No.

Japan International Cooperation Agency (JICA)
Ministry of Housing and Urban Affairs
National Earthquake Engineering Research Center

A Study of Seismic Microzoning of the Wilaya of Algiers in the People's Democratic Republic of Algeria

Final Report

Volume II

Main Report

December 2006

Oyo International Corp.
Nippon Koei Co., Ltd.

PREFACE

In response to the request from the Government of the People's Democratic Republic of Algeria, the Government of Japan decided to conduct the Study on Seismic Microzoning of the Wilaya of Algiers in the People's Democratic Republic of Algeria and entrusted the study to Japan International Cooperation Agency (JICA).

JICA organized and dispatched a study team headed by Mr. Osamu NISHII of OYO International Corporation and composed of OYO International Corporation and Nippon Koei Co., Ltd., to Algeria six times from February 2005 to November 2006. In addition, JICA set up an advisory committee headed by Dr. Kimiro MEGURO, Professor of University of Tokyo, which examined the study from technical point of view.

The study was completed as scheduled with submission of the final report, technical guideline and associated products. The study also included technology transfer of the seismic microzoning to the counterpart agency. We hope that the output of the study will be shared by all the relevant organizations and staffs and utilized as the foundations of earthquake disaster prevention planning.

It is clear that continued endeavors for establishing sound and effective policies and projects on disaster management and for implementing them at national, local and community levels are inevitable to achieve sustainable development of the People's Democratic Republic of Algeria. We also hope that this study will contribute to the promotion of the future projects and to the enhancement of the friendship between two countries.

Finally, we wish to express our sincere appreciation to the officials concerned in the Government of Algeria for their close cooperation extended to the Study.

December 2006

Ariyuki
MATSUMOTO
Vice President
Japan International
Cooperation Agency

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Abbreviation

Organizations

ADE	Algerian Water Agency
ANRH	National Agency for Hydraulic Resources
APC	Popular Communal Assembly
ASAL	Algerian Space Agency
ATC	Applied Technology Council
ATM	Algerian Telecom
CCO	Operational Coordination Centre
CDMG	California Division of Mines and Geology
CENEAC	National Coordination Center
CGS	National Research Center for Earthquake Engineering
CNAD	National Operational Center for Decision Support
CNERU	Public Consultant Agency in Urbanism
CNIG	National Council of Geographic Information
CNSPR	National Centre of Safety and Road Prevention
CNTS	National Centre of Space Techniques
COM.EN.A	Commissariat for Atomic Energy
COMEDOR	Greater Algiers Permanent Study and Organization Committee
CRA	The Algerian Red Crescent
CRAAG	National Center for Research in Astronomy, Astrophysics and Geophysics
CTC	Technical Control of Construction
CTTP	National Technical Control Center of Public Works
DGF	General Direction of Forests
DGPC	Civil Protection General Directorate
DHW	Direction of Hydraulic of Wilaya
DL	Direction of Housing
DNRM	National Delegation for Major Risk
DOCS	Direction of Rescue Organization and Coordination
DPAT	Direction of Planification and Regional Development
DPC	Direction of Civil Protection
DRAG	Director of Regulatory and General Affairs
DT	Transport Direction
DTP	Public Works Direction
DTPW	Public Works Direction of Wilaya
DU Alger	Direction of Urban affairs of Algiers' Wilaya
DUC	Direction of Urbanism and Construction
EGSA	Establishment of Management of the Airport Services
EPAL	Algiers Port Enterprise
FEMA	Federal Emergency Management Agency

INCT	National Institute of Geography and Remote Sensing
INPV	National Institute of Vegetable Protection
ISSMGE	Iinternational Society for Soil Mechanics and Geotechnical Engineering
JICA	Japan International Cooperation Agency
JMA	Japan Meteorological Agency
LCTP	Central Laboratory of Public Works
LEM	Maritimes Studies Laboratory
LNHC	National Laboratory of Housing and Construction
MATE	Ministry of Ground Planning and Environment
MHU	Ministry of Housing and Urban Affairs
MICL	Ministry of Interior and Local Collectivities
MPT	Ministry of Post and Telecommunications
MPTIC	Ministry of Post and Technologies of Information and Communication
MRE	Ministry of Water Resources
MT	Ministry of Transportation
MTP	Ministry of Public Works
ONG/NGO	Non Governmental Organization
ONM	National Meteorology Office
ONS	National Office of Statistic
ORGM	Office for Geological and Mining Research
PC	Civil Protection
PCF	Fixed Command Post
PCO	Operational Command Post
SNTF	National Railway Transportation Company
SONATRACH	National Company for Search, Production, Transportation, Processing and Commercialization of hydrocarbons
SONELGAZ	National Company of Electricity and Gas
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNII	Intervention Instruction National Unit
UNO	United Nations Organization
UPPC	Civil Protection Principal Unit
URBANIS	Planning and Urbanism Agency of Algiers Wilaya
USGS	United States Geological Survey

Technical Terms

CA	Administrative Unit
CPT	Cone Penetration Test
EMS	European Macroseismic Scale
GIS	Geographic Information System
GPS	Global Positioning System
DEM	Digital Elevation Model

DIG	Disaster Imagination Game
MMI	Modified Mercalli Seismic Intensity
MSK	Medvedev Sponheuer Karnik Seismic Intensity
ORSEC Plan	Plan of Organization of Intervention and Assistance
PDAU	Urban Planning Master Plan
PGA	Peak Ground Acceleration
PGV	Peak Ground Velocity
POI	Intervention Organization Plan
POS	Ground Use Plan
PPI	Intervention Particular Plan
RC	Reinforced Concrete
Sa	Spectral Acceleration
SAR (MDN)	Search and Rescue (air/mer)
SPT	Standard Penetration Test
SRTM	Shuttle Radar Topography Mission
UTM	Universal Transverse Mercator
Vs	S Wave Velocity

CHAPTER 1.

INTRODUCTION

Chapter 1. Introduction

1-1 Background

A large earthquake with a magnitude of 6.8 struck Algeria at 19:44 on 21 May 2003 (local time). The epicenter was located below the seabed, seven kilometers north of the Commune of Zemmuri in the Wilaya of Boumerdes. The tremor destroyed more than 20,000 buildings while the number of dead and injured reached 2,278 and 10,000, respectively. Some 180,000 were also left homeless.

The northern coast of Algeria abuts the Mediterranean Sea. In this area, the African and Eurasian plates push against each other resulting in increased seismic activity. As a result, the area has historically suffered from repeated earthquakes. For example, over 20,000 deaths were recorded in a major earthquake in Algiers in 1716. More recent earthquakes that have resulted in substantial damage include:

- September 9, 1954, magnitude 6.7, death toll of 1,200 with 20,000 houses destroyed.
- October 10, 1980, magnitude 7.23, death toll of 2,640 with more than 20,000 houses and buildings destroyed.

These earthquakes resulted from the activities of the two plates as mentioned above and it is estimated that similar or much larger earthquakes will occur in the future in this area.

Over seventy percent of the national population is concentrated in the northern part of the country, particularly in big cities such as Algiers, resulting in an over-populated urban environment. Furthermore, old cities developed before independence of the Democratic and People's Republic of Algeria, are characterized as having vulnerable urban conditions with congested buildings, steep local topography and narrow road systems. Political functions, economic activities and social activities are concentrated in the Wilaya of Algiers. If a large earthquake were to occur immediately below the Wilaya of Algiers, central areas of the city will be severely damaged and the national function will be severely impacted for a long period. Therefore, immediate countermeasures against possible earthquake damage should be implemented.

Under such circumstances and in response to a request by the Government of the People's Democratic Republic of Algeria, the Government of Japan has decided to conduct "A Study of Seismic Microzoning of the Wilaya of Algiers, People's Democratic Republic of Algeria" (hereinafter referred to as "the Study").

The Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of technical cooperation programs of the Government of Japan, will undertake the Study in accordance with the relevant laws and regulations in force in Japan.

1-2 Scope of the Study

1-2-1 Study Objectives

Objectives of the Study are as follows:

- To prepare seismic microzoning maps in the Wilaya of Algiers, which will be used to evaluate likely human casualties and loss of properties due to earthquakes;
- To suggest an earthquake disaster management system for the Wilaya of Algiers; and

- To pursue technology transfer to the Counterpart personnel throughout the course of the Study.

1-2-2 Study Concepts

(1) Microzoning

Results of the microzoning study, including the estimation of a detailed distribution of seismic ground motion (hazard) and foreseeable damage caused by the hazard, should be utilized to improve planning and capacity building for earthquake disaster management. The study therefore consists of the following six (6) steps.

Step 1 : Collection, analysis and evaluation of existing data on topography, geology, soil condition, population, buildings, disaster-related facilities, etc.

Step 2 : Investigation of ground and building conditions.

Step 3 : Database development and analysis based on GIS.

Step 4 : Analysis of earthquake motion for estimation of ground motion in each grid cell, after establishing earthquake models and parameters through examination on historical earthquake activities, records of recent earthquake activities, and location of active faults.

Step 5 : Estimation of seismic hazards (seismic ground motion) and damage (building damage, casualty, liquefaction, slope failure, etc.) in each grid cell.

Step 6 : Compilation of hazard and damage maps.

(2) Proposals for vulnerability analysis and retrofitting of strategic buildings

The Study Team and Counterpart personnel, together with related agencies, will hold discussions and compile a proposal for seismic retrofitting of buildings based on the following five (5) steps.

Step 1 : Collection and analysis of existing data, achievements
Existing achievements of the National Earthquake Engineering Research Center (CGS) will be collected and studied. Results of a seismic performance study of existing buildings will also be fully utilized.

Step 2 : Building inventory survey
The results will be applied directly to assist in damage estimation of buildings. Typical building types will be classified into model areas.

Step 3 : Selection of buildings for seismic evaluation
Typical building types will be selected for seismic evaluation and their related information will be collected and analyzed together.

Step 4 : Seismic evaluation, design of retrofitting
Procedures of retrofitting of vulnerable building will be examined based on results of seismic evaluation. The Study Team will support CGS's initiatives through the course of these processes.

Step 5 : Proposal for seismic retrofitting of buildings

Procedures on improvement of seismic performance of buildings, which are applicable to various types and scales of buildings in the Wilaya of Algiers, will be proposed. Finally, these procedures will be compiled as recommendations to achieve a safe and earthquake-resistant urban condition.

(3) Proposals for Disaster Management Plan

Key issues to achieve enhancement disaster management capability are as follows:

- To construct a framework for a disaster management system. This will consist of a vertical inter-administrative system (central government, provincial government of the Wilaya of Algiers, Communes, communities, and others) and horizontal inter-organizational system (related national departments and agencies, organizations and research institutes, and others).
- To define those functions and responsibilities.

Figure 1-1 shows the framework of earthquake disaster management activities together with the disaster management cycle. There are three (3) components, namely: 1) emergency response and relief; 2) rehabilitation and reconstruction; and 3) mitigation and preparedness. These shall be examined in detail and balanced to define a functional disaster management plan. In particular, regional characteristics of the Wilaya of Algiers will be considered in the plan.

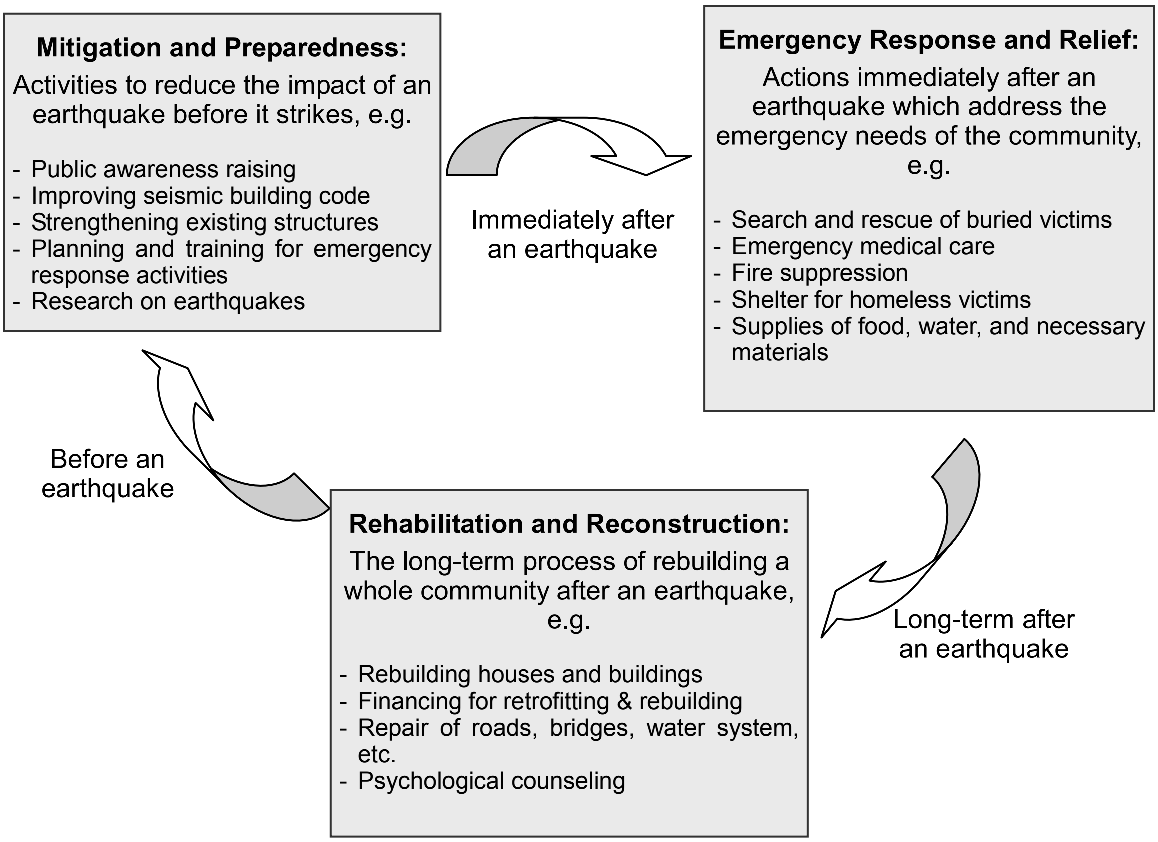


Figure 1-1 Framework of Earthquake Disaster Management Activities

Therefore, this study consists of two (2) components. One is the study of current disaster management capacity and the other is a proposal for enhancement of disaster management capacity. The former includes evaluation of disaster management resources, strategies, legal frameworks, existing plans, institutional frameworks, materials and previous activities at central and local government levels as well as at the community level. The disaster management cycle and cooperation among all levels should be considered as key elements in the proposal.

1-2-3 Study Area

The study area covers the Wilaya of Algiers and the microzoning mapping covers a total of approximately 225 km^2, including the surrounding urbanized area, as shown in Figure 1-2.

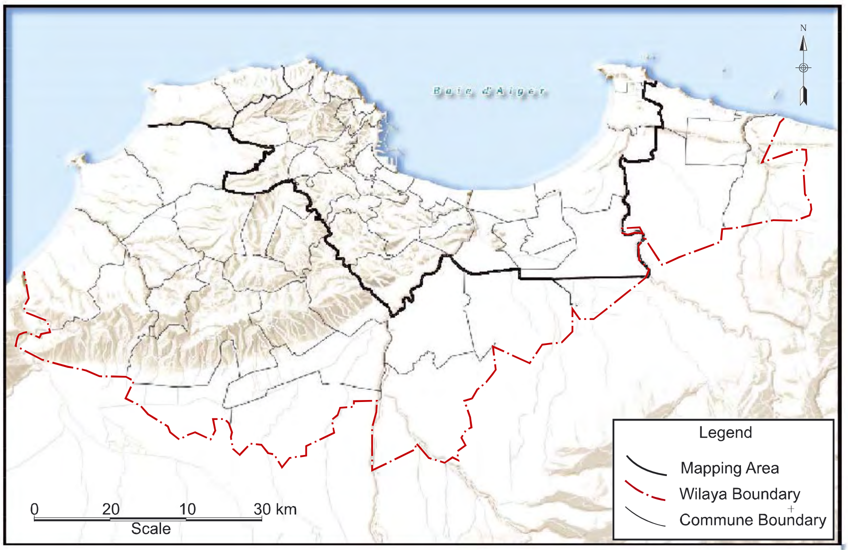


Figure 1-2 Map of the Study Area

1-2-4 Schedule of the Study

The Study comprises three phases as follows; the overall schedule is shown in Figure 1-3.

1st Phase : Data collection (February 2005 to August 2005, 7 months)
2nd Phase : Data analysis (September 2005 to March 2006)
3rd Phase : Preparation of microzoning maps and evaluation of vulnerability (April 2006 to December 2006)

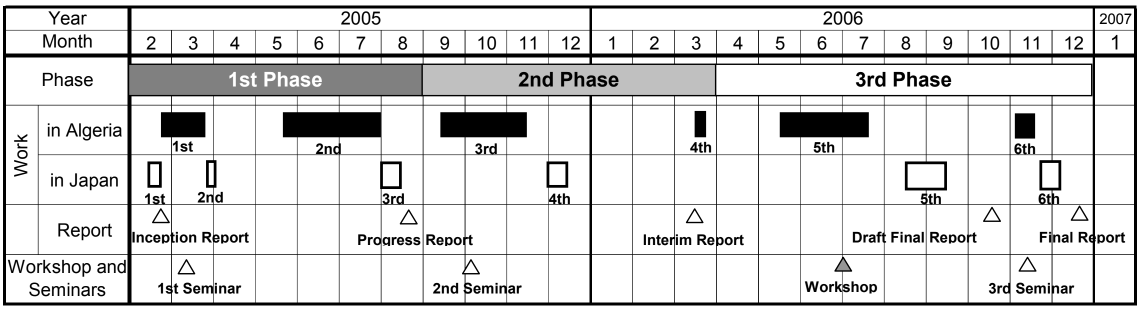


Figure 1-3 Overall Schedule

Figure 1-4 outlines the work items (Tasks) in the three phases. In August 2005, a Progress Report describing the work performed in the 1st Phase was submitted. In March 2006, a Interim Report summarizing the work in the 1st and 2nd Phase was submitted as scheduled.

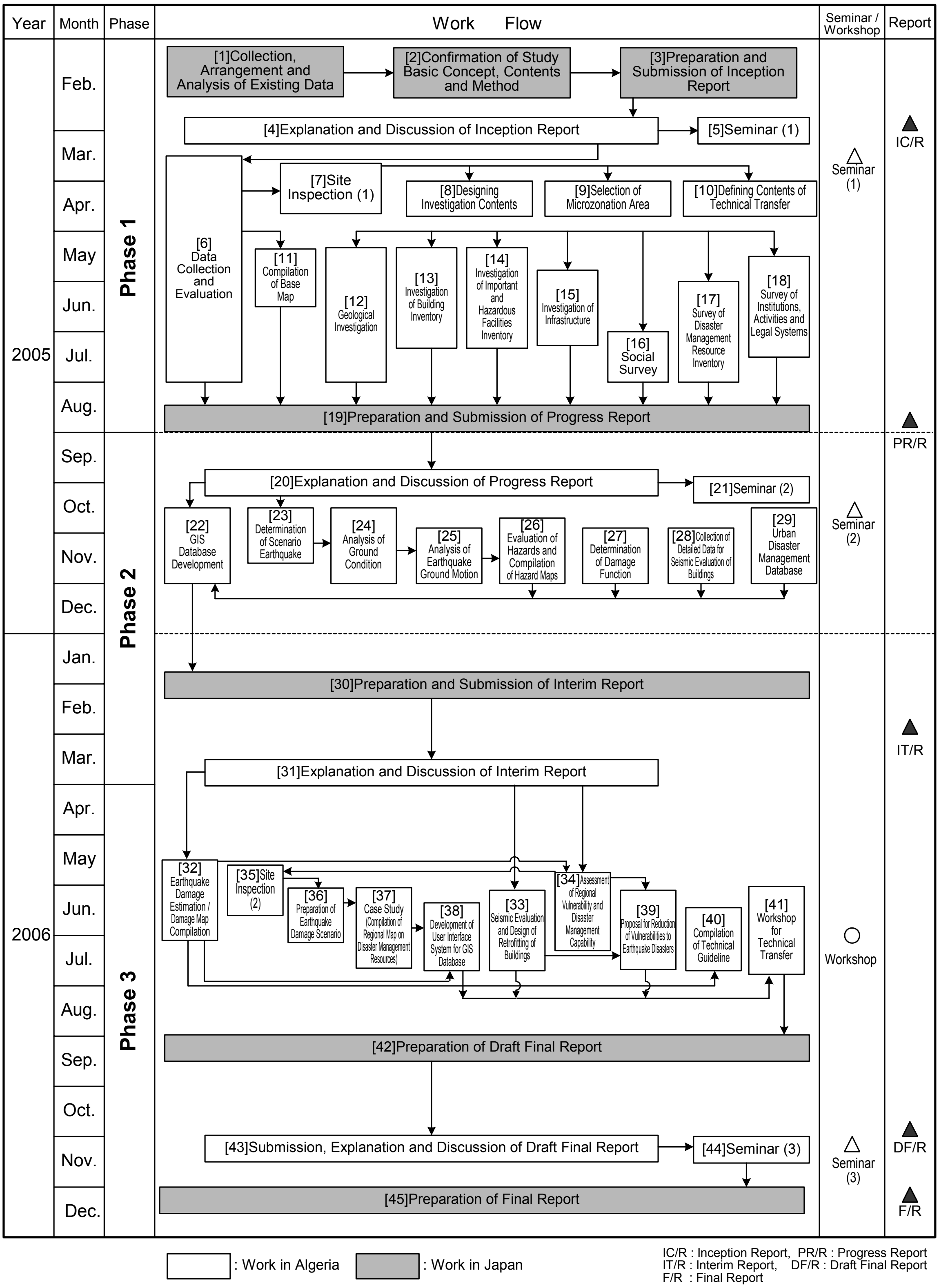


Figure 1-4 Work Schedule

1-2-5 Implementation Organization

The Study has been conducted through the joint efforts of the JICA Study Team and Algerian counterparts, which together have formed a study implementing body as shown in Figure 1-5.

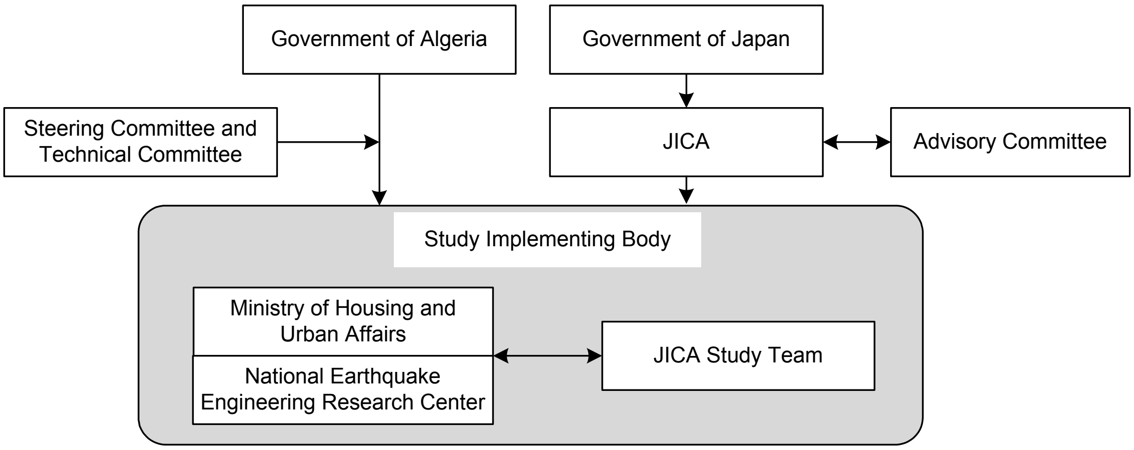


Figure 1-5 Organization for the Study

The members of the implementing body are as follows:

JICA Study Team

Name	Specialization
Mr. Osamu NISHII	Team Leader / Damage Estimation
Mr. Kenji YANO	Deputy Team Leader / Administration for Disaster Prevention
Dr. Pierre MOUROUX	Organization / Institution
Dr. Thierry WINTER	Seismology 1
Dr. Guillaume BERTLAND	Seismology 2
Mr. Jun MATSUO	Geology
Mr. Shukyo SEGAWA	Geotechnics
Mr. Hideo KAGAWA	Building Evaluation 1 (Earthquake resistance / Reinforcement)
Mr. Akira INOUE	Building Evaluation 2
Mr. Ryo MIYAZAKI	Infrastructure Evaluation
Mr. Kenichi TANAKA	Urban Prevention / Regional Planning
Dr. Philippe MASURE	Urban Prevention / Social Aspect
Mr. Daisaku KIYOTA	GIS / Database
Mr. Norihiko IGUCHI	Interpreter (Japanese/French)
Mr. Chihiro NISHIWAKI	Operational Coordination

Counterparts

Name	Organization
Dr. Mohamed FARSI	CGS
Mr. Djamel MACHANE	CGS
Mr. Youcef BOUHADAD	CGS
Mr. Hamou DJELLIT	CRAAG
Mrs. AIT BENAMEUR	CGS
Mr. Noureddine MEZOUER	CGS
Mr. Mourad AIT AMER	CGS
Mr. Abderrahmane KIBBOUA	CGS
Mr. Mehdi HADAD	INCT
Ms. Samira SADDI	CGS
Mr. Mehdi BOUKRI	CGS
Mr. M'Rizek KEFFOUS	DGPC
Ms. Rachida DOUAR	URBANIS
Mr. Youcef MEHANI	CGS
Mr. Abdelkader REMAS	CGS
Mr. Kamel NASRI	MHU
Mr. Mohamed AMRANE	DUC

For guidance and advice to the Study, JICA formulated an advisory committee comprising three members. In Algeria, a steering/technical committee has been organized to provide guidance/advice, assist in data collection, and to discuss earthquake disaster management.

JICA Advisory Committee

Name	Occupation
Dr. Kimiro MEGURO	University of Tokyo, Institute of Industrial Science International Center for Urban Safety Engineering
Mr. Mizuo INUKAI	Division Head, Evaluation System Division, Research Center for Land and Construction Management, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport
Mr. Kenji KOSHIYAMA	Disaster Reduction and Human Renovation Institution

Steering/Technical Committee

Ministry of Housing and Urban Affairs (MHU)
National Earthquake Engineering Research Center (CGS)
Ministry of Interior and Local Collectives
Ministry of Foreign Affairs
Ministry of Land Management and Environment
Ministry of Finance
Local Government of Algiers Wilaya
National Center for Research in Astronomy
Astrophysics and Geophysics (CRAAG)
National Institute of Cartography and Remote Sensing (INCT)
Civil Defense General Directorate (DGPC)
National Council for Geographical Information (CNIG)

1-3 Major Activities of the Study

The major topics included in the Study are summarized in Table 1-1.

Table 1-1 Major Activities of the Study

Date	Activity
26th February 2005	Commencement of the Study in Algeria
26th and 27th February 2005	1st steering committee meeting on Inception Report
1st March 2005	Exchange M/M on Inception Report
Early March	Commencement of data collection
15th March 2005	Determination of the Study Area
17th March 2005	1st Seminar in MHU Auditorium Objectives: Introduction of microzoning technology, analysis procedure and its application Contents: Explanation on basic concepts of microzoning Introduction of microzoning study in other cities
25th March 2005	Completion of 1st work in Algeria
22nd May 2005	Commencement of 2nd work in Algeria
Early June 2005	Commencement of various site investigations Geological investigation Building inventory Important and hazardous facilities inventory Investigation of infrastructure Social survey Disaster management resource inventory Institutions and legal systems
27th July 2005	2nd steering committee meeting on the progress of the Study
29th July 2005	Completion of 2nd work in Algeria
17th September 2005	Commencement of 3rd work in Algeria
3rd October 2005	2nd Seminar in Hotel El Aurassy Objectives: Develop understanding of microzoning technology, analysis procedure and its application Contents: Explanation of study results for the first stage survey Objective and procedures of microzoning study
Early November	Completion of various site investigations
13th November 2005	Completion of 3rd work in Algeria
18th March 2006	Commencement of 4th work in Algeria
19th March 2006	3rd steering committee meeting on the Interim Report of the Study
22nd March 2006	Completion of 4th work in Algeria
12th May 2006	Commencement of 5th work in Algeria
4th June 2006	4th steering committee meeting on technology transfer
12th June 2006	1st workshop (DIG)
20th June 2006	2nd workshop (DIG)
8th July 2006	Submission of revised Interim Report
9th July 2006	Completion of 5th work in Algeria

CHAPTER 2

DATA COLLECTION AND GIS DATABASE DEVELOPMENT

Chapter 2. Data Collection and GIS Database Development

2-1 Design of GIS Database

An earthquake is an unpredictable natural disaster which destroys buildings, roads and other infrastructure, and can cause the loss of city functions and human life in an instant. Although it is virtually impossible to predict the exact time when the hazard will happen, we can determine the relative probability of the occurrence of an earthquake. Thus, proper preparation is essential in earthquake zones like Algeria and Japan.

To reduce the risk of seismic hazard, it is very important to have realistic images of the hazard so that it is possible to make suitable preparations and take appropriate actions when the hazard happens.

Being aware of the possible consequences of a seismic hazard will drive people to prepare properly.

Hence, GIS is the most appropriate of tools to perform the things mentioned above and suitable designing of the contents of the GIS database is essential for the system itself.

2-1-1 Design of Geographic Database

A Geographic Information System (GIS) is a kind of database system which links various types of information using geographically referenced electronic maps as the key interface. It helps us to understand what is happening in the real world by compiling scattered, unlinked information together, which requires a great deal of time and expertise to do without GIS.

A GIS database has a large volume of data and requires a specific structure; thus, the architecture and data modeling have an enormous influence on its performance, maneuverability and functionality.

2-1-2 Base Map; Topographic Data Arrangement

The topographic information resources we have utilized for the basis of this study are as follows:

1) 1:7,500 topographic maps covering part of the study area (7 sheets)
2) 1:10,000 topographic maps covering part of the study area (14 sheets)
3) 1:25,000 topographic maps covering the study area (13 sheets)
4) SRTM (Shuttle Radar Topography Mission; NASA) height information covering the study area
5) LANDSAT (NASA; supplied by the USGS) images covering the study area
6) Administrative boundary information (MapInfo data format) supplied by INCT & URBANIS

To create the base map for this study, rectification and georeferencing of the scanned topographic maps and digitization of the administrative boundaries with the interpretation and compilation of the supplied information have been carried out. SRTM and LANDSAT images have also been georeferenced and transformed to "North Sahara 1959 Datum", which is adopted in

Algeria. For the slope and height information, a digital elevation model (DEM) covering the study area is scheduled by INCT.

(1) Items to be Constructed for This Study

For this study, the study team planed to construct the following items for the GIS database as the foundation of analysis while considering the necessity and the availability of the existing resources.

Items:

1) Municipality (Commune boundaries)
2) Geology
3) Resources for disaster prevention
4) Slope (height and slopes of the surface)
5) Buildings
6) Road Networks
7) Rail Roads
8) Power Lines (electric power)
9) Gas Pipes
10) Water Supply System
11) Sewage System
12) Phones (fixed-lines, mobile bases)

(2) Issues Solved

Designing the GIS database required proper understanding of the difference between the way between human beings and the GIS interpret cartographic elements as geographic objects. From this stand point, collected information had been assessed and the following measures had been implemented for maximum utilization.

1) Missing Information

The most important and beneficial function of the GIS is its ability to form the platform for many kinds of information that helps us understanding scattered, differently shaped information. To have this functionality, it is essential to have the basic descriptive information, like conditions, as the information acquired, geographic projection, criteria of acquiring geographic objects and so on.

Those are essential; however, not enough information could be obtained from the existing material for this project. After a precise assessment of the information supplied, the study team decided to use the orthophoto data supplied by INCT as the key map for this project because of its consistency with other information supplied. Yet, absolute coordinates can not be derived from this because of the deficiency of information described above and inconsistent deviations in the coordinates can be seen between it and the USGS supplied LANDSAT ETM (mosaic, 2002) image.

2) Topology

The common issue of designing and constructing a GIS database is the requirement for the particular data model “Topology”, while the human brain can interpret the simple cartographic elements properly with analogical reasoning based on its own experience.

(A) Recognizing Connections

In a case like that shown below, a person will recognize that the two lines are connected, but the computer can not make this interpretation unless nodes and arcs are properly attached.

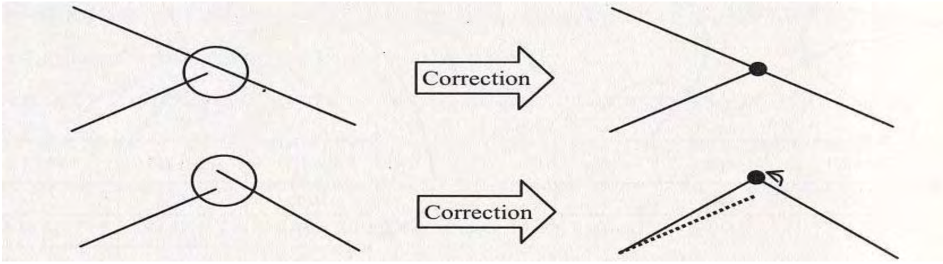


Figure 2-1 Connections

(B) Recognizing Intersections

In a case like that shown below, a person will recognize that the two lines intersect each other, but the computer can not make this interpretation unless nodes and arcs are properly attached.

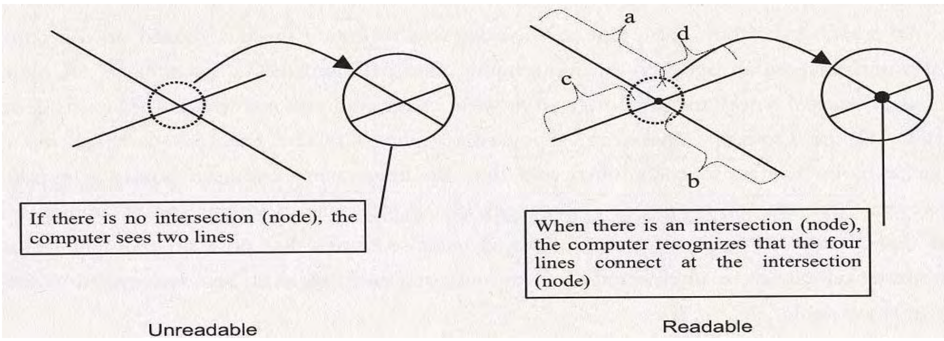


Figure 2-2 Intersections

(C) Recognizing Areas

In a case like that shown below, a person will recognize that the figure represents an area, but the computer can not make this interpretation unless nodes and arcs are properly attached.

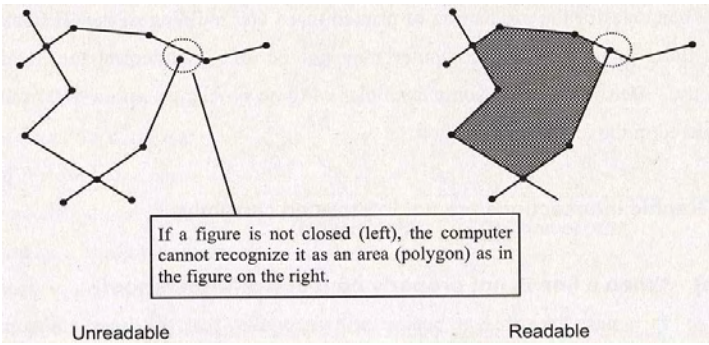


Figure 2-3 Areas

3) Different Criteria

Interpretation of the geographic objects should follow certain criteria such as the type of geographic objects that should be acquired and their format, for each project. However, no descriptive materials can be obtained and irregularities can be seen in the collected material especially between communes.

(3) Data Collection and Creation

1) Buildings

Shared building walls is an exceptional characteristic in the study area. First, the boundary of a collective body of buildings was constructed from the information supplied and lines were added afterward for partitioning each building as in the following figure with no topologic information. Therefore, the study team performed the following corrections.

- Closing areas by adjusting the starting point and endpoint and adding nodes.
- Adding nodes for the lines which represent the boundaries of building units.

2) Road Network

The edge of the road boundary is composed of the edge of several geographic objects and the combination of this is irregular and no documentation has been obtained. Manual extraction of the related edges and modification was performed for the creation of the road polygons which enabled us to construct the road center lines. Calculation of the center line has been performed where the deviation of width was relatively small. In other areas where the deviation cannot be ignored, or cross section, we performed manual modification and calculation of the width.

3) Edge Matching

Digitization has been performed frame to frame in most cases. Thus perfect consistency between frames could not be secured. Hence, edge matching has been performed to secure consistency of the GIS database for this project as depicted following. Then, the topology was reconfigured to update the connecting relations of adjacent figures, while the attribute data of the figures were also automatically updated.

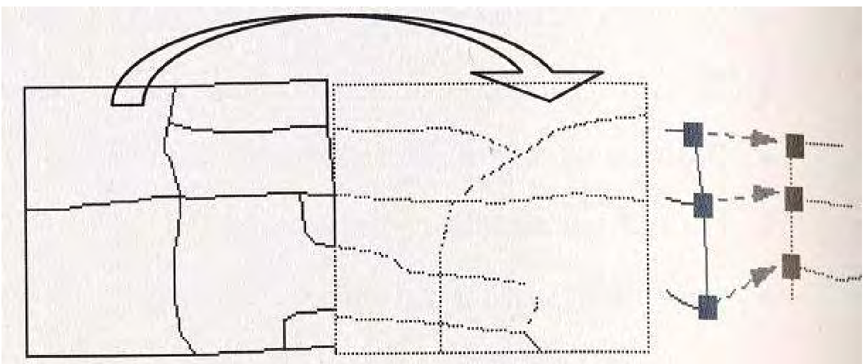


Figure 2-4 Edge Matching

2-1-3 Database for Urban Disaster Management

The GIS database for this study aimed to be the platform for various types of information, with the ability to compile, update and better utilize information. For this stage of the study, we have carried out the georeferrencing and transforming of corrected information to unify the separately created information. To create a solid basis for this platform, we have used the following parameters:

North Sahara 1959 UTM Zone 31N
Projection: Transverse Mercator
Project Easting: 500000.000000
Project Northing: 0.000000
Central Meridian: 3.000000
Scale Factor: 0.999600
Latitude of Origin: 0.000000
Angular Units: Degrees (0.017453292519943299)
Prime Meridian: Greenwich (0.000000000000000000)
Datum: North Sahara 1959
Spheroid: Clarke 1880 RGS
  Semimajor Axis: 6378249.144999999600000000
  Semiminor Axis: 6356514.869549775500000000
Inverse Flattening: 293.464999999999970000

The outline of the created GIS database items in this stage is described as follows:

Administrative Boundary
Microzonation (Grid data)
Slopes
Geology
Buildings
Road Network
Rail Roads
Infrastructure networks (power lines, water supply, sewage, gas lines, and phone lines)
Water bodies

Furthermore, the conceptual architecture of this database is described as follows:

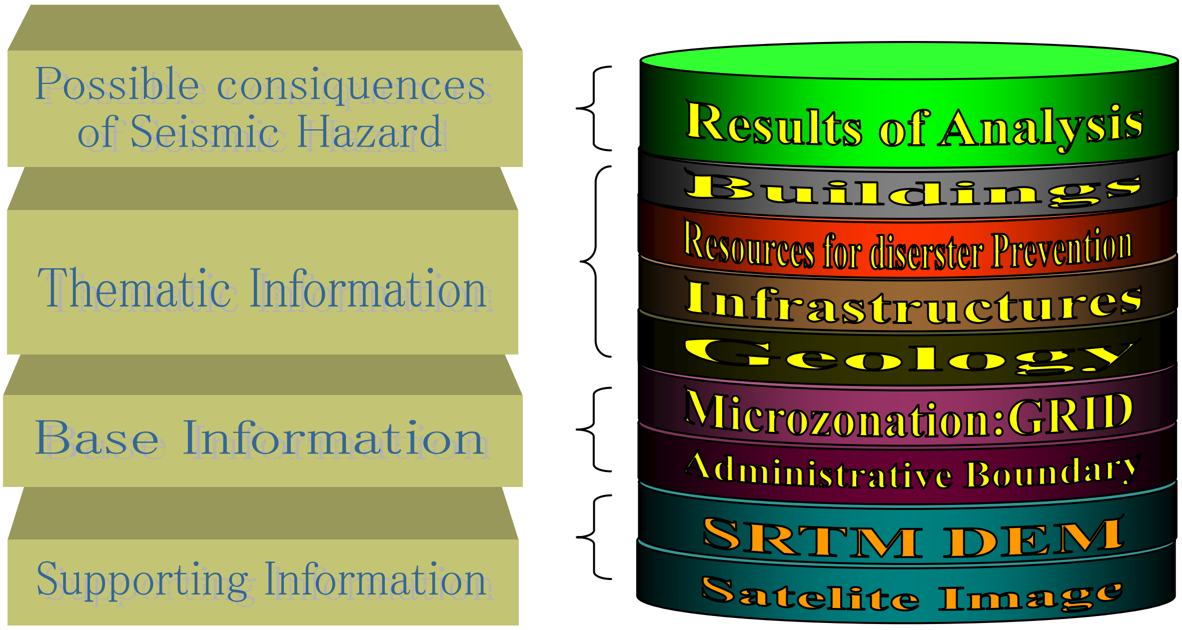


Figure 2-5　Conceptual Database Schematic

2-2　Data Collection and Input

2-2-1　Topography and Geology

(1)　Topography

INCT publishes topographic maps at several scales.　The Study Team purchased 1:10,000 and 1:25,000 scale maps:

1)　1:10,000 Scale

- year published: unknown (probably older than 1:25,000 scale map)
- contour interval: 5 m or 2.5 m
- area: 4 maps cover about 70% of the study area

2)　1:25,000 Scale

- years published: 1986, 1987
- contour interval: 5 m
- area: 8 maps cover all of the study area

Figure 2-6 is an index of these maps.

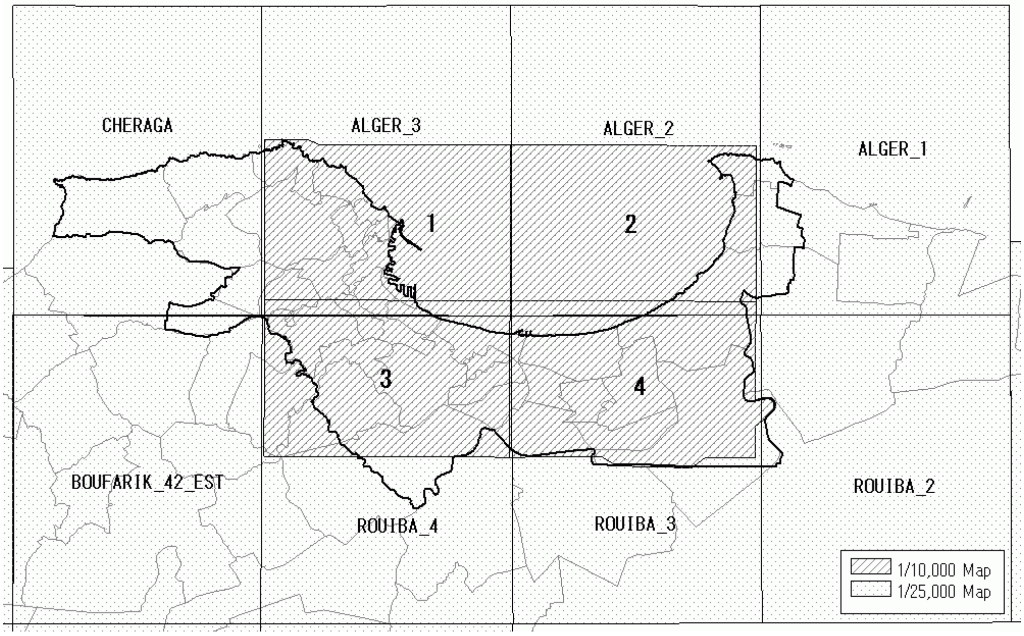


Figure 2-6 Index of Topographic Maps

The Study team digitized the contour lines of the 1:10,000 scale maps and created DEM (Digital Elevation Model) data.

(2) Elevations

The 5-m interval of the DEM data (Figure 2-7) was provided from INCT in the middle of May 2006. Since some errors were found in the data—such as artificial noise, building elevation instead of ground elevation, negative elevations in coastal areas, etc.—the elevation obtained from the 1:10,000 topographic maps was used alongside the DEM from INCT in the hazard analysis.

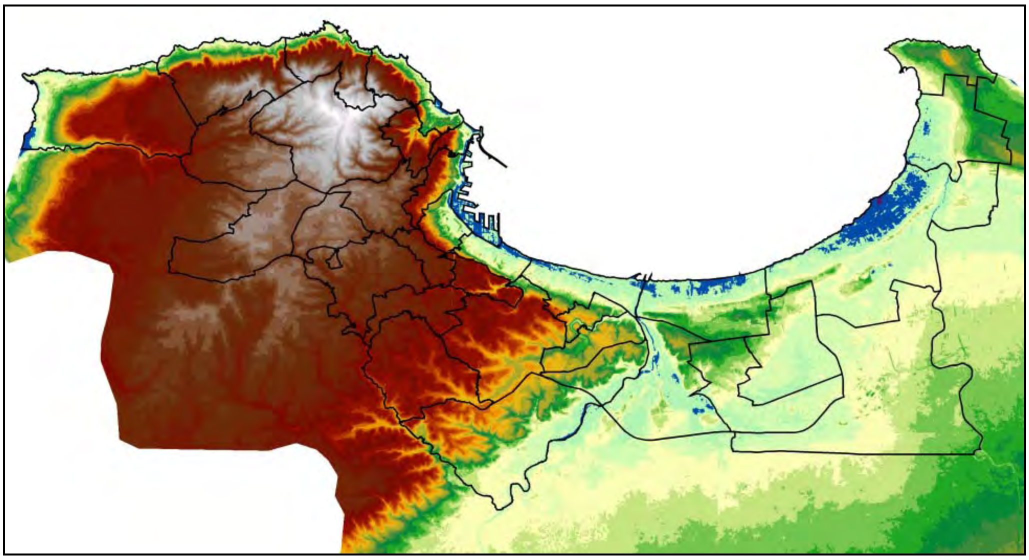


Figure 2-7 Digital Elevation Model

(3) Geology

The following 1:50,000 scale printed maps cover the study area; however, some of them are very old:

- No.20 CHERAGA,	published in 1963
- No.21 ALGER,	published in 1964
- No.22 MENERVILLE,	published in 1895
- No.40 KOLEA,	published in 1901
- No.41 ARBA,	published in 1935
- No.42 PALESTRO,	published in 1895

Of these, "CHERAGA" and "ALGER" are available in printed maps and only low resolution copies are available for the other very old maps. The definitions of the geological classifications are not uniform within these maps and many geological boundaries show large discrepancies at the boundaries of these maps. Based on the literature and discussions with geologists in CGS, the study team interpreted these maps and created total geological classifications and distributions in the study area. The unified geological map was digitized and GIS data was created. The resulting geological map is shown in Figure 3-19.

2-2-2 Buildings and Important Hazardous Facilities

(1) Buildings

1) Classification of Buildings

Buildings in Algiers are classified by structural type, year of construction and other aspects as outlined below.

(A) Structural Type

Masonry structures prevailed for buildings in ALGER CENTRE, CASBAH and adjacent areas during the first half of the 20th century. Reinforced concrete structures with un-reinforced hollow brick walls became more typical post-1960 in Algiers.

Most existing buildings in Algiers are reinforced concrete or masonry structures. Steel structures are less numerous but it is noted that a few high-rise housing complexes with approximately 15 stories were constructed in the 1950s.

a) Reinforced Concrete (RC) Moment Frames

Reinforced concrete moment frame structures consisting of columns and beams are one of the typical structures. Un-reinforced hollow brick work is usually used for external and internal walls. This structure was limited to 6 stories and 20 m in height in Algiers after 1999, and has been further limited to 2 stories and 8 m in height in Algiers since 2003.

b) Reinforced Concrete (RC) Moment Frames with RC Shear Walls

Reinforced concrete shear walls are provided with reinforced concrete moment frames. It is requested that RC moment frames be adopted for buildings of 3 stories and more than 8 m in height in Algiers on and after 2003. Concrete core, dual systems and box systems are included in this type of structure.

c) Reinforced Concrete Shear Walls without Moment Frames

This is one of the typical structure types used for medium height housing.

d) Steel Moment Frames

Steel moment frame structures consist of steel columns and beams. Some buildings are constructed using this structural system. Some medium to high-rise houses are constructed using this structural system with steel columns and beams being encased with concrete without reinforcing bars for fire resistance and durability.

e) Steel Moment Frames with Bracing

Steel moment frames with bracing are constructed to carry horizontal loads.

f) Masonry Structures

Masonry structures consist of stone or brick and mortar for walls and columns. Steel or timber floor beams are generally used to support the floor. This type of structure has a long history, and was a typical structural type before the seismic code was introduced in 1955. Existing masonry buildings still commonly serve as governmental office buildings, private housing and for other uses. A construction of tied (confined) masonry was limited to 4 stories in Algiers before 2003, and 3 stories in Algiers 2003 and after.

g) Others (Hollow Concrete Block and Wooden Frame)

A few buildings are constructed based on a hollow concrete block structure or wooden frames; a seismic design code is generally not applied.

Examples of each structure are shown in Figures 2-8 to 2-11.

(1) Housing with Crawl Space

(2) Commercial and Housing

(3) School

Figure 2-8 Reinforced Concrete Structures

(1) Housing

(2) Office

(3) Under Construction

Figure 2-9 Steel Structures

(1) Commercial and Housing

(2) Housing

(3) Housing

Figure 2-10 Masonry Structures

(1) Barrack Housing

Figure 2-11 Hollow Concrete Block Structures

(B) Year of Construction

Buildings are classified by their year of construction and based on the particular period that a new seismic design code and a related regulation was introduced and applied in Algeria.

Year of construction for existing buildings are divided into five periods, namely on and before 1955, 1956 ~1980, 1981 ~ 1999, 2000 ~ 2002 and 2003 and after. This category has been simplified into three periods, 1980 and before, 1981 ~ 2002, and 2003 and after.

(C) Other Aspects

Existing buildings in Algiers are not necessarily engineered buildings with respect to the application of a seismic code or quality control during construction. It was determined that most private buildings are non-engineered buildings, and seismic capacity is relatively low even for those built in 1981 or after.

a) Application of seismic design codes

It is said that difficulties were faced in implementing the seismic design code, particularly for buildings of private owners. All buildings constructed before 1981 and the majority of buildings by private owners after 1980 were not based on a seismic-resistant design. The seismic design code (RPA2003) is an obligation applying to buildings of private owners from 2003. These private buildings are mainly reinforced concrete structures, and buildings constructed before 2003 are generally evaluated as non-engineered buildings.

b) Quality control during construction

It is generally understood that the seismic quality of a building depends on seismic design, structural materials and workmanship. Buildings without quality control during construction are also generally evaluated as non-engineered buildings. It is noted that low strength of concrete and inadequate re-bar arrangement were observed in the field survey following the 2003 Boumerdes earthquake. A review of completeness of design documents and inspection during construction by CTC has been requested to maintain the structural quality for public buildings built in 1981 and after, and also for private buildings built since the beginning of 2003.

c) Irregularities

Buildings with irregularities reduce their seismic capacity. For example, there are some buildings with a crawl space, which is approximately 1 m high under the 1st floor for maintenance of plumbing (Mechanical & Electrical piping) works. These buildings have short reinforced concrete columns in the crawl space, and are evaluated as having low seismic capacity due to shear failure.

2) Seismic Design Codes for Buildings

A brief history and the contents of seismic design codes to date that were obtained through a review of seismic design codes and an interview with Counterparts is presented below.

There was no official seismic design code in Algeria before 1955.

AS55 was introduced in 1955 and PS62 to PS69 were introduced in 1962 and 1969 respectively. These were guidelines and recommendations only; they were not a requirement for the design of buildings.

The first code of Algerian Earthquake Design Requirements (RPA) appeared as RPA81 in 1981 after the earthquake disaster of El Asnam on October 10 1980. This was revised in 1983 as RPA83. RPA81 and RPA83 and were requirements for public buildings but not for private buildings.

RPA99 was introduced in 1999. 'Elastic behavior of a structure while facing a relatively frequent moderate seismic event' and 'no collapse or loss of stability while facing a rare major seismic event' were outlined as the objectives of the code. Seismic design code RPA99 was revised as RPA2003 through changes in seismic zones, with higher design accelerations in Algiers after the earthquake disaster of Boumerdes on May 21 2003.

～1955 : There was no seismic design code in Algeria.
Some buildings were constructed utilizing the seismic design code of France.

1956～1980 : AS55 was introduced in 1955, and seismic load was shown as a static horizontal load (dead load x coefficient). PS69 was introduced in 1969; however, this was not obligatory and was not applied to ordinary buildings. Most buildings were constructed without seismic design.

1981～1999 : El Asnam earthquake occurred on October 10 1980.
After the earthquake, RPA81 (revised in 1983) and RPA88 were introduced. There were three seismic zones, namely zone I (low seismicity), zone II (moderate seismicity), and zone III (high seismicity). Wilaya Algiers was located in zone II.
There were three groups for zone acceleration coefficients, group 3 (0.10, low importance), group 2 (0.15, moderate importance) and group 1 (0.25, high importance) in zone II; the importance factor is included in the zone acceleration coefficient.
These design standards were obligatory for all public buildings but not for private buildings. Inspections of building construction for public buildings were performed by CTC (Organization for Construction Technology Control) established in 1971.

2000～2002 : RPA99 was introduced. Seismic load was increased.
The number of groups for zone acceleration coefficients was increased from three to four and included group 3 (0.10, low importance), group 2 (0.15, moderate importance), group 1B (0.20, high importance), and

group 1A (0.25, vital importance). The zone acceleration coefficient in Algiers is 0.15 in the case of a moderately important building.
Dynamic Amplification Factor D was revised (increased) from 2.0 to 2.5. However, RPA99 was not obligatory for private buildings, and inspections of building construction by CTC for private buildings were not generally done.

2003～ : The Boumerdes earthquake occurred on May 21 2003.
A revision of RPA99 was introduced as RPA2003 soon after the earthquake. It was obligatory for private buildings for the first time. The seismic zone of Algiers was changed from II to III, and the zone acceleration coefficients were also revised to: group 3 (0.18), group 2 (0.25), group 1B (0.30), and group 1A (0.40). In the case of moderately important buildings, the zone acceleration coefficient in Algiers was increased from 0.15 (RPA99) to 0.25 (RPA2003).
All private housing units were required to proceed with seismic design in order to obtain building insurance in September 1 2004.

Seismic design loads for buildings in Algiers by seismic design codes RPA81 (revised in 1983), RPA88, RPA99 and RPA2003 are summarized in Table 2-1. The details of AS55 and PS69 were not provided.

Peak ground acceleration (PGA) for design is 0.15G for RPA83, RPA88 and RPA99, and 0.25G for RPA2003. This PGA for design is not the same as the static seismic design load coefficient for buildings.

For example, the lower limit static seismic design load (base shear) coefficient in the case of 3 to 4 storey reinforced concrete moment frames with moderate importance, which seems to be a typical building, is calculated as 0.075 (RPA83), 0.075 (RPA88), 0.11 (RPA99) and 0.16 (RPA2003).

The seismic design load coefficients by PS69 of buildings similar to the above are calculated to be approximately 0.08 to 0.12. These changes depend on building foundation type, according to the JICA Study Team Report for the 1980 El Asnam Earthquake (in Japanese) dated October 1981.

It is noted that the expected ductility is relatively high for reinforced concrete moment frames, since a required ductility factor μ of more than eight is necessary where a Behavior Factor R of 4 (RPA99) or Structural Component Factor 1/4 (RPA83) is used (as calculated by Newmark's formula $R = \sqrt{(2\mu-1)}$). It is generally estimated that static the seismic design load coefficient for buildings with moderate importance in each code is too small in comparison to the intended design load corresponding to the value of design PGA in each code.

In terms of the requirements for reinforced concrete structures, a) 25 cm was specified as the minimum size of columns in Algiers in RPA83, and was revised to 30 cm in RPA2003 through the change of zoning from II to III for Algiers, b) RPA83 specified that main reinforcing bars must make up a minimum of 1% of the total cross sectional area of columns. This was revised to 0.8% in RPA88, and to 0.9% in RPA2003 through the change of zoning from II to III for Algiers, c) 15 cm was specified as the minimum interval of hoop reinforcing at the top and bottom of columns for Algiers in RPA83, and was revised to 10 cm in RPA2003 through the change of zoning from II to III for Algiers, d) the axial force ratio for columns can not be greater than 0.30 against seismic load to provide ductility according to RPA99.

Regarding the seismic joint condition, the minimum width of seismic joints for two adjacent buildings, d ≥ H1/300 and 2 cm (H1: building height) was specified in RPA83, and d =15 mm+δ1+δ2 ≥ 40 mm (δ1, δ2: maximum displacements of two blocks) was specified in RPA99 for reinforced concrete structures.

As far as the requirements for tied masonry structures in RPA2003, a) Sections of bearing walls can not be less than 4% of floor area in both directions, b) Walls must have a minimum thickness of 20 cm and maximum distance is 6 m in zone III (Algiers), c) Minimum mortar compression strength is 5 Mpa (51 kgf/cm^2), d) Horizontal and vertical wall ties are required.

Table 2-1 Summary of Design Loads for Buildings in Algiers by Seismic Codes

Code	Static Seismic Load: V	Zone Acceleration Coefficient: A	Dynamic Amplification Factor: D	Quality Factor: Q	Behavior Factor: R Structural Component factor: B	Application of Code
RPA2003	V=(ADQ/R)xW	ZoneⅢ (Algiers) Group1A: 0.40 Group1B: 0.30 Group2: **0.25** G3: 0.18	**2.5** in case: 0<T<0.3(S1) : 0<T<0.4(S2) : 0<T<0.5(S3) : 0<T<0.7(S4)	1～1.35	RC Frame 1a: 5(2 stories or 8m) RC Frame 1b: 3.5(2 stories or 8m) RC Shear Wall, Core: 3.5 RC Dual System: 5 RC Fr. w/ Wall: **4**(10 stories or 33m) Steel: 6～4～2 Tied Masonry: **2.5**(3 srtories)	Public and Private Buildings
RPA99	V=(ADQ/R)xW	Zone Ⅱ (Algiers) Group1A: 0.25 Group1B: 0.20 Group2: **0.15** Group3: 0.1	**2.5** in case: 0<T<0.3(S1) : 0<T<0.4(S2) : 0<T<0.5(S3) : 0<T<0.7(S4)	1～1.35	RC Frame 1a: 5(6 stories or 20m) RC Frame 1b: **3.5**(6 stories or 20m) RC Shear Wall, Core 3.5 RC Dual System 5 RC Fr. w/ Wall 4(10 stories or 33m) Steel: 6～4～2 Tied Masonry: **2.5**(4 srtories)	Public Buildings only
RPA88	V=ADBQW	Zone Ⅱ (Algiers) Group1: 0.25 Group2: **0.15** Group3: 0.10	**2.0** in case: 0<T<0.3(Firm) : 0<T<0.5(Soft) formula is revised	1～1.35	RC Frame 1: 1/5,**1/4** Steel Frame: 1/5 RC Frame w/ Wall: 1/4 RC Wall : 1/3 Masonry :2/3	Public Buildings only
RPA81 (ver83)	V=ADBQW	Zone Ⅱ (Algiers) Group1: 0.25 Group2: **0.15** Group3: 0.10	**2.0** in case: 0<T<0.3(Firm) : 0<T<0.5(Soft)	1～1.35	RC Frame 1: 1/5,**1/4** Steel Frame: 1/5 RC Frame w/ Wall: 1/4 RC Wall : 1/3 Masonry :2/3	Public Buildings only
PS69	$\sigma=\alpha\beta\gamma\delta$ Note 1					Recommendation only
AS55						Recommendation only

Where; V : Total Static Seismic Load (coefficient)
A : Zone Acceleration Coefficient Group 1A (Vital Importance), Group 1B (High Importance), Group 2 (Moderate Importance), Group 3 (Low Importance)
Classification of Soil: S1: Rocky, S2: Firm, S3: Soft, S4: Very Soft
D : Mean Dynamic Amplification Factor T: Natural Period in Sec.
Q : Quality Factor Q=1+Σ P(Penalty)
P1 Bracing lines : 0.05 P2. Plan redundancy : 0.05
P3 Plan regularity : 0.05 P4. Elevation Regularity : 0.05
P5 Material Quality : 0.05 P6. Construction Quality : 0.10
R : Behavior Factor for RC, Steel and Masonry B: Structural Component Factor
W : Total Weight of the Structure
Note 1: Seismic load (base shear) coefficinet is approxmately 0.08 to 0.12, by JICA Study Team Report of El Asnam Earthquake 1980
α: seismic zone coefficient β: response coefficient γ: vertical distribution coefficient δ: ground coefficient

(2) Important and Hazardous Facilities

The important facilities will be functioning strategic base buildings required for rescue and relief activities following an earthquake, and these facilities should not be vulnerable to fire or accidents after such an event. Accordingly, a survey of these must be performed to provide a statistical database for the evaluation of vulnerability in the microzoning study. The surveyor was selected based on quotations from three parties and the local subcontractor, URBANIS was proposed based on cost and ability.

CGS and the Study Team discussed and then defined the inventory survey plan for important and hazardous facilities. The result was outlined in the following Section 1). The distribution procedure is described in Section 2).

1) Plan of Important and Hazardous Facilities Inventory Survey

Based on discussions between CGS and JST, 530 of the following facilities, selected at random, were surveyed as a part of the building inventory survey.

(A) Important and Hazardous Facilities

Some 14 important and hazardous facilities in the 34 communes have a strategic disaster management function. The contents of the surveyed items are the same as those in the Building Inventory Survey, for which a total of 476 samples (facilities) were surveyed. The surveyed facilities will include:

- Headquarters of APC “Communal Popular Assembly”: 1 no.
- Primary Schools: 2 nos.
- Fundamental School: 1 no.
- High School: 1 no.
- Urban Safety Department: 1 no.
- Police box: 1 no.
- Medical Center: 1 no.
- Sports Hall: 1 no.
- Mosque: 1 no.
- Cultural Center: 1 no.
- Gas Stations: 2 nos.
- Fire Station: 1 no.

The inventory survey form is the same as the building inventory survey. Refer to Chapter 2-2-2 (1).

(B) Particular (Important and Hazardous) Facilities

Some 54 important and hazardous facilities in special communes have a strategic disaster management function and are should not be vulnerable to fire and accidents during an earthquake. As for 1), the contents of surveyed items are basically the same as in the Building Inventory Survey, with additional items on the survey form including hazardous material and its storage conditions and volume. The particular (important and hazardous) facilities in the special communes include:

- Palace of the Government: 1 no.
- Prefectural Office of the WILAYA ALGIERS: 1 no.
- Headquarters of DAIRA (for each DAIRA): 8 nos.
- Safety Department of the DAIRA (for each DAIRA): 8 nos.
- Civil Protection: 3 nos.
  PORT OF ALGIERS, SCHOOL OF EL HAMIZ and HIDRA HEADQUARTERS
- Hospitals: 10 nos.
  MUSTAPHA, MAILLOT, PARNET, BENI MASSOUS, BIRTRARIA, KOUBA, ZMIRLI, El KETTAR, AIT IDIR and BAINEM
- Universities: 11 nos.
  BAB EZZOUAR, EPAU, INA, RNS, ENA, ENTP, ENP, BOUZAREAH, FAC CENTRALE, COMMERCE TAFOURA and ISLAMIC UNIVERSITY OF CARROUBIER
- Central telephone center of AISSAT IDIR Place of 1st MAI: 1 no.
- Central Rail Station “SNTF” (national company for railways) Algiers: 1 no.
- “HOUARI BOUMEDIENE” Airport: 1 no.
- Algiers Port: 1 no.
- SENATE: 1 no.
- APN (National Popular Assembly): 1 no.
- Court of justice of Algiers: 1 no.
- Church of “NORTRE DAME D’AFRIQUE”: 1 no.
- Prison of “EL HARRACH”: 1 no.
- Museum of EL HAMMA: 1 no.
- SONATRACH of CARROUSIER (gas and oil company): 1 no.
- Mosque “KETCHAOUA” in CASBAH: 1 no.

2) Distribution of Important and Hazardous Facilities

An assessment of the distribution of important and hazardous facilities was undertaken based on discussions within the team (CGS, the Study Team and URBANIS). This process involved:

a) Selection of 14 important and hazardous facilities based on their strategic disaster management function.
b) These selected facilities are distributed across all (34) communes.
c) All facilities in each commune are assigned a number in the digital mapping system.
d) The target facilities were decided randomly.

3) Distribution of Particular (Important and Hazardous) Facilities

As noted in Section 1) (B), 54 important and hazardous facilities were selected based on strategic disaster management function.

Despite the fact that detailed census data on population and residential buildings was obtained, the total number of non-residential buildings i.e. governmental offices, offices, hospitals, schools and so on, are unknown. Therefore, the distribution of buildings was determined based on the coefficient of population in each commune.

2-2-3 Infrastructure and Lifelines

(1) Infrastructure

1) Roads

The road network information was compiled using the URBANIS data, topographic maps (1:10,000 and 1:25,000, see Figure 2-12) issued by INCT, and a schematic road map provided by DTP (see Figure 2-13). The road width and length information for the national roads and the Wilaya roads was provided by MTP. The digitized map is shown in Chapter 6.

Source: INCT

Figure 2-12 Topographic Map, Scale = 1:10,000

Source: DTP

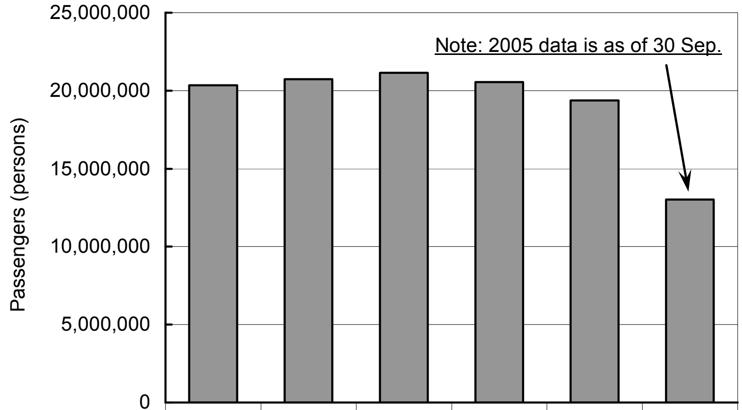
Figure 2-13 Schematic Road Map

Bridge data were compiled using the results of the bridge inventory survey conducted by a local contractor under the JST and the counterpart.

2) Railways

The length of the railway network in the Wilaya of Algiers totals 61 km. It is a double railroad with a reinforced rail type UIC 54.

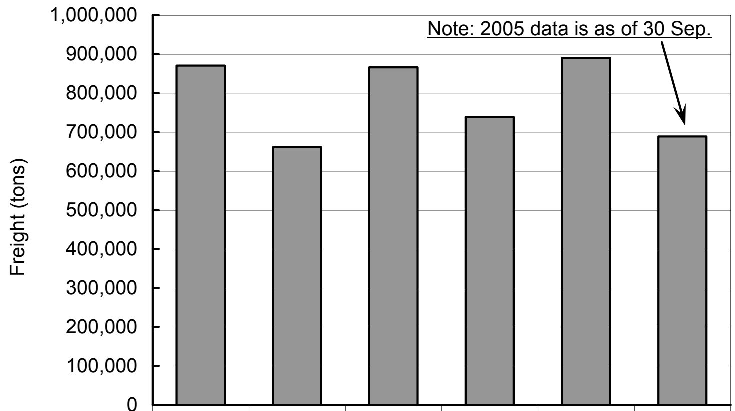
The annual number of passengers transported and quantity of freight (grains, fuel and so on) by train are shown in Figure 2-14 and Figure 2-15, respectively.



Year	2000	2001	2002	2003	2004	2005
Passengers	20,355,279	20,743,752	21,145,391	20,548,048	19,367,543	13,019,723

Source: SNTF

Figure 2-14 Annual Passengers Transported



Year	2000	2001	2002	2003	2004	2005
Freight	871,062	661,182	866,042	738,912	890,269	689,160

Source: SNTF

Figure 2-15 Annual Freight

A summary of the railway damage due to the Boumerdes Earthquake according to SNTF is outlined below.

- The railway network and bridges did not suffer heavy damage.
- The shelters of the platforms and footbridges of some railway stations were affected by cracks in some of their supporting columns and so on (Oued-smar, Bab-ezzouar, Dar-el-Beida, Rouiba, industrial zone of Rouiba, Reghaia)
- Repair works on the railway were completed within 8 hours.

- Emergency works to allow the recommencement of railway traffic on the bridges were begun within 24 hours and were completed within 2 days.
- The final reinforcing works were completed within 6 months.
- The railway did not stop for a long period due to earthquake damage, and was only closed during the nights of 21 and 22 May 2003 to allow inspection of the railway network and bridges.

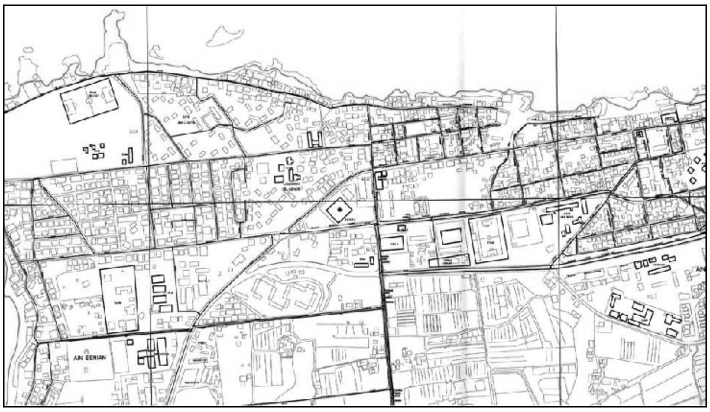
3) Ports and Airport

The layouts of the Algiers port and airport were obtained based on the URBANIS data.

(2) Lifelines

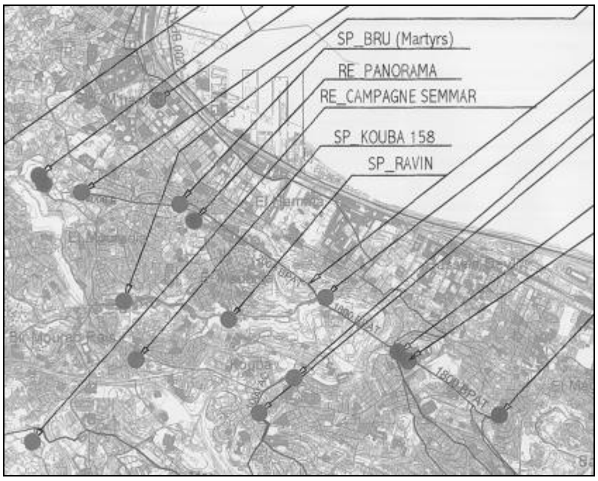
1) Water Supply

DHW provided the JST with digital data on the water supply pipelines (see Figure 2-16) and a hard copy of the water tower locations (see Figure 2-17).



Source: DHW

Figure 2-16 Example of Digital Data for the Water Supply Pipelines

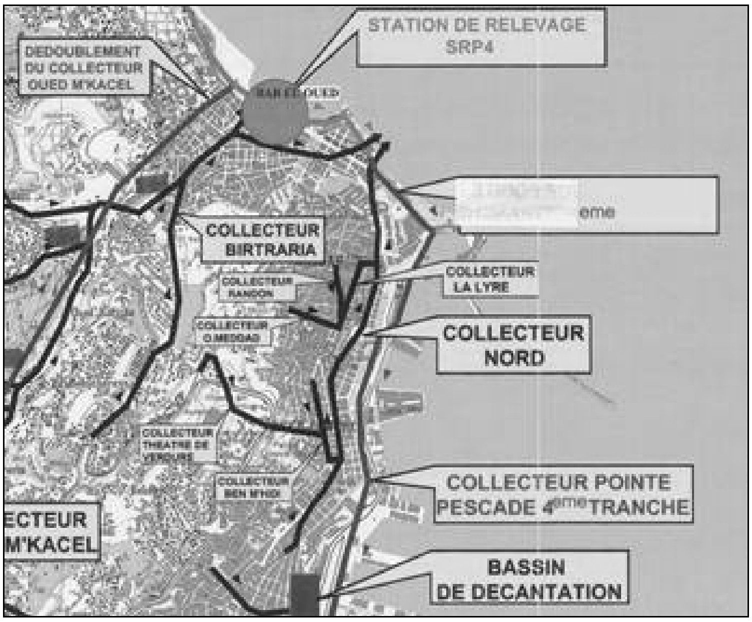


Source: DHW

Figure 2-17 Example of Water Tower Location Map

(2) Sewerage

DHW provided the JST with hard copies of the sewerage network layout (see Figure 2-18) and a summary of its components (see Table 2-2). However, the network map and the components table did not contain all information.



Source: DHW

Figure 2-18 Example of Map of the Sewerage Network

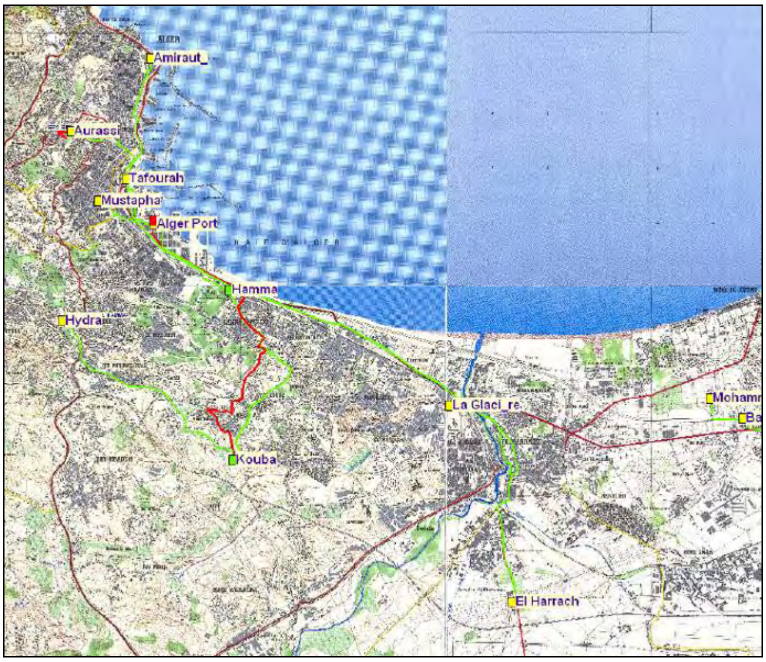
Table 2-2 Example of Summary of the Sewerage Pipeline Attributes
(extract from the list)

Area	Sewerage pipeline	Pipeline		Year Service Began
		Length (m)	Diameter (mm)	
ZERALDA	Collecteur champs de tir (Zeralda)	3,200	800, 1000, 1,200	
	Collecteur Littoral Ouest (deuxième tranche)	5,600	600, 700, 1,000	2004
	Collecteur Oued Laghar (Zeralda)	1,000	2,000	2005
STAOUELI	Collecteur Site El Djillalli	2,000	800	1990
	Collecteur Staoueli	1,000	1.2 x 0.8 m	Ancient
	Collecteur Oued Boukraa	3,000	800, 1,000, 2,000	2002 - 2003
CHÉRAGA	Collecteur Dely Brahim (Dely Brahim)	6,000	700, 800	1997
	Collecteur Cheraga I (Cheraga)	5,000	1,000, 1,500, 2,000	Ancient
	Collecteur Bouchbouk (Cheraga)	1,200	800	2001

Source: DHW

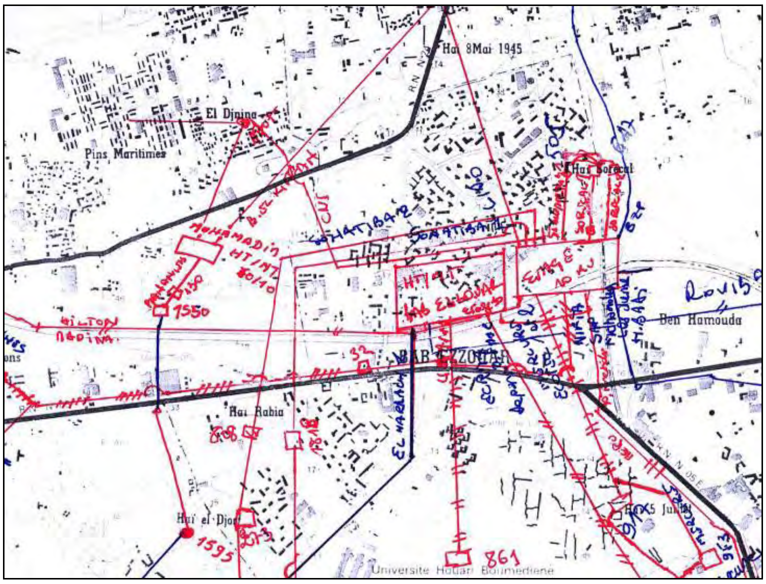
3) Electricity

Sonelgaz electricity division provided the JST with the digital data for the high voltage (220,000V or 60,000V) cable network (see Figure 2-19) and hard copies of the medium voltage (30,000V for rural areas or 10,000V for urban areas) cable network (see Figure 2-20).



Source: Sonelgaz

Figure 2-19 Example of High Voltage Cable Network Map

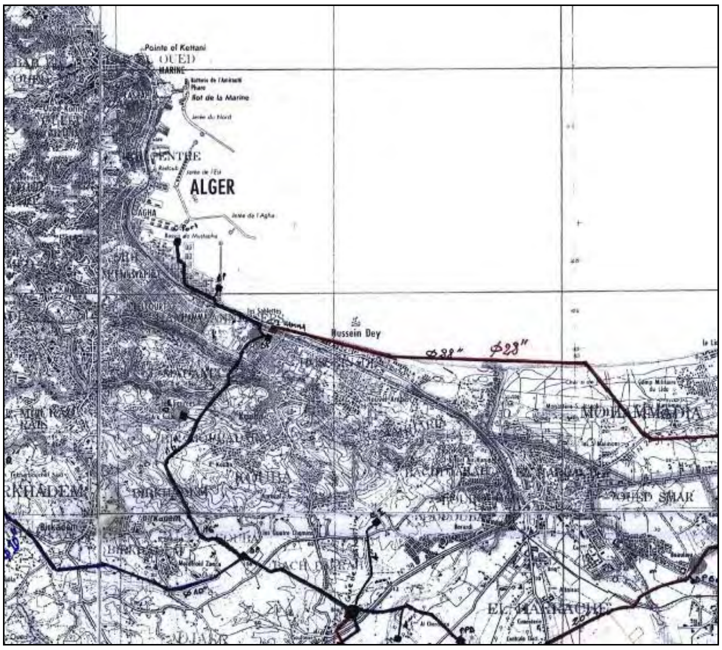


Red line: buried cables, Blue line: aerial cables
Source: Sonelgaz

Figure 2-20 Example of Medium Voltage Cable Network Map

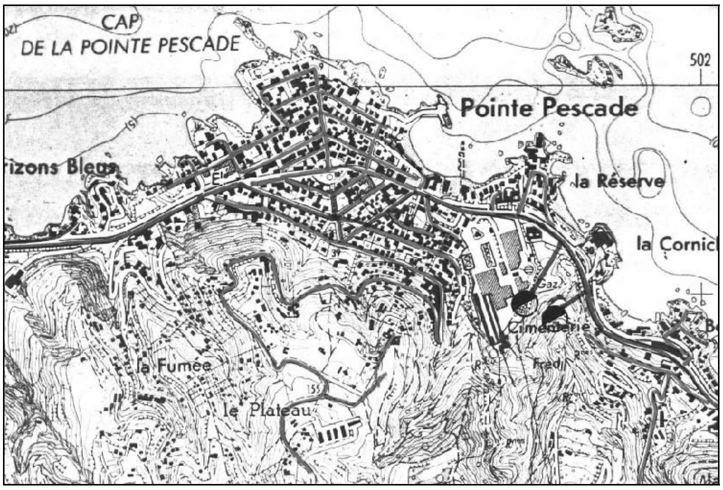
4) Gas

Sonelgaz gas division provided the JST with hard copies of the high pressure gas pipeline (20 bar to 70 bar) (see Figure 2-21) and medium pressure gas pipeline (4 bar to 5 bar) (see Figure 2-22).



Source: Sonelgaz

Figure 2-21 Example of the Network Map of High Pressure Gas Pipelines



Source: Sonelgaz

Figure 2-22 Example of the Network Map of Medium Pressure Gas Pipelines

5) Telecommunications

The telecommunication cable network layout (optic fiber cable) was not available in map form for the study area.