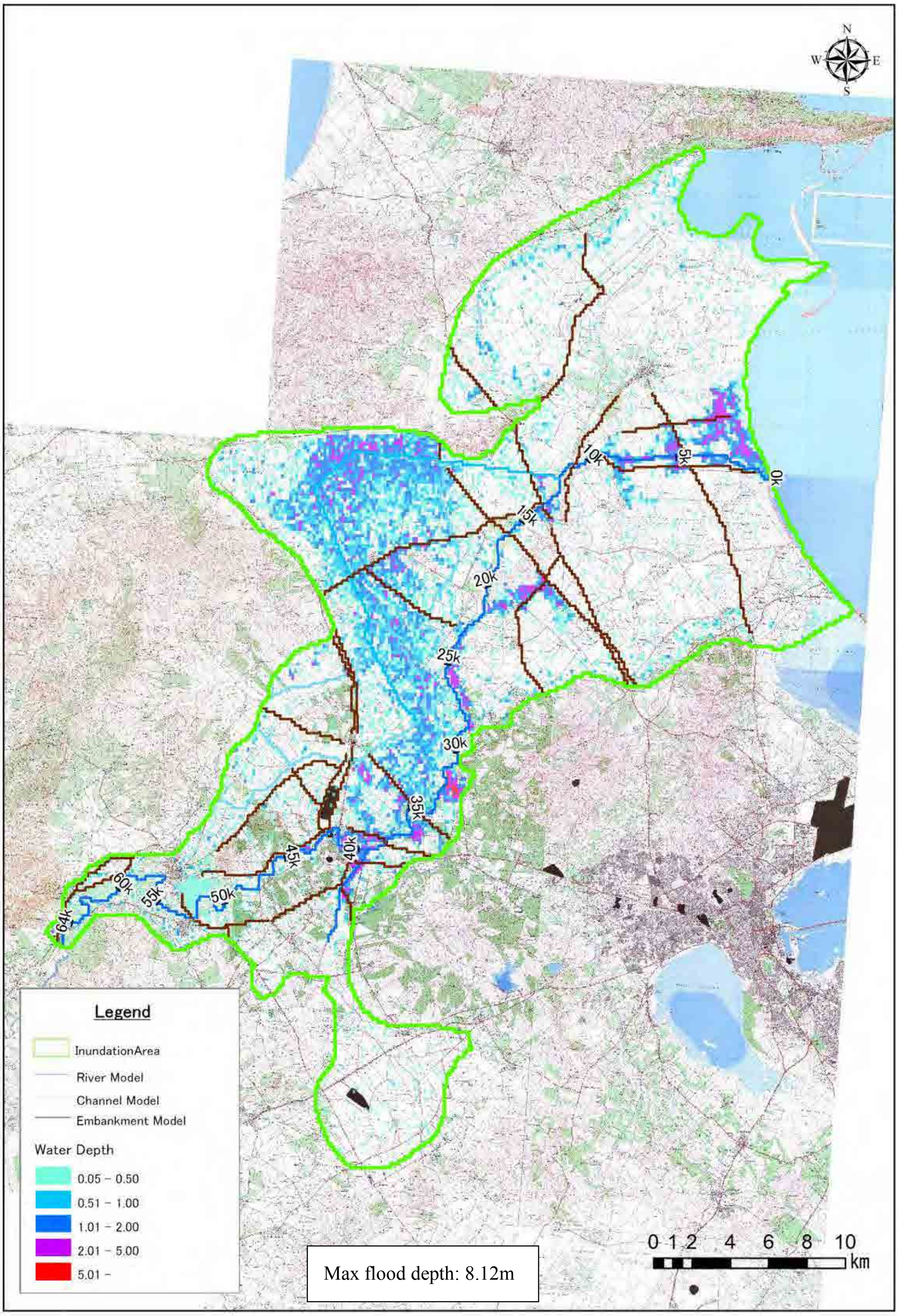
Source: JICA Survey Team

Figure 4-33: Inundation Analysis (current channel, 5th-year discharge)



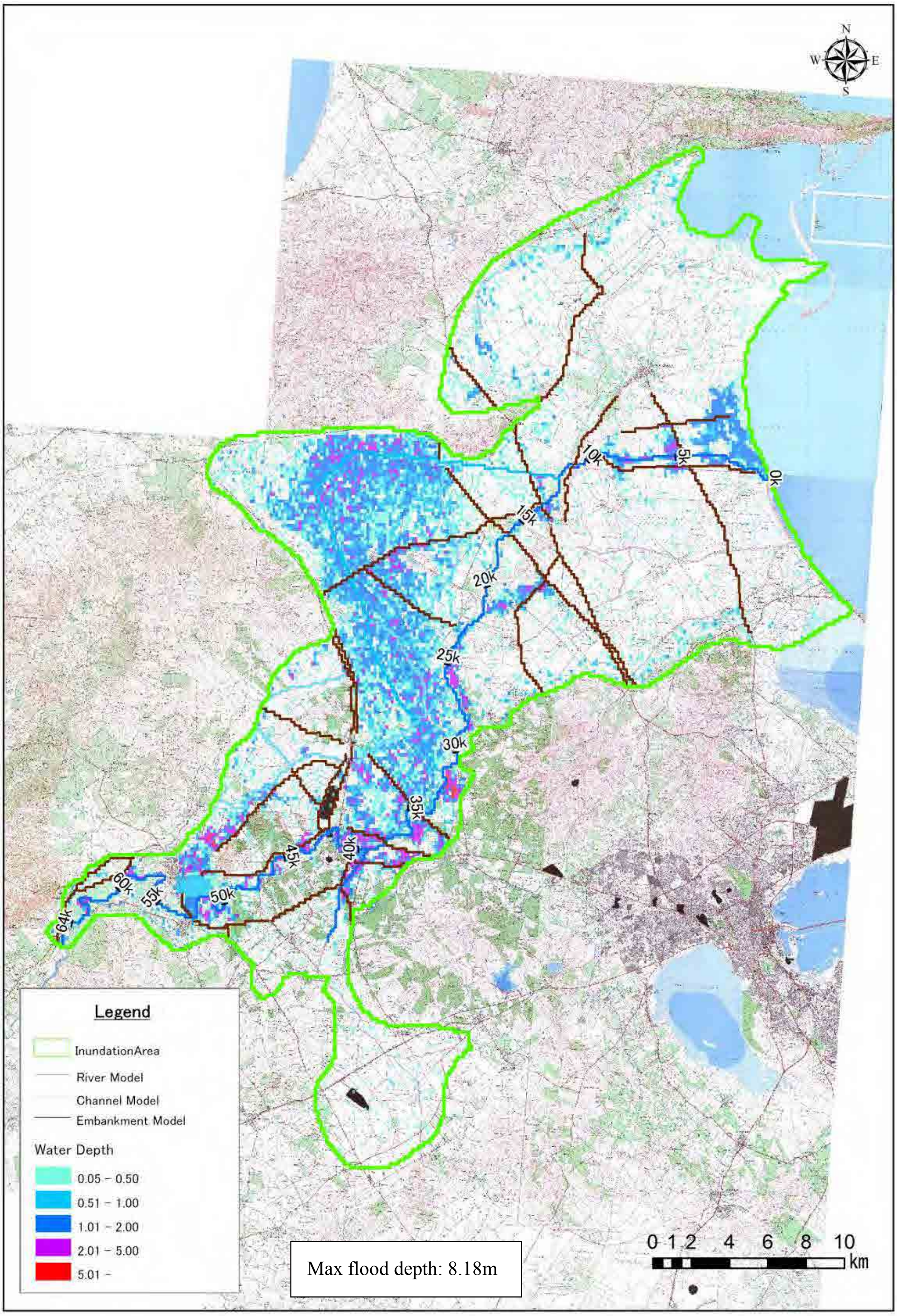
Source: JICA Survey Team

Figure 4-34: Inundation Analysis (current channel, 10th-year discharge)



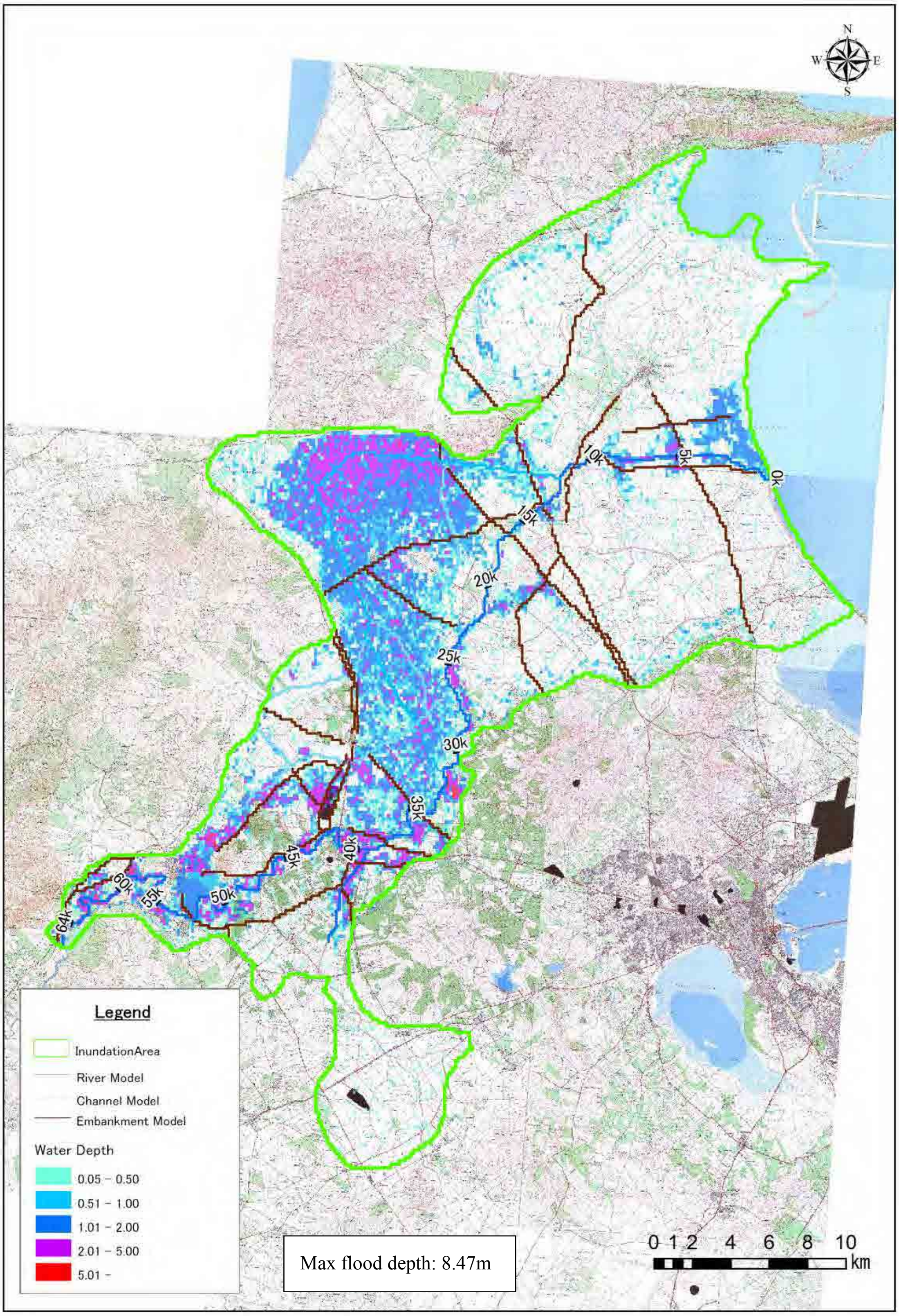
Source: JICA Survey Team

Figure 4-35: Inundation Analysis (current channel, 20th-year discharge)



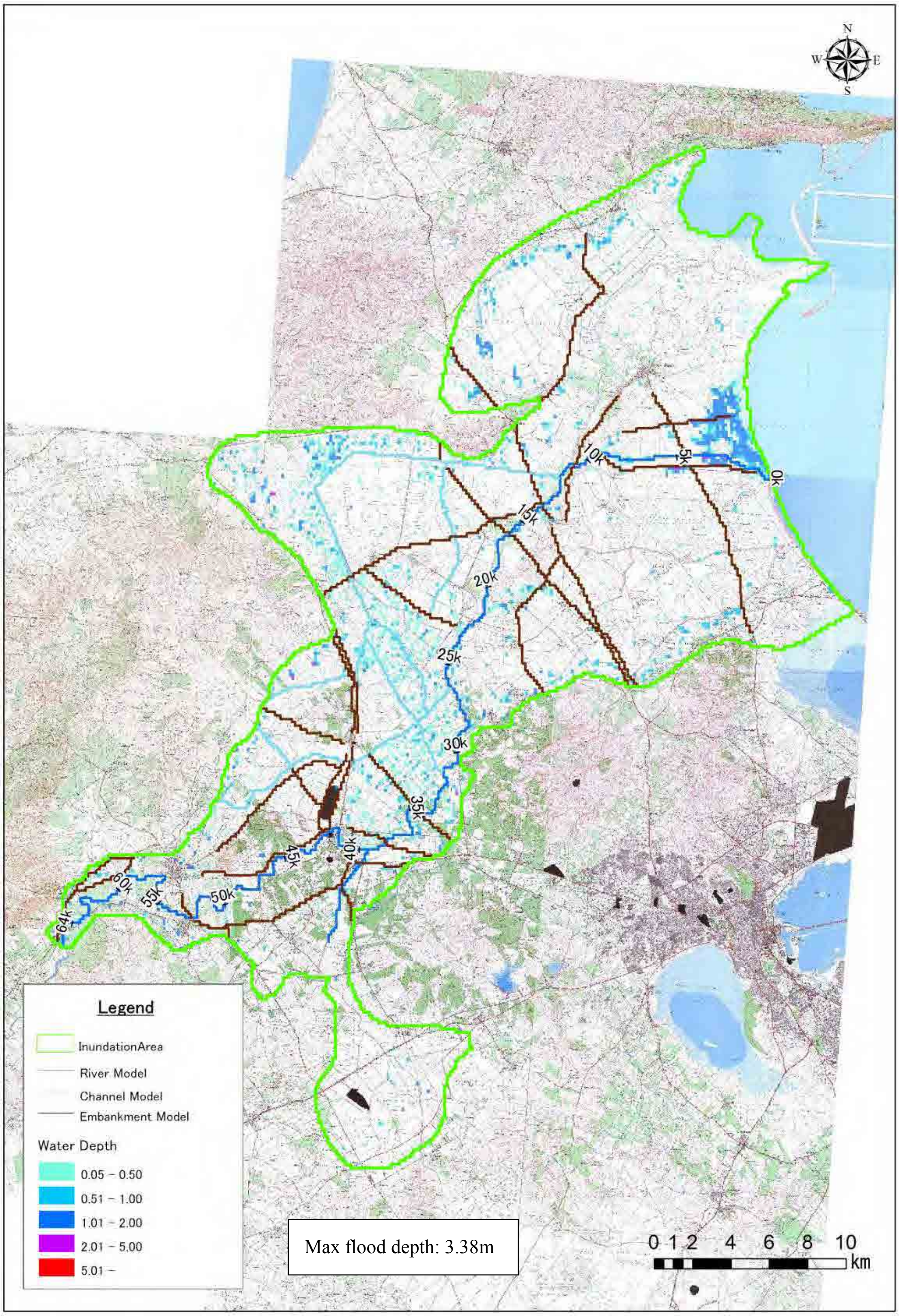
Source: JICA Survey Team

Figure 4-36: Inundation Analysis (current channel, 50th-year discharge)



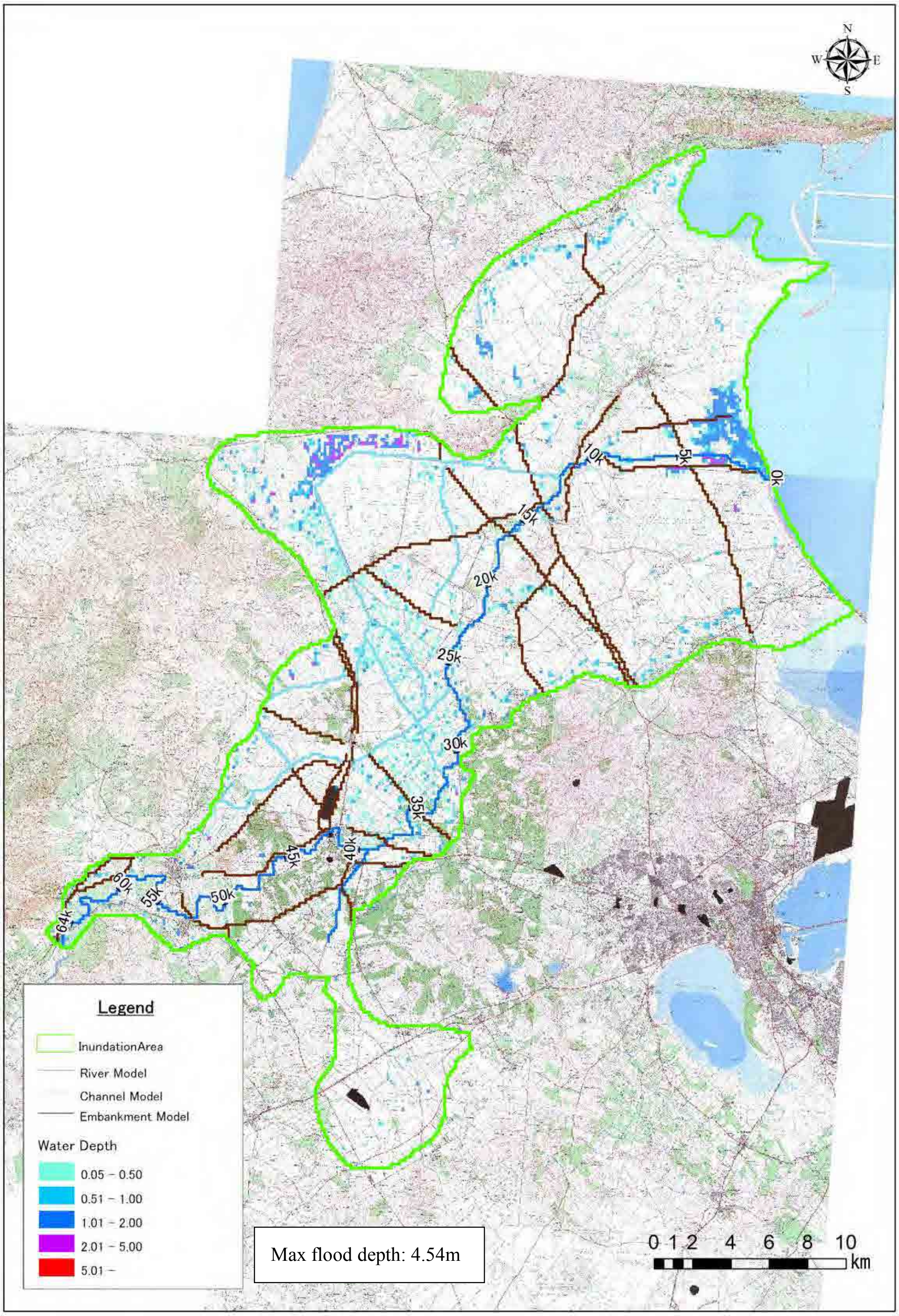
Source: JICA Survey Team

Figure 4-37: Inundation Analysis (current channel, 100th-year discharge)



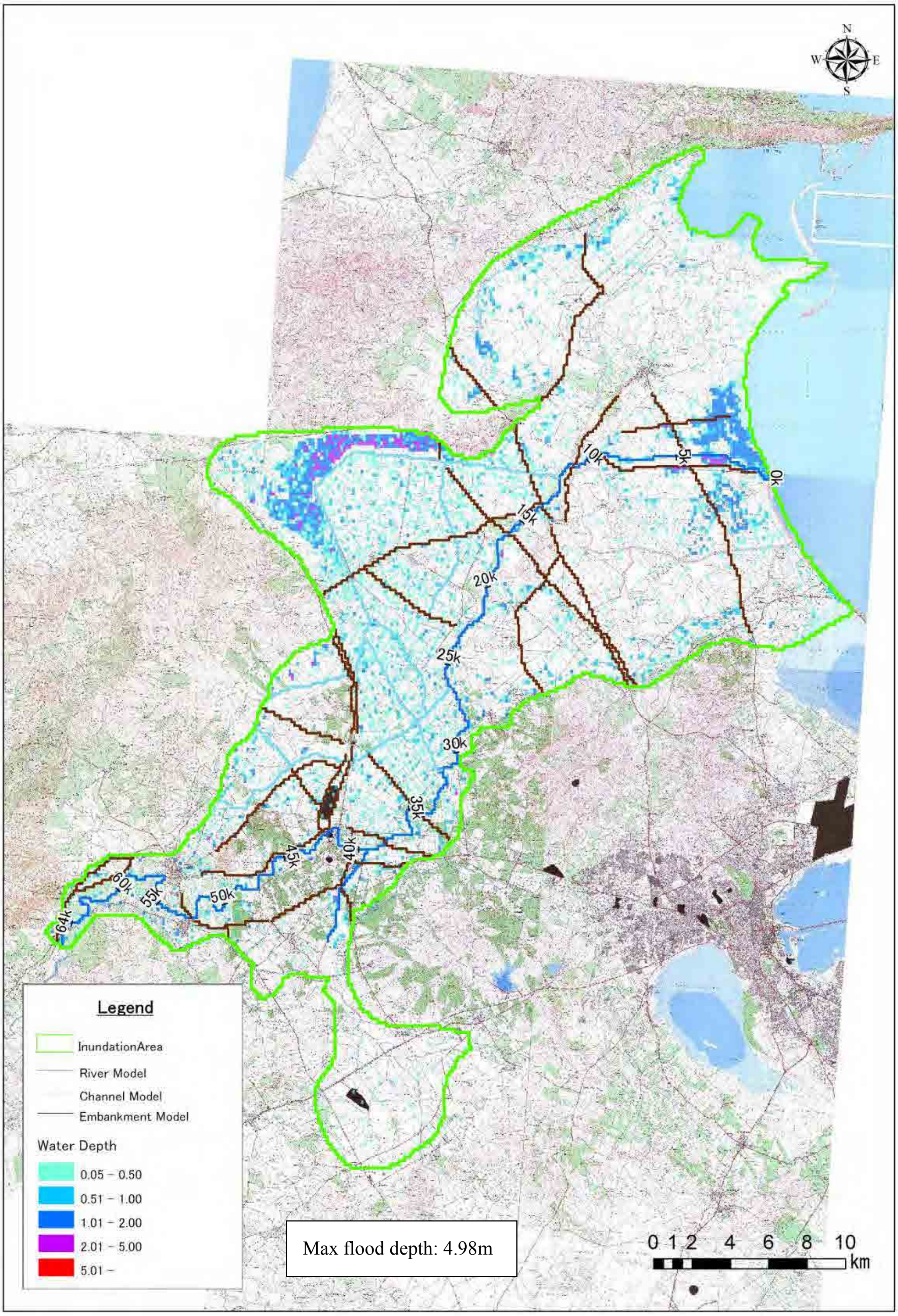
Source: JICA Survey Team

Figure 4-38: Inundation Analysis (current channel, 5th-year discharge)



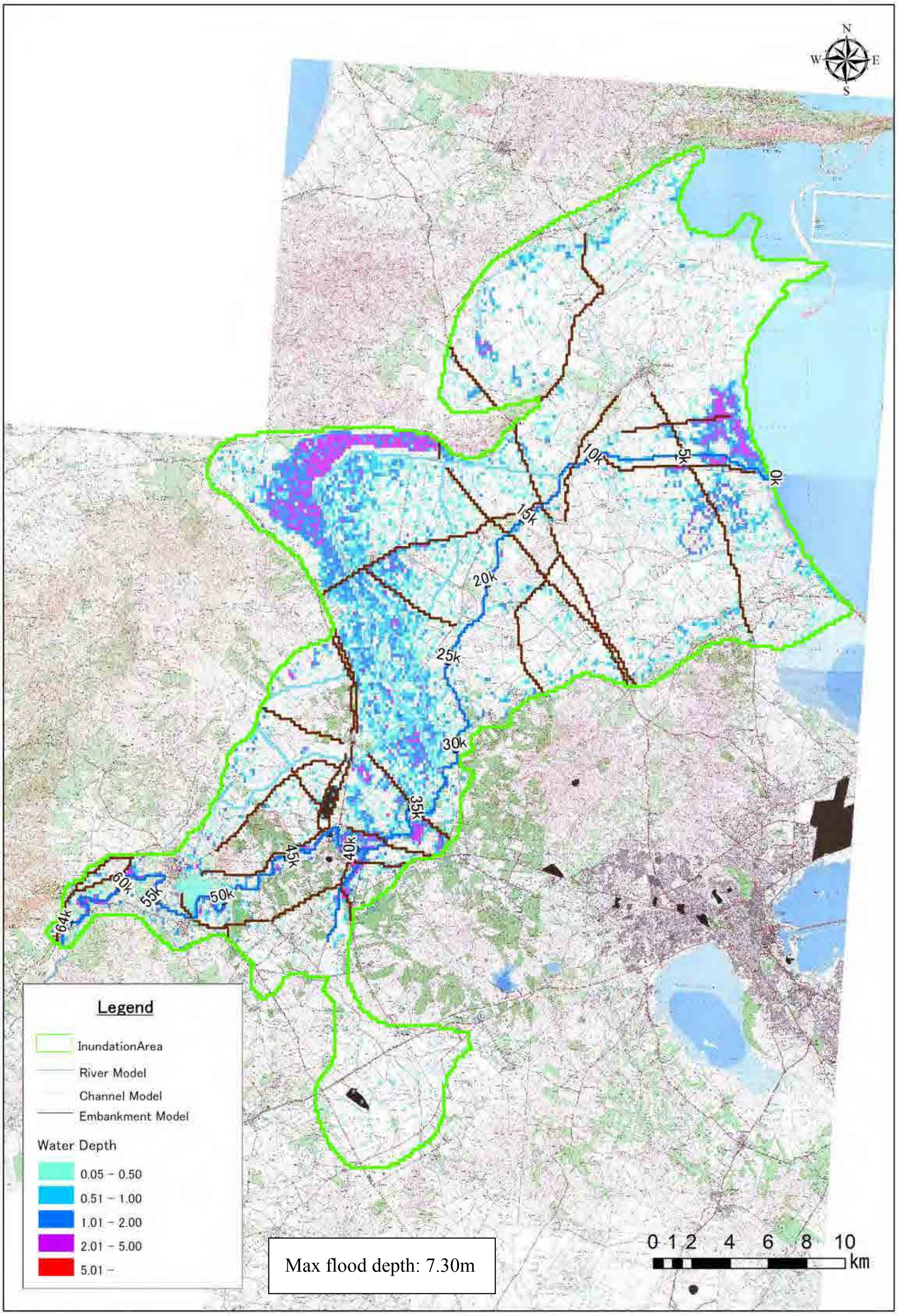
Source: JICA Survey Team

Figure 4-39: Inundation Analysis (design channel, 10th-year discharge)



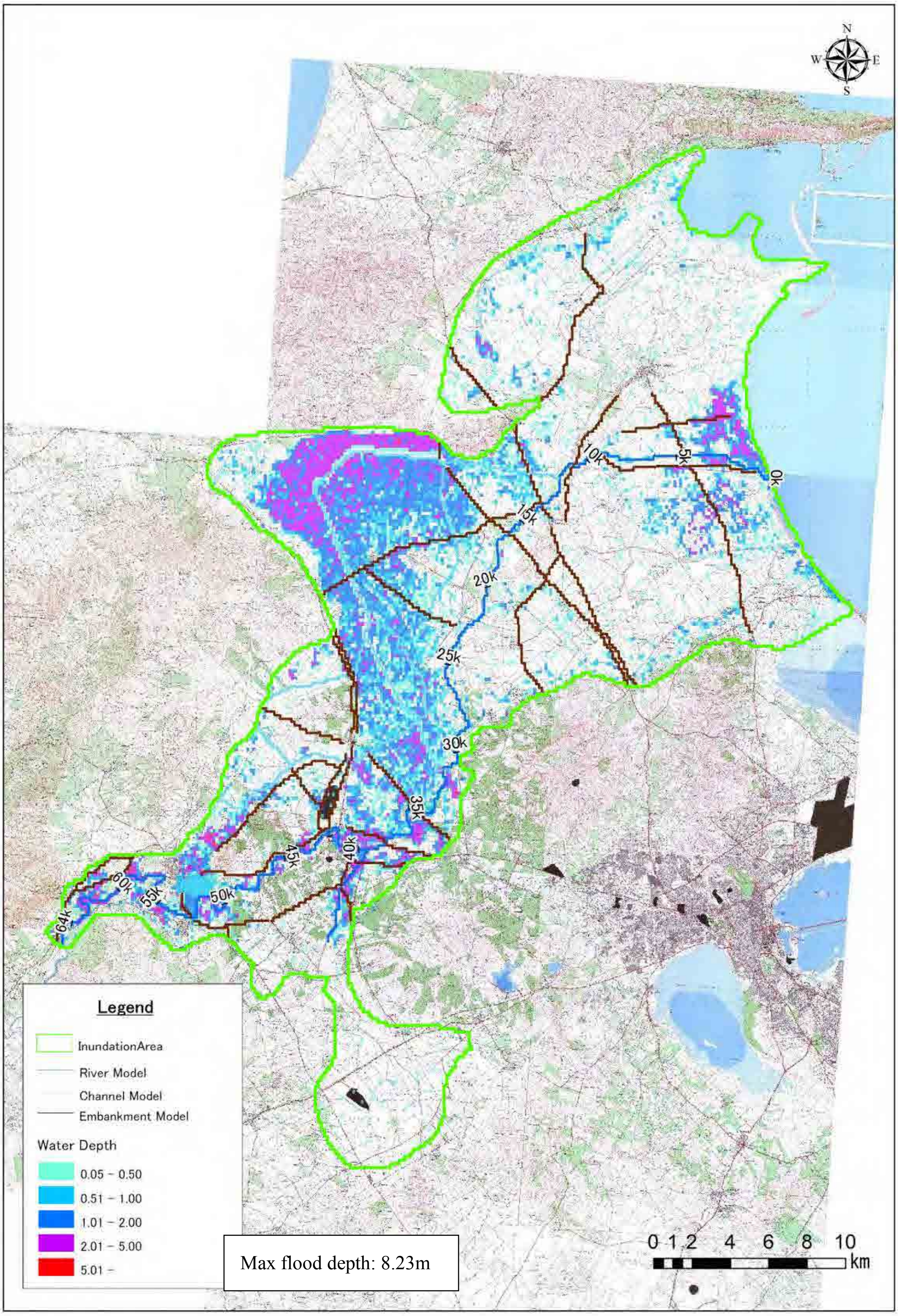
Source: JICA Survey Team

Figure 4-40: Inundation Analysis (design channel, 20th-year discharge)



Source: JICA Survey Team

Figure 4-41: Inundation Analysis (design channel, 50th-year discharge)



Source: JICA Survey Team

Figure 4-42: Inundation Analysis (design channel, 100th-year discharge)