No.

JAPAN INTERNATIONAL COOPERATION AGENCY

KINGDOM OF MOROCCO
MINISTRY OF COUNTRY PLANNING, WATER AND ENVIRONMENT
DIRECTORATE GENERAL OF HYDRAULICS

THE MASTER PLAN STUDY ON FLOOD FORECASTING AND WARNING SYSTEM FOR ATLAS REGION IN THE KINGDOM OF MOROCCO

FINAL REPORT

VOLUME 3 SUPPORTING REPORT




JANUARY 2004

CTI ENGINEERING INTERNATIONAL CO., LTD.
YACHIYO ENGINEERING CO., LTD.

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The cost estimates in this Study are based on the prices levels indicated below and expressed in Moroccan Dirham according to the following exchange rates:

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COMPOSITION OF FINAL REPORT

Volume 1 SUMMARY REPORT

Volume 2 MAIN REPORT

Volume 3 SUPPORTING REPORT

APPENDIX A AERIAL PHOTOGRAPHY AND GROUND SEUVEY

APPENDIX B GEO-MORPHOLOGY

APPENDIX C HYDROLOGICAL AND HYDRAULICS ANALYSIS

APPENDIX D HYDRAULIC SIMULATION

APPENDIX E SOCIAL SURVEY

APPENDIX F TOURISM

APPENDIX G ENVIROMENTAL CONSIDERATIONS

APPENDIX H STRUCTURAL MEASURES

APPENDIX I TELEMETRY AND WARNING SYSTEM

APPENDIX J OBSERVATION FACILITY

APPENDIX K ECONOMIC EVALUATION

APPENDIX L INSTITUTION

Volume 4 DATA BOOK

APPENDIX A

AERIAL PHOTOGRAPHY AND GROUND SURVEY

THE MASTER PLAN STUDY ON
FLOOD FORECASTING AND WARNING SYSTEM
FOR ATLAS REGION IN THE KINGDOM OF MOROCCO

APPENDIX A AERIAL PHOTOGRAPY AND GROUND SURVEY

TABLE OF CONTENTS

LIST OF FIGURES

APPENDIX A AERIAL PHOTOGRAPHY AND GROUND SURVEY

CHAPTER 1. INTRODUCTION

1.1 Introduction

This report describes the survey work conducted during the first field survey phase between March and October 2000. The survey area covers all the six river basins of Issyl, Ourika, Rheraya, N'fis, R'dat and Zat.

The survey works include 3 different works, namely aerial photography, ortho-photo mapping and river survey. The survey works are summarized in the following table and the objective areas are given in Fig.A.1.1:

General Specifications of Survey Works

Survey Works	Scale or Width	Objective Area	Quantity		
Aerial Photography	SCALE = 1/25,000 SCALE = 1/20,000 SCALE = 1/15,000	Whole Study Area (3,500 km²)	3,500 km²		
	SCALE = 1/10,000	River courses of R'dat, Zat, Ourika, Rheraya, N'fis Rivers. 200km² area for Issyl River	R'dat R. Zat R. Ourika R. Rheraya R. N'fis R. Issyl R.	25 15 33 30 17 170	Km line Km line Km line Km line Km line Km line
Ortho-photo mapping	SCALE = 1/5,000	River courses of R'dat, Zat, Ourika, Rheraya, N'fis Rivers. 200km² area for Issyl River.	R'dat R. Zat R. Ourika R. Rheraya R. N'fis R. Issyl R.	15 11 20 25 15 200	Km² Km² Km² Km² Km² Km²
River Survey Longitudinal Survey		R'dat, Zat, Ourika, Rheraya, N'fis (including Wirgane R.) and Issyl Rivers	R'dat R. Zat R. Ourika R. Rheraya R. N'fis R. Issyl R.	20 13 25 26 18 21	km km km km km km
River Survey Cross Section Survey	Average Width ＝500m	R'dat, Zat, Ourika, Rheraya, N'fis (including Wirgane R.) and Issyl Rivers	R'dat R. Zat R. Ourika R. Rheraya R. N'fis R. Issyl R.	41 27 52 51 40 41	Sections Sections Sections Sections Sections Sections

CHAPTER 2. AERIAL PHOTOGRAPHY

2.1 Equipment

The airplane "SENEKA II" PA-34 CN-TAG, equipped with a GPS navigation system, was used for the photographic flying. An aerial survey camera WILD RC 8 with calibrated focal length of 152.84mm was also used.

2.2 Objectives of Aerial Photography

The aerial photographs are divided into two categories according to purposes, namely those for the geomorphologic analysis and those for the ortho-photo mapping.

In the original photography plan, a smaller scale of about 1/40,000 was preferred for the geomorphologic analysis so as to cover the whole study area by the least number of photographs. However, the cloudy weather did not allow the high altitude photography, and the scale of 1/25,000 to 1/15,000 were alternately applied.

For the ortho-photo mapping, the 1/10,000 scale photographs taken along the river courses of Ourika, Rheraya, N'fis, R'dat and Zat Rivers and over the 200 km^2 probable inundation area of the Issyl River were used, as explained in the following chapter.

An index map of the photography courses is given in Fig.A.2.1.

CHAPTER 3. ORTHO-PHOTO MAPPING

3.1 Introduction

This ground control survey was carried out to obtain the necessary plan-metric position and elevation data of control points selected in the Study Area, which were later taken to Japan for the generation of 1/5,000 ortho-photo maps.

3.2 Ground Control Survey

Prior to the commencement of the aerial photography, 45 control points were selected in the ortho-photo mapping area and marked on the ground. In addition, 345 control points in the field were directly identified on the photographs.

Number of Control Points

River	Pre-marked	Identified	Total
Issyl	0	238	238
Ourika	10	29	39
Rheraya	12	26	38
R’dat	9	20	29
Zat	6	14	20
N’fis	5	14	19
Wirgane	3	4	7
Total	45	345	390

The control point positions were determined through GPS observations. Two bi-frequency GPS instruments, WILD - System 200 and System 300 were used.

The GPS observations were grouped into 3 projects: Ourika (including Ourika, Rheraya, N’fis and Wirgane), R'dat (including R’dat and Zat) and Issyl. For each project, a necessary number of existing national trigonometry stations and bench marks were observed for the coordinate transformation between the WGS 84 coordinate system and the local grid coordinate and level system of Morocco.

3.3 Data Processing and Ortho-Photo Mapping

All measurements taken by the WILD GPS systems were processed by a software package, SKI release 2.3 LEICA. The standard deviations of latitude, longitude and height for every computed baseline did not exceed 4 mm.

For the conversion from the WGS 84 system coordinates to the local ones, a stepwise approach that consists of a rigorous 2D Helmert transformation and an interpolation method for the transformation of elevation data was applied.

Based on the above ground coordinate and elevation data, the 1/10,000 photographs were processed into 1/5000 ortho-photo maps with contour lines.

CHAPTER 4. RIVER SURVEY

4.1 River Survey

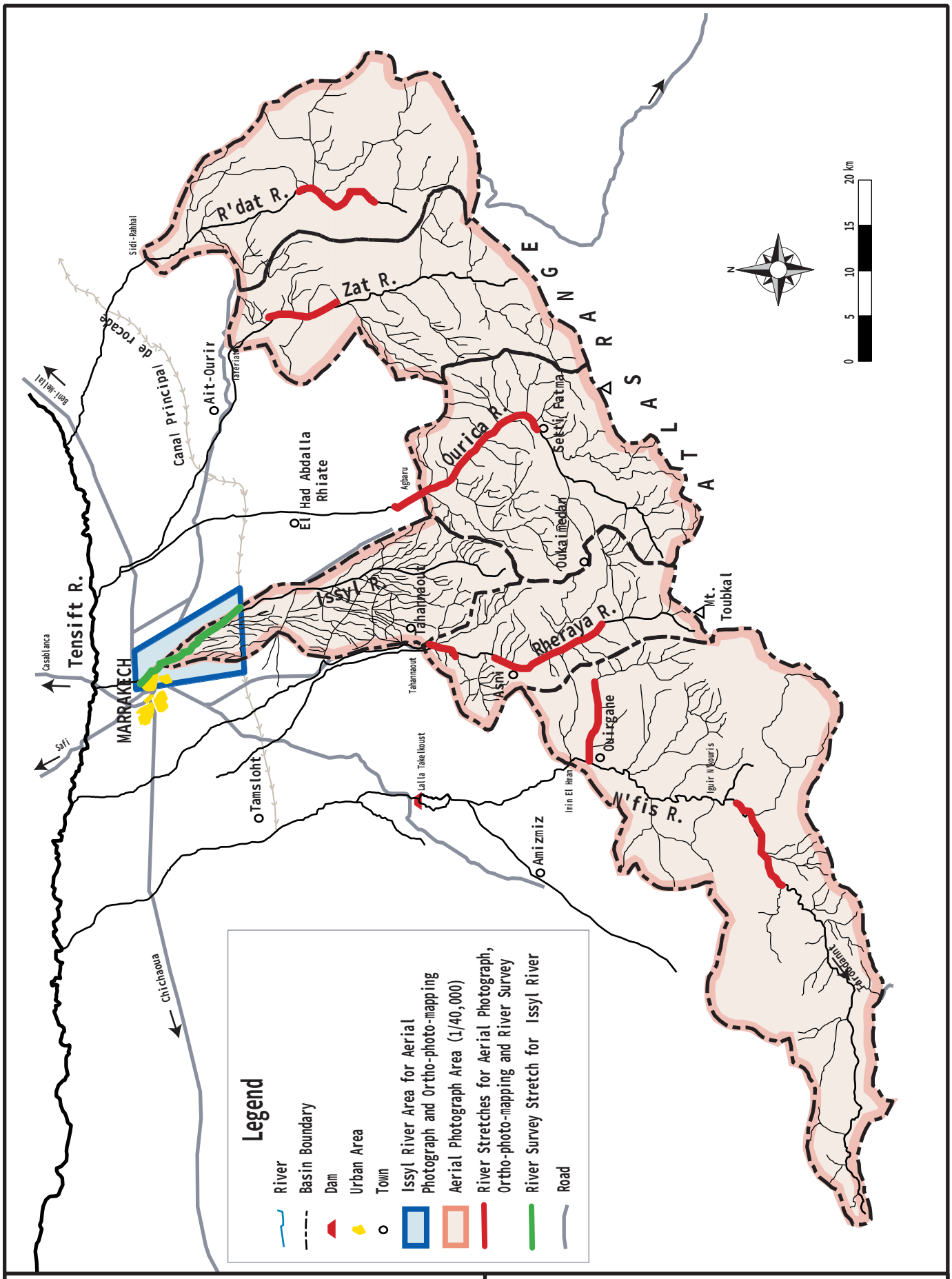
River survey was carried out to prepare longitudinal and cross sectional profiles of Issyl, Ourika, Rheraya, R'dat, Zat, N'fis and Wirgane Rivers.

All results of longitudinal profile and cross sections data were compiled by using AutoCAD system release 14. Drawings were carried out by HP DesignJet 750C plotter on polyester film of A1 size.

Longitudinal and Cross Sections Profiles

River	Length of Longitudinal profile	Number of Cross Sections	Polyester Film (sheets)
Issyl	21.0km	41	11
Ourika	25.1km	52	11
Rheraya	25.6km	51	17
R'dat	21.5km	41	8
Zat	13.0km	27	8
N'fis	14.0km	32	10
Wirgane	3.7km	8	3
Total	123.9km	252	68

FIGURES



THE MASTER PLAN STUDY ON
FLOOD FORECASTING AND WARNING SUSTEM
FOR ATLAS REGION IN THE KINGDOM OF MOROCCO

Fig. A.1.1 OBJECTIVE AREA FOR SURVEY WORKS

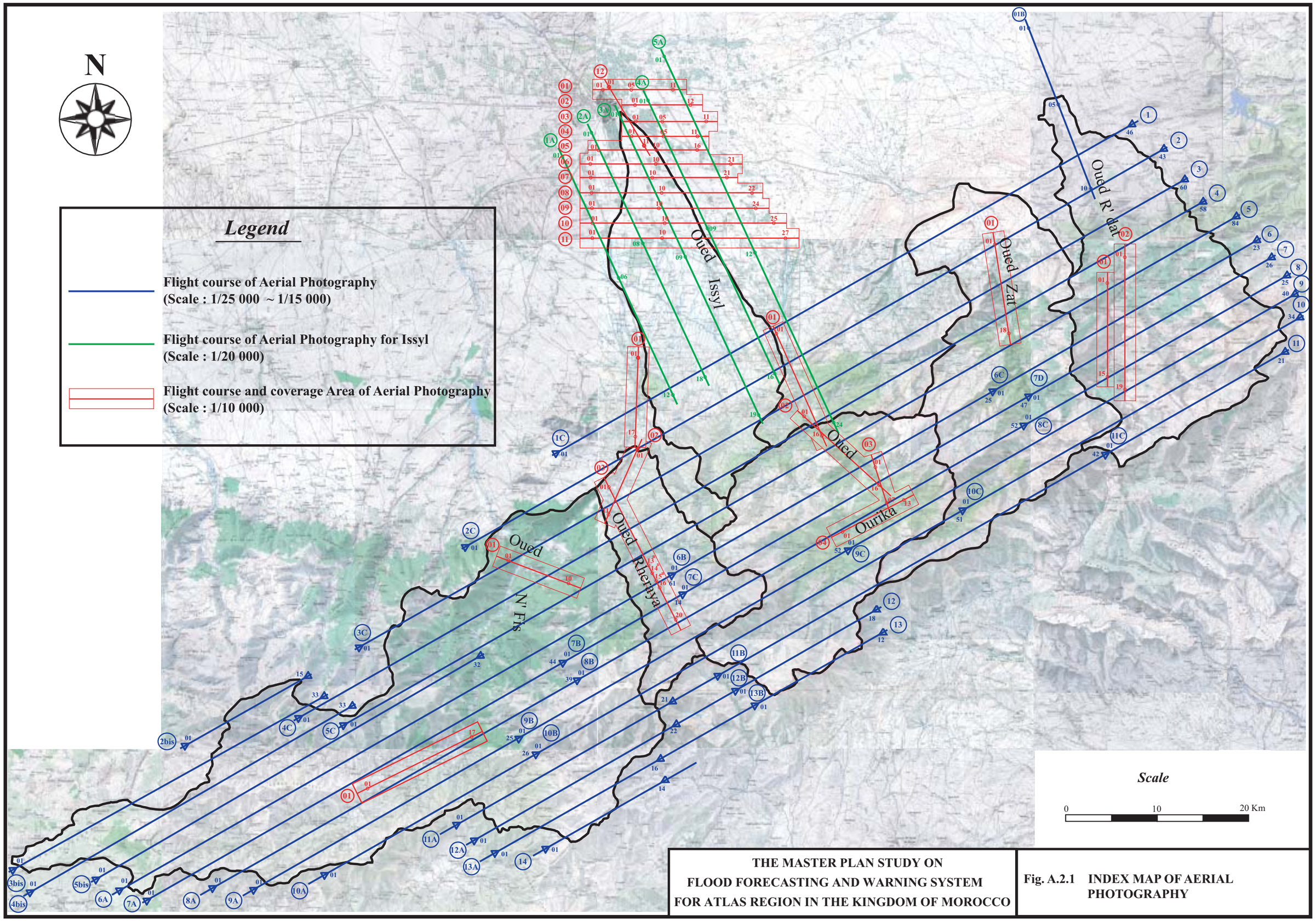


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Fig. A.2.1 INDEX MAP OF AERIAL PHOTOGRAPHY

APPENDIX B

GEO-MORPHOLOGY

THE MASTER PLAN STUDY ON
FLOOD FORECASTING AND WARNING SYSTEM
FOR ATLAS REGION IN THE KINGDOM OF MOROCCO

APPENDIX B GEO-MORPHOLOGY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX B GEO-MORPHOLOGY

CHAPTER 1. GEO-MORPHOLOGICAL LAND CLASSIFICATION MAP

1.1 Objective and Method of Preparation

Geo-morphological land classification maps were made for the objective six river basins as a first step for the preparation of flood and sediment hazard maps. Landforms are interpreted using aerial photographs newly taken in this Study, and the results were transferred to 1/50,000 or 1/100,000 topographical map sheets. Figs.B.1.1, B.1.2, B.1.3 B.1.4, B.1.5, B.1.6 are the geo-morphological land classification maps of the six river basins.

1.2 Landform Classifications in Geo-morphological Land Classification Map

The landform interpretation was based on the landform classifications given in Table B.1.1, each of which is generally related to potential disasters as follows:

Relationship between Land Classification and Potential Disasters

Landform classifications	Flood	Sediment Flow	Debris Flow	Slope Failure	Large-scale Slope Failure	Land Slide	Rock-fall
Steep Slope				H	L		H
Riverbed	H	H	H				
Floodplain (valley plain)	H	H					
Alluvial fan	H	H					
Former waterway	H	H					
Natural levee	H	H					
Flood-prone terrace	H	H					
Terrace							
Shallow Valley	H						
Terrace cliff				H		H	H
Alluvial cone (debris flow-prone alluvial fan)	H	H	H				
Talus				H			H
Pediment		H	H	H			
Landslide morphology (creeping slope)				H	H	H	H
Landslide scar					H	H	H
Erosion Surface		L					
Moraine				H			H
Cirque				H	L		H

H: Potential is high, L: Potential is low, Blanc: Potential is nil.

CHAPTER 2. PREPARATION OF DISASTER HAZARD MAP

2.1 Introduction

Following the geo-morphological maps, disaster hazard maps were also prepared for the six river basins to identify areas vulnerable to disasters such as debris flow, slope failure and land slide and flood inundation, as shown in Figs. B.2.1, B.2.2, B.2.3, B.2.4, B.2.5 and B.2.6.

2.2 Potential Debris Flow Disaster Stream

2.2.1 Debris flow section

Causes of a debris flow are classified into the following five major phenomena:

- Sediments deposited on a mountain stream bed is fluidized due to an increase of stream water.
- Sediments that slid over a mountainside slope flow down a stream, maintaining the force at a time of a flood.
- A soil mass that slid over a slope turns into a debris flow.
- A natural levee fails.
- A volcano erupts.

Four of the above causes except the volcanic eruption are observed in the Study Area. A debris flow generally occurs where the stream bed slope is 15 to 30 degrees, and its sedimentation starts at a slope of about 10 degrees and ends until it reaches a slope of three degrees. In the Study Area, sedimentation of debris flows is also observed in sections with a slope of about three degrees. Stream sections with a bed slope of three or higher degrees are, therefore, defined as debris flow sections.

2.2.2 Definition of Stream

Since it is difficult to differentiate slope failures from debris flows when failed slope mass flows down, sediment flow along a stream is defined as a debris flow for convenience sake. Then, the differentiation between the stream and the slope is necessary. Here blue dotted lines in the 1/50,000 topographical map are defined as streams.

According to field surveys, some of the streams represented by blue lines in the map are small torrential streams that may be called slopes. However, the landforms created at the mouths of such streams by sedimentation have a slope of about 10 degrees, and are apparently composed of sediment that used to contain much water. It is judged that debris flows took place in these small torrential streams. The streams represented by blue dotted lines in the 1/50,000 topographical map are, therefore, defined as torrential mountain streams carrying debris flows.

2.2.3 Potential Debris Flow Disaster Streams

In a stream with a slope of three degrees or more, debris flows are likely to run. However, debris flows cause no damages if there is nothing valuable in the debris flow areas. A disaster can be generated where assets are available. Thus Potential Debris Flow Disaster Streams are defined as those with a slope of three degrees or more that have assets to be protected in places subject to inundation with sediment and/or stream waters. Such torrential mountain streams are specified as Potential Debris Flow Disaster Streams.

Assets to be protected are listed below.

- Houses and buildings (including those in Azib)
- Major roads (the roads along the Ourika and Rheraya valleys, the national road leading to Ouarzazate and Taroudannt, and the road from the Ourika valley to Oukaimedan)

2.2.4 Risk of Debris Flow

Assessing the risk of a debris flow in the Study Area is difficult because no records are available on debris flows in the Study Area. In this Study, however, a risk assessment of debris flows is being made based on mainly experiences in Japan, as follows:

Generally the larger the slope of stream bed and the larger the catchment area, the greater the danger of debris flows. Risk of debris flows is then assessed based on combinations of the stream slope and the catchment area upstream of a point where a debris flow was likely to occur (where the stream slope is 15 or higher degrees). This method of risk assessment using the stream slope and catchment area is based on a Japanese guideline for investigating torrential mountain streams and debris flow-prone areas. In Japan, geomorphology, geology and vegetation cover in the basin are also considered in risk assessment.

2.2.5 Distribution of Potential Debris Flow Disaster Streams

A total of 1,431 streams were identified as potential debris flow disaster streams through close examinations based on aerial photographs and topographical maps. Among them 960 streams are ranked A, the highest in terms of disaster risk. The number of the potential disaster streams by river basin is given as follows:

Number of Potential Debris Flow Disaster Streams

River Basin	Catchment Area (km^2)	Number of Potential Streams
R'dat	1,256	285 (170)
Zat	221	147 (91)
Ourika	495	330 (267)
Rheraya	528	145 (111)
N'fis	532	488 (304)
Issyl	421	36 (17)
Total	3,453	1,431 (960)

Numbers in parentheses are the numbers of those of Rank-A.

2.3 Potential Slope Failures Disaster Areas

The failure of surface layer due to heavy rain is likely to occur on slopes with a gradient of 30 degrees or more. Most parts of the Study Area are located in steep mountain areas. The mountainside slopes except flat or mild slopes at the summits, terraces, alluvial fans and floodplains are mostly sloped at 30 degrees or more. These slopes are, therefore, vulnerable to failure. It is said that debris travels a distance two to three times longer than the height of the slope. After the preparation of geo-morphological land classification maps, therefore, slopes of 30 degrees or more including the assets to be protected within the travel distance were extracted as Potential Slope Failure Disaster Areas .

A total road length of 164 km was found under a threat of such slope failures. The number of the potential disaster areas by river basin is given as follows:

Number of Potential Slope Failure Disaster Areas

River Basin	Catchment Area (km^2)	Number of Potential Slope Failure Disaster Areas	Road Length under threat of Slope Failures (km)
R'dat	1,256	225	37
Zat	221	180	5
Ourika	495	240	36
Rheraya	528	128	14
N'fis	532	490	69
Issyl	421	17	2
Total	3,453	1,280	164

2.4 Potential Landslide Disaster Areas

Of areas classified as the landslide morphology (creeping slopes) in the geo-morphological land classification maps, those with the assets to be protected were specified as Potential Landslide Disaster Areas.

A total of 226 areas are identified as Potential Landslide Disaster Areas. A total road length of 18 km was found under a threat of landslides. The number of the potential disaster areas by river basin is given as follows:

Number of Potential Landslide Disaster Areas

River Basin	Catchment Area (km^2)	Number of Potential Landslide Disaster Areas	Road Length under threat of Landslides (km)
R'dat	1,256	61	5
Zat	221	70	0
Ourika	495	23	9
Rheraya	528	35	2
N'fis	532	30	2
Issyl	421	7	0
Total	3,453	226	18

2.5 Flood Inundation Area

After the preparation of geo-morphological land classification maps, areas vulnerable to inundation by flood were determined based on the geo-morphological land classification maps and the hydraulic simulation (refer to Supporting Report, Appendix D: Hydraulic Model Simulation).

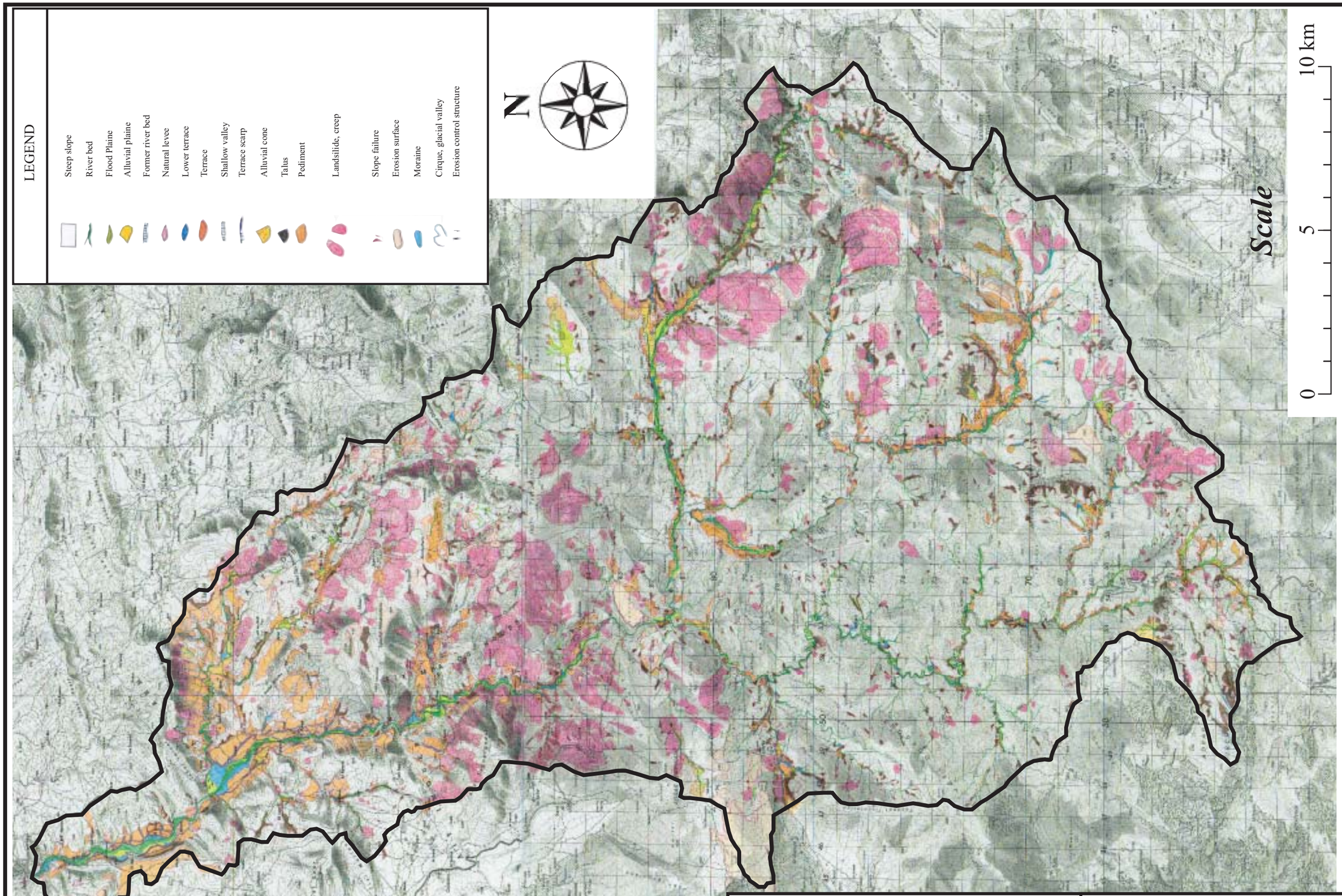
Present river beds with a gradient of 3 degrees or less, flood plains, lower terraces, alluvial fans, former waterways, natural levees are included in the flood inundation areas. As for the Issyl River Basin of which the downstream areas are mostly classified as alluvial fans, inundation of the main stream and major tributaries was taken into consideration, but inundation from the Rheraya River was not considered although it possibly affects the left bank of the Issyl River.

TABLES

Table B.1.1 CLASSIFICATION OF LAND FORM

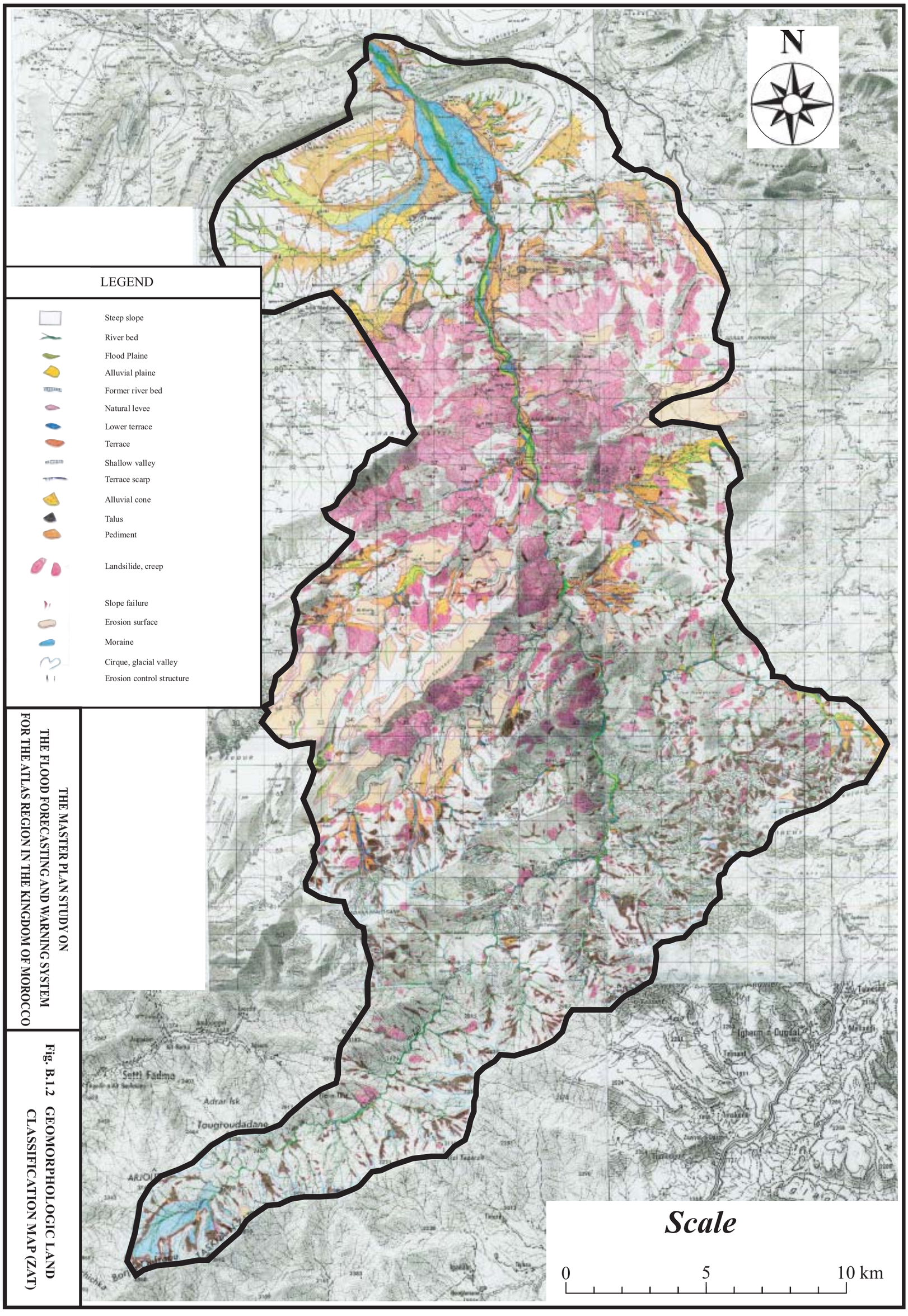
Landform classifications	Definition
Steep Slope	Mountainous and hilly steep slopes of 15 degrees or over. Landslide and creeping slopes are excluded in this classification. Possibility of slope failure is very high where slope exceeds 25 to 35 degrees. Surface soil is seen in a forest, but rocks and/or residual sediments including big boulders that are seen at tree-less places could be a source of rockfalls.
Riverbed	Present riverbed. Sediment has moved on the riverbed recently.
Floodplain (valley plain)	It has such a small relative height from the present riverbed that it is subject to flooding.
Alluvial fan	Mildly sloped landform at the mouth of a valley through which a river runs. It is created by sedimentation. Where the relative height from the present riverbed is small, the alluvial fan may be subject to flooding.
Former waterway	Trace of an old waterway in a floodplain or an alluvial fan. Since former waterways are in an slightly low-lying area, they tend to be main courses of flood waters.
Natural levee	Slightly raised landform in a floodplain or an alluvial fan that is subject to inundation during a great flood.
Flood-prone terrace	Landform created on the bank of a torrential mountain stream by sedimentation. The low-level terrace with a relative height from the present riverbed of about 5 m is almost free from small to medium flooding. A rise of the riverbed may, however, result in flooding. Where the torrential mountain stream has a steep slope in particular, there is no guarantee of safety against flooding.
Terrace	Flat or mildly sloped surface with a large relative height form the present riverbed, free from the danger of flooding. There may, however, be inundation due to sedimentation or water inflow from a torrential mountain stream behind the terrace.
Shallow Valley	This is a shallow valley formed on terraces and alluvial fans where surface runoff is likely to concentrate. Flood inundation water may be confined in a shallow valley.
Terrace cliff	It generally has a steep slope, has a thick layer of unconsolidated sediment, and thus may be subject to failure.
Alluvial cone (debris flow-prone alluvial fan)	Steep small alluvial fan formed at he mouth of a steep valley by debris flows or sediment flows. There is a great danger of inundation by debris flows or sedimentation.
Talus	Landform created by sedimentation of soil that slid on a slope or of rockfalls, sloping at an angle of repose for sediment. It suggests past slope slides or rockfalls on the slope. There is a great danger of failure or rockfall. The steep sloped talus itself causes debris flows, failures or rockfalls.
Pediment	Flat and mild erosion slopes developed in a mountain-foot in dry areas. This is generally covered by a thin layer of sands and gravels, but foundation rocks are sometimes cropped out. Flood inundation takes place during a heavy rainfall, and possibility of debris flow is high in a steep place.
Landslide morphology (creeping slope)	Landform created by the sliding of a mountainside slope. Landslide blocks and circular scarps are outstanding. Landslide blocks come in many variations such as a talus created by fracture, fractured rock mass or rock mass that is hardly fractured. There is a danger of large-scale failure, and the front surface of the block is subject to failure. Slopes with their mountainside rock mass creeping are classified under this category. The slopes that crept are regarded as landslide landforms in the initial stage. Large-scale failures are likely to occur.
Landslide scar	Landform created by the falling of weathered rock or surface soil. Landslide scars are frequently found where the slope is subject to failure or failure has recently occurred frequently due to heavy rains or other phenomena.
Mild slope at the summit	Sediment disasters seldom occur on a mild slope near the summit.
Moraine	Sediment carried and deposited by a glacier in the glacial age, observed in areas at a high latitude.
Cirque	Circular glacial valley
Erosion and sediment control facilities	Check dams and groundsill

FIGURES



THE MASTER PLAN STUDY ON
THE FLOOD FORECASTING AND WARNING SYSTEM
FOR THE ATLAS REGION IN THE KINGDOM OF MOROCCO

Fig. B.1.1 GEOMORPHOLOGIC LAND CLASSIFICATION MAP (R'DAT)



THE MASTER PLAN STUDY ON
THE FLOOD FORECASTING AND WARNING SYSTEM
FOR THE ATLAS REGION IN THE KINGDOM OF MOROCCO

Fig. B.1.2 GEOMORPHOLOGIC LAND CLASSIFICATION MAP (ZAT)