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Japan International Cooperation Agency (JICA)
Centre for Earthquake and Environmental Studies of Tehran (CEST)
Tehran Municipality

The Study on Seismic Microzoning of the Greater Tehran Area in the Islamic Republic of Iran

Final Report
Executive Summary

November 2000

Pacific Consultants International
OYO Corporation

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PREFACE

In response to a request from the Government of the Islamic Republic of Iran, the Government of Japan decided to conduct " The Study on Seismic Microzoning of the Greater Tehran Area in the Islamic Republic of Iran" and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Itaru Mae of Pacific Consultants International, and composed of members of Pacific Consultants International, and OYO Corporation, four times between April 1999 and September 2000 to the Islamic Republic of Iran.

The team held discussions with the officials concerned of the Government of the Islamic Republic of Iran and conducted field surveys at the study area. Upon returning to Japan, further studies and analysis were made and the present report was prepared.

I hope that this report will contribute to the promotion of the seismic disaster management of Iran and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Islamic Republic of Iran for their close cooperation extended to the team.

November 2000

Kunihiko SAITO
President
Japan International Cooperation Agency

Mr. Kunihiko SAITO
President
Japan International Cooperation Agency
Tokyo, Japan

November 2000

Letter of Transmittal

Dear Mr. SAITO,

We are pleased to formally submit herewith the final report of "The Study on Seismic Microzoning of the Greater Tehran Area in the Islamic Republic of Iran".

This report compiles the result of the study which was undertaken in the Islamic Republic of Iran from March 1999 through September 2000 by the Study Team organized jointly by Pacific Consultants International and OYO Corporation under the contract with the JICA.

The Final Report is composed of the two volumes, "Main Report" and attached "Microzoning Maps".

In the main report, existing social and physical conditions of the study area are described and seismic damage analysis was carried out based on the potential big earthquakes. Necessary recommendations for the seismic disaster management and mitigation were also made. The Study Team developed a comprehensive geographic database (GIS) to support data analysis and presentation of the study results. "Microzoning Maps" were compiled out of this GIS data base in such a way that those who are interested in urban analyses, detailed disaster management, studies and planning for Tehran area may easily make use of the data base.

Finally, we would like to express our sincere gratitude and appreciation to all the officials of your agency, the JICA advisory Committee, the Embassy of Japan in I.R.Iran, and Ministry of Foreign Affairs. We also would like to send our great appreciation to all those extended their kind assistance and cooperation to the Study Team, in particular, relevant officials of Centre for Earthquake and Environment Studies of Tehran (CEST), the Iranian counterpart agency.

Very truly yours,

Itaru MAE
Team Leader,
The Study on Seismic Microzoning
of the Greater Tehran Area
in the Islamic Republic of Iran

Foreword

The Study on Seismic Microzoning of the Greater Tehran Area has successfully achieved its objective of reasonably estimating the magnitude of damage that may be caused by the occurrence of a scenario earthquake. The maximum damage, which was estimated by the Ray Fault model, is in fact of the most serious nature and magnitude that would likely amount to some 500,000 or 55 percent of collapsed buildings together with almost 400,000 human casualties. Should this scale of damages occur actually, probable economic loss, either direct or indirect, would cost not less than the national GDP.

It is safely construed that the Study gave a reasonable justification for the importance and significance of implementing appropriate disaster prevention and management measures for the City of Tehran where diverse national functions are concentrated. In this context, in order to substantiate the outputs of the Study, a Seismic Disaster Prevention and Management Plan needs to be formulated, aiming at providing a comprehensive yet viable framework for the implementation of the disaster prevention and management measures for the City of Tehran.

Apparently, urban disaster prevention and management is one of the most important administrative mandates of municipal governments, and hence, a Seismic Disaster Prevention and Management Plan is to be formulated under the initiative of the Tehran Municipality. We will be very much pleased if the Study of this time will be followed by the formulation of the Plan and its implementation, thus contributing to mitigating possible earthquake damaged in the future.

Lastly, we would like to express our sincere appreciation for the excellent coordination and cooperation extended by the Tehran Municipality, our counterpart agency CEST, and all other agencies an organisation.

November 2000, in Tokyo

Digest of the Study

1. Background and Objectives of the Study

The Grater Tehran Area is located at the foot slope area of the Alborz Mountains, which is a higher potential zone of earthquake, however, Tehran city has not experienced strong earthquakes since 1830. It has been said by seismologists that return period of strong earthquake is at 150 years. Not having proper disaster prevention system against strong earthquake, Tehran city is growing rapidly. Therefore, it is urgently necessary to implement seismic damage estimation for preparation of disaster prevention plan.

The Objectives of the Study are,
1) to compile the seismic micro-zoning maps which can serve as a basis for the preparation of a regional and urban seismic disaster prevention plan of the Greater Tehran Area
2) to make recommendations for the mitigation of seismic disaster.

2. Existing Data Collection and Analysis

In the study, necessary data of natural and social conditions for seismic damage estimation is collected, and built up data base by using Geographic Information System (GIS). After completion of Geographic Database Development, detailed analysis of collected data had been undertaken. Major collected data is shown below.

Natural Conditions: 1) Earthquake Catalogue, 2) List of Earthquake and Waveform, 3) Geography and Geology, 4) Active Fault Distribution, 5) Topography, 6) Slope Classification, 7) Existing Borehole, etc.

Social Conditions: 1) Population Census, 2) Building Census, 3) Public Facilities, 4) Land Use, 5) Hazardous Facilities, 6) Lifeline, 7) Road Network, 8) Railway/Subway Network, 9) District Boundaries, 10) Census Zones, 11) Traffic Survey Zones, etc.

3. Geological Investigation and Scenario Earthquake

In the study, in order to understand the characteristics of ground condition, fifty (50) new boreholes were drilled. In addition to the new data, total of four hundred (400) existing boreholes data were collected and compiled the ground classification map.

To set up the Scenario Earthquake, several discussions with counterpart agency and related organisation were held, and appropriate scenario earthquake, which affects to Tehran City, was decided. Scenario Earthquake which was set up for the study as follows.:

1) Ray Fault model (Located at South of Tehran)
2) NTF model (Located at North of Tehran)
3) Mosha Fault model (Located at Northeast of Tehran)
4) Floating model (Not a actual fault. Model to evaluate relative vulnerability of Tehran)

4. Damage Estimation

Damage Estimation was calculated by analysing existing data and scenario earthquake. Items of damage estimation are as follows.:

1) Residential Building Damage, 2) Human Casualties, 3) Bridge Damage, 4) Public Facility Damage, 5) Lifeline Damage, 6) Hazardous Facility Damage, 7) Liquefaction Potential, 8) Slope Stability

From the result of damage estimation, it has been clearfied that maximum damage to the city will be caused by Ray Fault model . And is in fact of the worst seismic disaster in the world.

In case of Ray Fault model, seismic damage estimation is summarised as follows.:

Residential Building Damage:	483,000 Buildings (Damage Ratio: 55%)
Damage Cost (% of GDP):	22.07% (Reconstruction cost of residential Buildings only)
Number of Death:	383,000 persons (6% of total population within Tehran 22 Municipal Districts based on 1996 Census)

5. Conduct of Pilot Study

From the result of the worst damage to the city by Ray Fault model, to understand reality of worst damage area, pilot study area were selected within District 17, which locates at South of Tehran. And detailed survey was undertaken to know the problems concerning urban disaster prevention.

6. Recommendation

The most serious damage to Tehran city was estimated caused by Ray Fault model compared with other seismic disaster in the world. And Tehran City does not prepare proper disaster management plan against such a strong earthquake to mitigate damage.

The study team recommended to prepare seismic disaster prevention and management plan for Tehran City urgently with organising appropriate body for implementing a plan urgently.

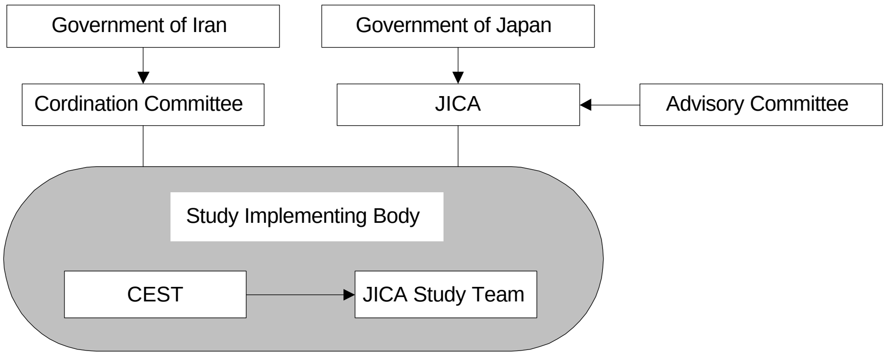
OUTLINE OF THE STUDY

1. Introduction

1.1 Study Organisation

The figure shown below is the implementing organisation of the Study.

Study Title:	*The Study on Seismic Microzoning of the Greater Tehran Area in the Islamic Republic of Iran*
Implementing Agency:	*Japan International Cooperation Agency*
Counterpart Agency:	*Centre for Earthquake and Environmental Studies of Tehran (CEST)*
Study Period:	*From March 2000 to November 2000*



1.2 Background of the Study

The Greater Tehran Area is located at the foot slope area of the Alborz Mountains, which form a part of the Alps-Himalayan Organic Zone, which is a higher potential zone of earthquake having many peculiar active faults. The urban area of Tehran has been developed on the alluvial layers accumulated on the hard rocks of complex geological formations. According to the historical seismic data, Tehran had been suffered from strong earthquakes at 150 years return period. Manjil city, located at 200 km west from Tehran, was attacked by a strong earthquake in 1990 and approximately 14,000 people were killed. Seismologists presume a strong earthquake in Tehran in near future, because the City has not experienced any disastrous earthquake since 1830.

Urban development has been rapidly progressing in Tehran without proper disaster prevention systems against the potential strong earthquake. It is urgently necessary to prepare a regional/urban earthquake disaster prevention plan in order to mitigate possible seismic damages in Tehran.

1.3 Objectives and Contents of the Study

The objectives of the Study are 1) to compile the seismic micro-zoning maps which can serve as a basis for the preparation of a regional and urban seismic disaster prevention plan of the Greater Tehran Area, and 2) to make recommendations for the mitigation of seismic disaster.

2. Geographic Database Development

In order to carry out the Study, a wide range of urban/regional data must be collected and analysed by the proper methodology to evaluate the spatial vulnerability of seismic disaster in the study area. GIS is considered the most practical and appropriate methodology for the purpose. Many map data, which show regional characteristics were combined and overlaid each other by computer and analysed to present spatial distribution of seismic disaster vulnerability. The Study Team developed geographic database for the Study.

3. Existing Natural and Social Conditions in the Study Area

3.1 Natural Condition

The Study Area is located at the foot of the southern slope of the Alborz range. The area can be simply classified into 5 topographic units such as (1) Mountain, (2) Hill, (3) Old fan, (4) Young fan and (5) Alluvial plain. The geological map in the Tehran region was prepared by Geological Survey of Iran (GSI) for this Study. This geological map represents the distribution of the Pliocene and Quaternary alluvial and glacial deposits of Tehran plain. CEST (1998) compiled detail distribution maps of faults. The main active faults in and around Tehran City are Mosha Fault, North Tehran Fault (NTF), South and North Ray Faults. Total of 2860 m investigation borehole at 50 locations were drilled. PS logging works were undertaken to compile shear wave velocity profiles in cooperation with Institute of Geophysics, Tehran University (IGTU).

3.2 Social Condition

1996 Population Census was compiled by Statistical Center of Iran(SCI). Population of Tehran is 6,742,165. Average population density is 110 persons per hectare.

1996 Building Census was also compiled by SCI. Data only covers residential buildings. Total number of dwelling unit is 1,484,138. The data was converted into number of buildings in the Study. Buildings are classified into four categories according to the type of structures such as 1) Steel, 2) RC, 3) Others and 4) Unknown.

4. Earthquake Analysis

4.1 Ground Classification

The ground condition of the Study Area was analysed and classified to construct the ground model for seismic analysis.

Fifty boreholes, which include three of 200 m depth, were drilled in the Study. Shear wave velocities of ground were measured in technical cooperation with IGTU (Exploration Division, Institute of Geophysics, Tehran University). About 400 borehole data were used to analyse the soil condition.

Engineering seismic bedrock for the Study is defined. Based on the depth of the seismic bedrock and the soil condition above the bedrock, the ground is classified into 41 types.

4.2 Scenario Earthquakes and Earthquake Analysis

The earthquake that would affect Tehran would occur on an active fault near the city. The most probable hazardous fault models are the following: 1) Mosha Fault Model, 2) North Tehran Fault Model, 3) Ray Fault Model. It should be noted that ‘hidden’ faults might exist underneath sediment layers of the city of Tehran. If such were the case, it would be difficult to determine their location, and the probability of occurrence would be the same anywhere in the city. To take into account this situation, the Floating Model concept can be considered. The amplification of the subsurface was analysed using a one-dimensional response analysis. The non-linearity effect was not considered because the soil is stiff enough to neglect the non-linearity.

4.3 Peak Ground Acceleration and Seismic Intensity

Peak ground acceleration and seismic intensity were calculated. Characteristics are as follows:

		Ray Fault model	NTF (North Tehran Fault) model	Mosha Fault model	Floating model
Length (km)		26	58	68	13
Width (km)		16	27	30	10
Moment Magnitude (Mw)		6.7	7.2	7.2	6.4
Peak ground acceleration (gal)	Northern area	500 and over	200 and less	200 and less	300 to 400
	Southern area	200 and less	400 and over	200 and less	300 to 400
Seismic Intensity (MMI scale)	Northern area	8	8 to 9	7	8 to 9
	Southern area	9	7 to 8	7	8 to 9

5. Damage Analysis

5.1 Building distribution, damage functions for residential buildings and human casualties

The building census data provides information by dwelling unit. Therefore, dwelling units data were converted to buildings data. Damage function is relationship between seismic intensity and damage ratio. The functions for building were constructed for each types of structure. The functions for human casualties were also constructed. The definition of dead people is those people killed only because of building collapse.

5.2 Damage to Residential Buildings and Human Casualties

Damages to residential building and human casualties were estimated. The emergency rescue operations are the basic factor in determining the death. The effects were also examined as type of operation and occurrence time. The followings are damages for case of night-time and no rescue operation.

	Ray Fault Model	NTF Model	Mosha Fault Model	Floating Model	Current Condition
Building Damage	483,000	313,000	113,000	446,000	Number of Buildings
Building Damage Ratio	55%	36%	13%	51%	876,000
Damage Cost (% of GDP) (Re-construction cost of residential buildings)	22.7%	14.30%	5.16%	20.38%	Gross GDP (1998) 109 Billion US$
Number of Dead People	383,000	126,000	20,000	302,000	Population
Death Ratio	6%	2%	0.3%	5%	6,360,000

Note: Damage cost is calculated by using published GDP(1998) at price of US$50,000 per building (government official exchange rate 1US$=Rls.3,000)

In the case for Ray Fault Model, seismic intensity is high in the southern area, where vulnerable building are prevailing. The number of damaged buildings in District 15 is the largest. The building damage ratio in Districts 11, 12, 16 to 20 show a very high value of around 80%. The death ratio in Districts 11 and 12 will be as high as 15 to 20%.

In case of NTF Model, seismic intensity is high in the northern area, where vulnerable buildings are not prevailing. In northern part of the city, the building damage ratio in District 1 to 5 will be around 50%. The death ratio in the northern part of the City, in Districts 1 to 5 will be high, around 3%. The death ratio in the southern part will be low, around 1%.

5.3 Damage to bridges

The damage of bridges was analysed by the multi-dimensional quantification theory one applied by Tokyo Metropolitan. Results of analysis are as follows:

Fault Model	Ray Fault Model	NTF Model	Mosha Fault Model	Floating Model
Collapsed	6	0	0	0
Unstable	5	7	0	10

5.4 Damages to public facilities

Information on seismic damage to major public facilities is very important for the preparation of a seismic disaster mitigation and management plan. The method of damage estimation is the same as that of residential buildings. Results of analysis are as follows:

	Number of Damage and Damage Ratio (%)																	
	Govern-mental Facility		Police		Traffic Police		Fire Fighting		Hospital		Elementary School		Intermediate school		High School		Higher Education Center (University)	
Ray Fault Model	18	(40)	27	(43)	7	(52)	28	(52)	56	(50)	623	(57)	369	(54)	340	(52)	66	(42)
NTF Model	11	(25)	18	(28)	5	(35)	21	(38)	33	(29)	376	(35)	250	(36)	242	(37)	61	(39)
Mosha Fault Model	4	(8)	7	(11)	2	(16)	7	(12)	11	(9)	133	(12)	81	(12)	75	(12)	18	(12)
Floating Model	16	(36)	26	(41)	6	(48)	28	(53)	50	(44)	558	(51)	350	(51)	331	(51)	76	(48)

The damage ratio in the southern Districts is relatively high. The results show that all public facilities will suffer damages to the same extent as residential buildings. Public facilities are important for the seismic disaster management plan. Therefore, all public facilities are required to have much more aseismic resistance than the residential buildings.

5.5 Damages to lifelines

Information on seismic damage to lifelines is very important for the preparation of a seismic disaster management plan. The following 4 types of lifelines are considered: 1) Water supply pipelines, 2) Gas pipelines, 3) Electric power supply cables, 4) Telecommunications cables.

The damages are huge in the southern districts in response to the seismic intensity.

5.6 Damages to hazardous facilities

A possibility of fire outbreaks from facilities where inflammable liquids or gases materials are handled was estimated. The leaking liquids or gases ignite to fire are estimated. There is limitation on quality of data, therefore the results represent only a relative possibility of fire occurrence. The damages are huge in the southern districts in response to the seismic intensity.

5.7 Liquefaction

Almost the entire area is rated as having ‘very low’ or ‘relatively low’ liquefaction potential. Stiff cohesive clayey soil is predominantly deposited in the analysed area. Only one borehole location was judged as having ‘relatively high’ liquefaction potential. The geological circumstances indicate that the distribution of high-potential liquefable soil in this area is relatively limited.

5.8 Slope Stability

Stability of large-scale natural slopes was examined. In case for Ray Fault Model, Mosha Fault Model and Floating Model, most of the meshes are judged as stable. In case for NTF Model, many meshes at the edge of the Alborz Mountains are judged as unstable. Most of this unstable area is not in residential areas. Slopes located at planning raw water transmission tunnels and behind the oil tank are judged as high-risk.

6. Overall Vulnerability Evaluation

Risks in each district of Tehran for seismic disaster were evaluated based upon the results of the damage analysis and social condition. To consider future development to strengthen the structure of the city, it is important to know which criterion (seismic hazard and damage or social conditions) is critical in each district. Each district can get a sense of where they stand in terms of earthquake risk and use this knowledge to plan for future development corresponding to the priority by each model.

6.1 Ray Fault Model

District 17 has the highest disaster risk.

There are a high seismic intensity, a high building damage ratio because of weak structures, and a high death ratio. Evacuation will prove difficult because the district has narrow roads. The southern area of the city has relatively high disaster risk.

6.2 NTF Model

The northern part of the city recorded higher seismic hazard and damage risk. The disaster is considered lesser than that attributed to the Ray Fault Model, because ground conditions and social conditions of the northern areas are better than those of the southern areas.

6.3 Floating Model

Relative seismic damage risk that is not caused by a specific earthquake was evaluated using the Floating Model. District 10 is evaluated as the most hazardous, followed by Districts 12 and 17.

7. Recommendations

A strong earthquake caused by the activity of Ray Fault will bring the largest damage in history to Tehran City. Huge seismic damages both building and human casualty will be estimated, especially, in the southern part of Tehran City, where densely populated and traditional non-engineered buildings are dominant. However, Tehran City does not prepare any proper master plan for seismic disaster mitigation.

Master Plan Study for Seismic Disaster Management for Tehran City should be formulated immediately to take the necessary measures for disaster mitigation systematically. In the course of the master plan study, necessary project/program for seismic disaster mitigation should be discussed from short, medium and long term point of view. Urgent project/program should be recommended for immediate implementation. Comprehensive action plan for the seismic disaster mitigation should be prepared immediately to secure the human life and people's assets. However, present organisation of Tehran Municipality does not have appropriate implementing body for preparation of Urban Seismic Disaster Prevention and Management Plan, therefore, it is necessary to reorganise the body properly for implementation of the Master Plan which should be prepared immediately.

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ABBREVIATION

General

GTA	Greater Tehran Area
NTF	North Tehran Fault
PSA	Pilot Study Area
SHR	Shahran Station of Seismograph Observatory

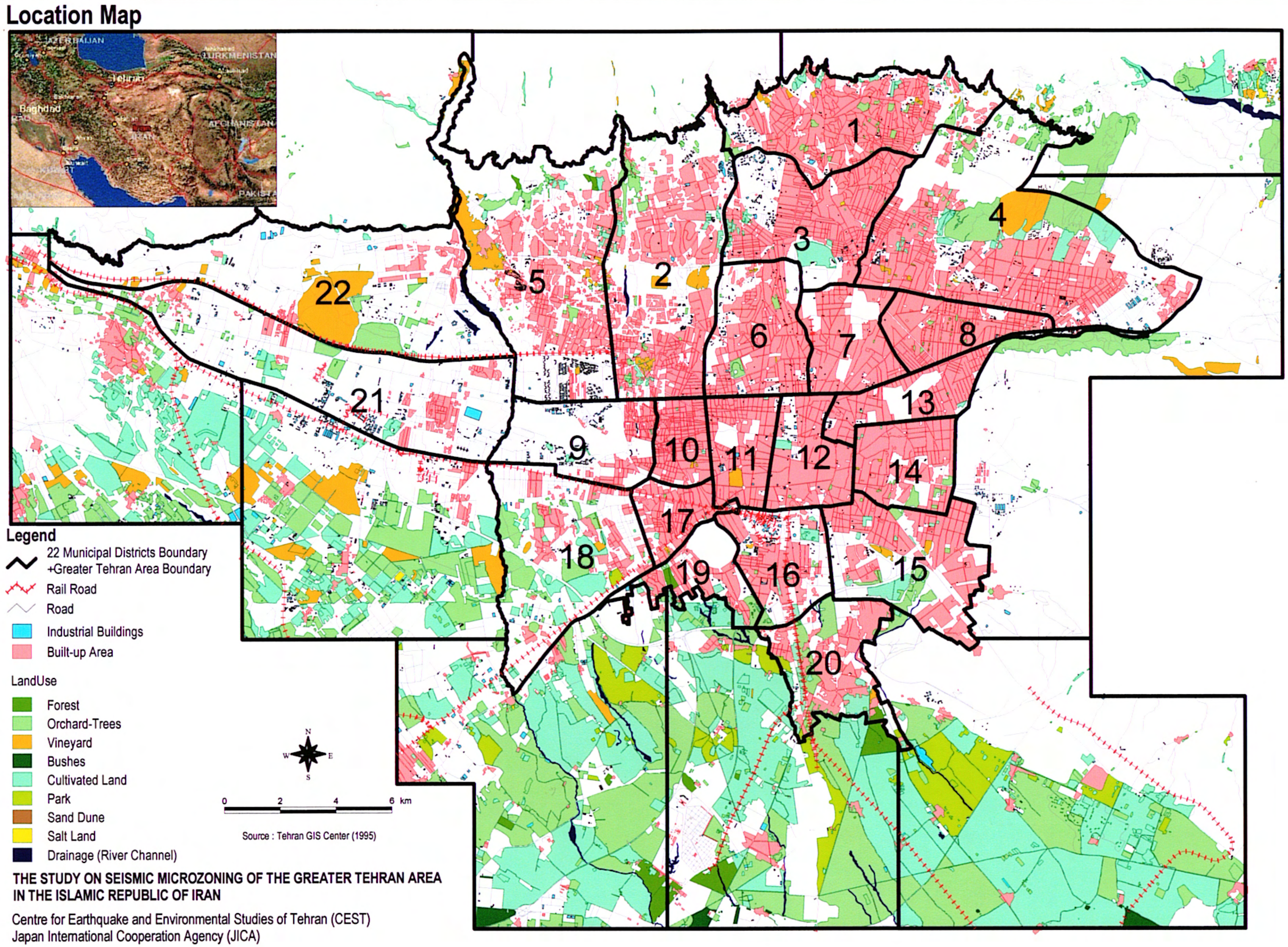
Organisation

AEO	Iran Atomic Energy Organization
BHRC	Building and Housing Research Center, Ministry of Housing and Urban Development
CEST	Centre for Earthquake and Environment Studies of Tehran, Tehran Municipality
CUDPMP	Comprehensive Urban Disaster Prevention and Management Plan
DDTF	District Disaster Task Force
DTF	Disaster Task Force
EPD	Environmental Protection Department
FRO	Forestry and Rangeland Organization
GSI	Geological Survey of Iran
GSMSC	Geotechnical and Strength of Materials Study Center, Tehran Municipality
IESTU	Institute of Environmental Study Tehran University
IGTU	Institute of Geophysics, Tehran University
IIEES	International Institute of Earthquake Engineering and Seismology, Ministry of Culture and Higher Education
IMI	Institute of Meteorology Iran
IRHF	Islamic Revolution Housing Foundation
IRICB	Islamic Republic Iran Central Bank
JICA	Japan International Cooperation Agency
MCHE	Ministry of Culture/Higher Education
MDAF	Ministry of Defence and Armed Forces
MHUD	Ministry of Housing and Urban Development
MOA	Ministry of Agriculture
MOC	Ministry of Commerce
MOC	Ministry of Cooperative
MOE	Ministry of Energy
MOEF	Ministry of Economics and Finance
MOH	Ministry of Health
MOI	Ministry of Interior
MOJC	Ministry of Jihad of Construction

MORT	Ministry of Road and Transportation
MPTT	Ministry of Post, Telegraph and Telephone
NCNDR	National Committee for Natural Disaster Reduction
NDTF	National Disaster Task Force
PBO	Plan and Budget Organization
PDTF	Provincial Disaster Task Force
PMC	Police and Military Commanders
RCSI	Red Crescent Society of Iran
SDDTF	Sub-District Disaster Task Force
SSO	Social Security Organization
TETCO	Tehran Engineering and Technical Consulting Organization, Tehran Municipality
TGIS	Tehran GIS Center, Tehran Municipality
TV/R	Islamic Republic of Iran TV/Radio

Technical Terms

gal	Unit of acceleration, 1 gal equals 1 cm/s^2, 980 gals equal 1 gravitational acceleration
GIS	Geographic information system
JMAI	Japan Meteorological Agency Intensity (seismic intensity scale)
mb	Body wave magnitude
MMI	Modified Mercalli Intensity (seismic intensity scale)
Ms	Surface wave magnitude
Mw	Moment magnitude
N	Blow counts of standard penetration test
Neq	Equivalent SPT N value for 30cm penetration
PGA	Peak Ground Acceleration
RC	Reinforced Concrete
SPT	Standard Penetration Test
Vs	Shear wave velocity


Location Map
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+Greater Tehran Area Boundary
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Road
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Built-up Area
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Vineyard
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Source : Tehran GIS Center (1995)
THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA
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Japan International Cooperation Agency (JICA)