2.2.5. Earthquake

(1) Earthquake Damage in Tehran

Fortunately, Tehran has not suffered severe damage due to an earthquake in over 150 years. Based on the historical earthquake catalogue, earthquakes that could likely affect Tehran can be speculated as follows:

Year 855:

A major earthquake in Ray destroyed many houses and caused a large number of casualties in the district. The shock was strongly felt, perhaps with some damages in Qum and Kashan. Aftershocks continued for more than a month.

Year 958:

There was a catastrophic earthquake in the northern part of central Persia. It destroyed all villages in the districts of Ray and Taliqan, both in the plains and in the mountains, and much of the city of Ray was totally ruined, heavy casualties being reported from both districts. In Taliqan were only 30 survivors and in the district of Ray 150 villages were destroyed, one village in the mountains being overwhelmed by landslides. A mountain near Ray was fissured and water spouted out of the ground. In the mountains of Ruyan to the north of Ray, large-scale landslides blocked the course of a river whose waters receded to form a lake. Damage extended the northwest into Dailam and south to Qum and Kashan. The shock was possibly felt in Isfahan and as far as in Baghdad. Damaging aftershocks continued for forty days, and were felt throughout the north-central Persia. It is possible that the earthquake was connected with an abnormal drop in the level of the Caspian Sea which, however, seems to have occurred before the event.

Year 1177 :

An earthquake destroyed many towns of Persian Iraq, along the southern slopes of the Alburz up to the region beyond Ray. The cities particularly devastated were Qazvin and Ray, where many people were killed. Internal evidence indicates that the Ray area, eastern Buyin Zahra and the Karaj settlements were worst affected.

Year 1665 :

There was a destructive earthquake in Damavand and its dependencies. The earthquake destroyed many houses and buildings in Damavand. An inscription in the Masjid-i jami refers to the earthquake damage and records the restoration work done in 1670.

Year 1830 :

On the morning of 2 Shawwal 1245, a major earthquake in the southern Mazandaran almost totally destroyed the districts of Shamiranat and Damavand, east of Tehran. About 70 villages, lying eastwards of the Jai-rud, along the routes via Damavand to Simnan and Damghan, were ruined and more than 500 people were killed in Damavand alone. Damage extended to Jaj-rud, where the Caravanserai was shattered and in Tehran, many old houses collapsed killing about 30 people. Not a single house in the capital escaped from the damage and part of the palace, together with many adjoining houses and part of the bazaar were thrown down. The Arg, the Great Audience Hall, a number of mansions, as well as the old British Embassy building were badly damaged and garden walls were levelled off on the ground. The loss of property in Tehran was estimated at half a million tomans. The shock caused some damage to a number of public buildings in Amul, Sari and Damghan and triggered rock-falls that blocked the passes on the Harhaz and Talar-rud roads to the north. The earthquake was felt as far as Baku and was followed by violent aftershocks that caused additional damage in the Shamiranat region and great panic in Tehran, where a large

proportion of the population camped in tents. The royal court also encamped in the open courts of the Arg. The aftershock of 6 April destroyed the old caravanserai totally at Jajrud.

As have been mentioned, Tehran has not suffered severe damage in over 150 years, but there occurred many devastating earthquakes in recent years in other regions of Iran. In 1997, three disastrous earthquakes occurred. On 4 February, a magnitude 6.1 earthquake rocked Northern Khorasan and East Mazandaran in northeast Iran. In total, 91 people died and 5,500 houses collapsed. On 28 February, an earthquake of magnitude 5.5 hit Ardebil and Meshkin-shahr in northwest Iran. A total of 800 people died and 8,500 houses, 100 % of houses in the area, collapsed. On 10 May, a large earthquake of magnitude 7.3 hit Birijand and Qaen in the southern part of the Khorasan Province in eastern Iran. The overall damage was 1,568 dead and 13,605 houses completely destroyed.

On 21 June 1990, a magnitude 7.3, large earthquake hit the Manjil region. The damage was devastating, 37,000 people died and 100,000 houses collapsed. After the disastrous earthquake, many academic investigations were carried out and many reports were written. However, there are only a few quantitative studies on vulnerability functions of different types of structures. It is necessary to continue research of this type with relevant organisations in Iran.

2.2.6. Population

According to the 1996 population census, the total population of Tehran for its 22 districts is calculated at 6,742,165. District 4 has the largest population, counted at 663 thousand, and district 15 has the second largest population, counted at 622 thousand. The least populated district is District 22, with 56 thousand. Districts 9, 12 and 21 also have relatively smaller populations.

Population density is also calculated by census zone and based on 1996 population census data (Table 2.2.2 and Figure 2.2.5). The average population density of the entire city of Tehran is 110 persons per hectare. The average density of District 10 is 349 person/ha and 347 person/ha in District 17. These two districts have the highest population density value. District 14 has 269 person/ha and District 8 has 250 person/ha. These are the second-highest density districts in Tehran. On the contrary, the district with the lowest population density is District 22, with 9 person/ha. The second lowest district is District 21, with 36 person/ha. The density of district 1, 2, 3 and 4, which are located in northern Tehran, is shown to be between 71 person/ha and 92 person/ha.

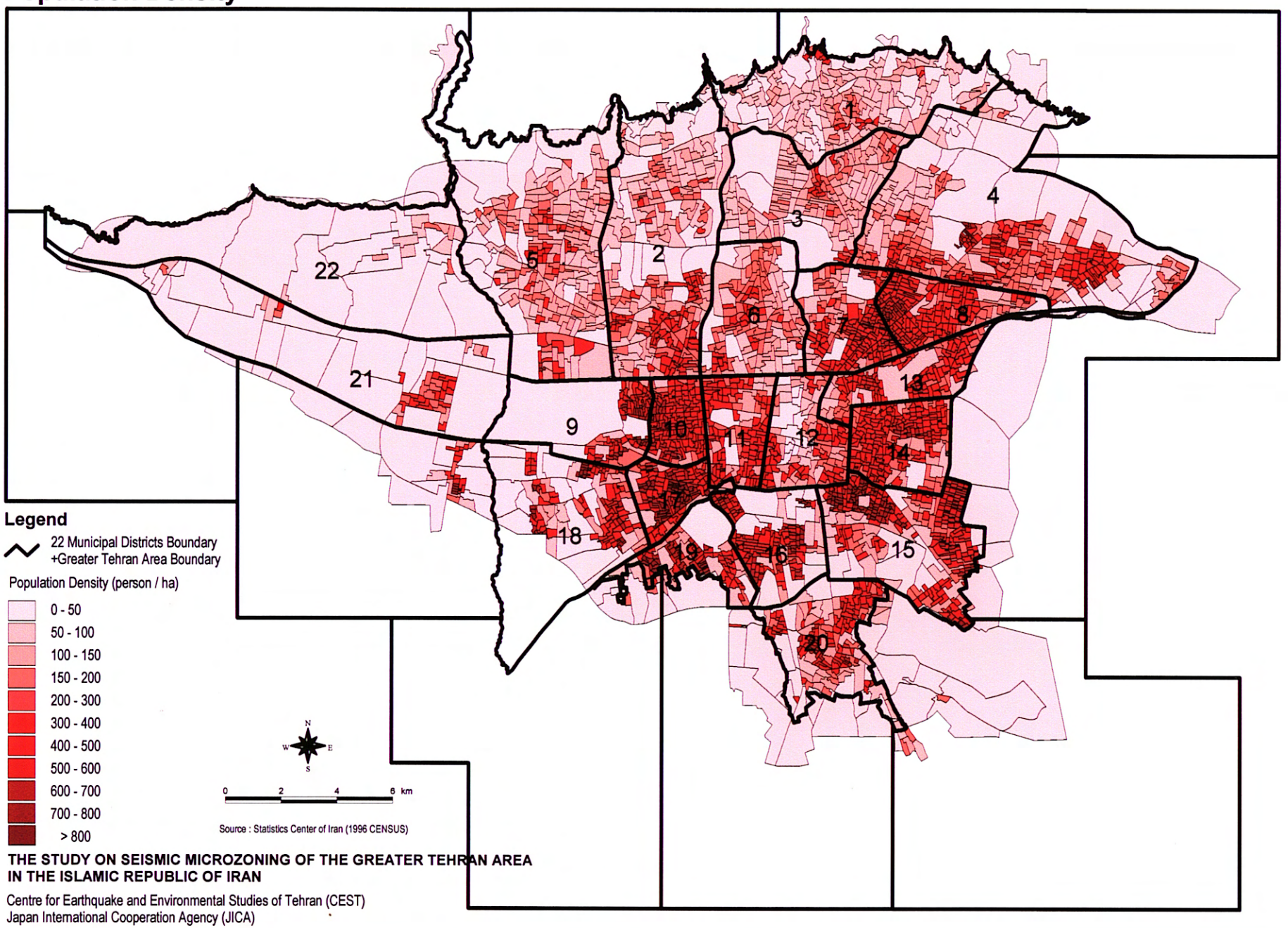
Table 2.2.2 Population / Density Distribution by Districts

District	No of Census Zones	Number of Census Zones		Number of Census Zones		Area (ha)	Population	Population Density (Person/ha)
		Density exceeds 600 p/ha	Density exceeds 600 p/ha	Density (person/hectar)	Zone No.			
1	163	0	0	391	01075	3,462	245,502	71
2	238	0	0	313	02149	4,968	456,414	92
3	155	0	0	449	03108	2,945	259,019	88
4	297	5	0	710	04133	7,260	663,166	91
5	215	1	0	673	05033	5,915	427,955	72
6	123	0	0	324	06088	2,149	220,331	103
7	151	0	0	554	07081	1,541	300,212	195
8	150	5	0	712	08014	1,327	332,005	250
9	80	10	0	761	09047	1,960	173,482	89
10	125	2	0	632	10083	808	282,308	349
11	110	0	0	446	11089	1,189	225,840	190
12	108	0	0	422	12060	1,359	189,625	140
13	113	0	0	508	13034	1,391	245,142	176
14	168	1	0	621	14119	1,459	392,524	269
15	252	33	4	878	15060	2,852	622,517	219
16	129	6	0	744	16077	1,649	298,410	181
17	109	30	0	783	17082	829	287,367	347
18	121	14	1	826	18097	3,794	293,598	77
19	88	8	0	680	19041	1,152	227,389	197
20	167	0	0	588	20093	2,033	354,449	174
21	85	4	0	778	21048	5,208	188,890	36
22	26	0	0	164	22010	6,154	56,020	9
Total	3,173	119	5			61,404	6,742,165	110

Source: Statistics Center of Iran (1996)

Figure 2.2.5

Population Density



THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA IN THE ISLAMIC REPUBLIC OF IRAN

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

2.2.7. Buildings

(1) Structural Types

Building statistics were also prepared by SCI based on 1996 census data, however, census data only covers residential buildings. For 1996, the total number of residential buildings in Tehran is 1,484,138 units. This figure seems to represent each dwelling unit. Apartment houses or connected buildings should be counted as one residential building unit, from seismic damage analysis point of view. In Chapter 4, section 4.1.2, the methodology and figures used for building units are explained in detail. In this section, based on available statistics, characteristics of existing building distribution in Tehran are described.

District 2, 4, 5 and 15 have more than 100 thousand building units. The total number of building in District 22 is only 11,982 units, the smallest number of buildings per district within the entire city. The district with the second smallest number of buildings is District 21 and the third is District 9.

Buildings are classified into four categories according to structural type 1) Steel, 2) RC, 3) Others and 4) Unknown. Table 2.2.3 shows the distribution of these four categories aggregated into each district. The category " Others" is further classified into nine (9) structure types. The number of Steel structure building is counted at 604,363 units (41 %), RC is 169,960 (11 %), Others is 678,273 (46 %) and Unknown is 31,542 (2 %). Steel and RC structure buildings are considered to be relatively new and large sized building in Tehran. " Others" are older, more traditional types of buildings. The distribution pattern of these buildings shows the characteristics of Tehran7s urban growth. Districts having more than 60 % of Steel structure plus RC structure are District 1, 2, 3, 4, 5, 6 and 22. All of these districts, except for District 22, are located in northern Tehran. District 5 consists of 83 % of steel and RC buildings and District 2 consists of 81 % of these structural types. On the contrary, District 10, 16 and 17, which are located in southern Tehran consists of less steel and RC structures. District 9, 11, 12, 13, 18 and 19 are also have a lower percentage of steel and RC structures.

Table 2.2.3 Building Distribution by Structure (Dwelling Unit)

District	Structure (No. of buildings)				Total by district	Percentage of Steel and RC Structures
	Steel	RC	Other	Unknown		
1	28,961	13,886	18,319	1,392	62,558	68
2	59,945	34,875	20,453	2,325	117,598	81
3	41,122	13,652	14,111	1,308	70,193	78
4	72,009	19,877	52,246	3,397	147,529	62
5	47,974	37,014	15,703	1,850	102,541	83
6	31,756	6,380	20,039	937	59,112	65
7	35,575	4,131	36,591	1,762	78,059	51
8	33,972	2,431	45,383	1,735	83,521	44
9	9,346	2,930	25,032	518	37,826	32
10	14,049	415	46,501	1,230	62,195	23
11	19,640	1,033	32,498	1,125	54,296	38
12	12,570	799	24,876	1,000	39,245	34
13	19,784	1,650	36,483	1,188	59,105	36
14	32,549	4,543	48,515	1,837	87,444	42
15	44,767	9,162	65,853	2,830	122,612	44
16	12,104	1,966	34,592	1,426	50,088	28
17	9,452	242	31,333	1,251	42,278	23
18	15,180	436	30,420	1,304	47,340	33
19	13,828	759	27,152	794	42,533	34
20	27,098	5,821	36,227	1,453	70,599	47
21	16,046	3,752	14,942	744	35,484	56
22	6,636	4,206	1,004	136	11,982	90
Total	604,363	169,960	678,273	31,542	1,484,138	52

Source: Statistics Center of Iran (1996)

(2) Building Age

Building age data is classified into four categories: 1) before 1966, 2) 1966 to 1975, 3) 1976-1988 and 4) after 1988.

According to the book " Tehran – The Jewel on the Silk Road" (Taher Art & Cultural Institute, 1999), buildings in older Old parts of Tehran (District 10, 11, 12, and their surrounding area) were built before 1950' s. Moreover, the old urbanised area called " Old Tehran" is said to have been built up before 1891.

Table 2.2.4 Distribution of Building Age

District	Before 1966	Age 1966-75	Age 1976-88	After 1988	Unknown	Total by District
1	7,681	8,850	29,404	16,051	572	62,558
2	5,612	18,652	47,562	44,634	1,138	117,598
3	6,168	15,239	31,046	17,168	572	70,193
4	5,497	15,976	88,139	36,492	1,425	147,529
5	1,557	2,547	56,177	41,219	1,041	102,541
6	15,588	14,794	18,545	9,827	358	59,112
7	24,271	17,911	18,878	16,435	564	78,059
8	20,270	24,825	26,379	11,381	666	83,521
9	7,621	18,493	9,400	2,069	243	37,826
10	28,433	15,111	9,505	8,549	597	62,195
11	22,932	10,012	12,195	8,572	585	54,296
12	19,096	5,850	9,348	4,367	584	39,245
13	17,726	16,991	16,293	7,659	436	59,105
14	19,526	24,874	27,371	14,273	1,400	87,444
15	10,774	16,904	74,894	17,973	2,067	122,612
16	13,085	16,591	15,924	3,658	830	50,088
17	8,979	16,670	13,534	2,385	710	42,278
18	1,120	5,973	31,530	7,926	791	47,340
19	263	2,241	33,353	6,285	391	42,533
20	8,383	12,978	38,094	10,331	813	70,599
21	326	1,482	20,209	13,095	372	35,484
22	37	2,324	4,409	5,118	94	11,982
Total	244,945	285,288	632,189	305,467	16,249	1,484,138
Percentage	16.5	19.2	42.6	20.6	1.1	100.0

Source: Statistics Center of Iran (1999)

2.2.8. Urban Facilities

In the study, wide ranges of data for urban facilities were collected. Those data consist of:

1) Facility Name, Address and Function
2) Size of land, building
3) Structural type and age of building

The list of the urban facilities for the Study is as follows:

1) Fire Fighting Stations
2) Police Stations
3) Traffic Police Stations
4) Hospitals
5) Governmental Facilities
6) Educational Facilities
    - Elementary Schools
    - Intermediate Schools
    - High Schools
    - Higher Education Centers (Universities)
7) Parks and Public Open Spaces

In order to strengthen the disaster response capacities of Tehran, the above information can be used in future urban planning. Such information can be extremely useful in making decisions related to locations of new facilities in order to improve their function. Also, when an earthquake occurs, having lists and knowing the locations of these facilities can minimise or prevent damage from a serious disaster.

This information was collected in cooperation with 20 Municipal Districts except for Fire Fighting Station data, which were compiled by Tehran's Fire Fighting Department, and Hospital data, which were compiled by Ministry of Health.

Since volume of data is relatively large, one of the most critical problems in the process of compiling the data is the difficulty of unifying the data. Also, related agencies were requested to prepare maps of the locations of these facilities, however, most of the agencies are not able to do so, therefore, the Study Team prepared these maps whenever possible in the limited time available. However, to maintain the quality and accuracy of the database in the future, the municipality itself will have to check the data and update it in order to improve it.

Concerning the data requested from the 20 Municipal Districts, several districts have not yet prepared the data, and almost all districts have many discrepancies in their data. Since the time for this study is limited, the Study Team expects the data will be updated by the local Iranian team for future improvement. Therefore, the Study Team has analysed the damage based on the available data supplied by each district and agencies.

In accordance to the data received from each district, the number of each facility per district is summarized in Table 2.2.5.

Table 2.2.5 Facility Distribution by District

District	Fire Fighting Station	Police	Traffic Police	Hospital	Governmental Facility	Elementary School	Intermediate School	High School	University	Park and Public Open Space
1	1	13	0	19	12	69	34	45	17	18
2	4	3	2	3	1	102	97	92	19	37
3	4	13	0	11	4	39	43	48	40	44
4	5	9	0	6	1	83	67	66	19	131
5	4	2	2	4	2	50	52	56	6	46
6	4	3	1	28	15	59	54	33	48	27
7	1	13	2	22	11	51	36	38	16	28
8	2	1	2	5	2	70	37	36	0	26
9	0	2	0	2	3	45	29	33	5	10
10	3	0	2	9	4	54	34	33	2	19
11	6	6	1	13	1	92	62	54	21	10
12	3	5	1	13	1	16	14	14	5	11
13	3	1	0	5	0	66	46	27	10	13
14	2	4	1	14	6	58	25	53	0	36
15	3	3	2	2	10	249	4	2	1	26
16	1	4	0	6	5	62	38	39	0	32
17	1	2	0	2	1	26	26	20	0	27
18	1	2	0	8	0	86	52	43	5	62
19	2	1	0	2	7	27	30	20	1	18
20	2	5	0	4	2	102	56	80	10	37
21	3	1	0	1	0	13	5	10	0	0
22	2	0	0	1	0	1	5	2	0	0
Outside	2	-	-	-	-	-	-	-	-	-
Total	59	93	16	180	88	1,420	846	844	225	658

2.2.9. Lifelines

In relation to the lifeline facilities and networks, at the time of earthquake, two kinds of damage to the citizen's life and the city itself can be considered. One is no access to lifelines for ordinary daily use (e.g. no access to drinking water, electricity, gas and telecommunication) due to damaged lifeline facilities and networks, in general. The other is that, due to damaged lifeline facilities and networks; occurrence of secondary disasters (e.g. fire, electric shock, explosion, etc.) may take place. For these reasons, lifeline management agencies have to establish disaster management system to minimise the damage in the event of an earthquake.

In the study, a wide-range of data has been gathered from lifeline-related agencies and companies. (water, gas, electricity, telecommunication) Since the comprehensive database set-up initiated by this Study is the first of its kind in Tehran, a lack of quality and missing data can be observed. However, basic data, including information on the system's main networks, were set up. In the report, these preliminary data can be seen on the maps in each lifeline system.

Since May 1999, the Study Team has collected lifeline data. Details of data collection for lifelines are shown in Table 2.2.6. Unfortunately, limited data has been gathered for the Study, and therefore, future improvement of the database is strongly suggested. In general, all lifeline agencies somehow relate each other. For example, if the telecommunication company does not have a self-generated system, and if the electric company cannot supply electricity, all the telecommunication system will be non-operational. This problem can be applied to the water and gas companies as well. Therefore, the exchange of information and cooperation between agencies is important to reduce the problem.

Table 2.2.6 Collected data from lifeline agencies

Lifeline Data	Related Agency	Necessary Data			
		Map			Data Table
		Own Sub-districts Map	Main Network Map	Main Distribution Map	Length of Local Distribution Line
Water	Tehran Province Water & Sewage Co.	○	○	○	×
	Format	Paper	AutoCAD File	AutoCAD File	-
Gas	National Iranian Gas Co.	○	○	○	○
	Format	Paper	Paper	Paper	Paper
Electricity	Power Generation & Transmission Co.	○	○	×	○
	Format	Paper	AutoCAD File	-	Paper
Telecommunications	Telecommunications Co. of IRAN	○	○	×	○
	Format	Paper	-	-	Paper

○ Received

× Not Received

2.2.10. Roads

With cooperation of the Tehran GIS Center, road width data was prepared. These data include a variety of information as follows:

1) Road Width: 3 meters
2) Road Width: 6 meters
3) Road Width: 8 meters
4) Road Width: 10 meters
5) Road Width: 12 meters
6) Road Width: 15 meters
7) Road Width: 20 meters
8) Road Width: 24 meters
9) Road Width: 30 meters
10) Road Width: 35 meters
11) Road Width: 40 meters
12) Road Width: 45 meters
13) Road Width: 76 meters
14) Road Width: 120 meters

Three (3) and six (6) meter wide roads, which are relatively narrow streets, are considered as weak in the event of an earthquake in relation to rescue activities. In Tehran, the older part of urbanised area has longer lengths of 3- and 6-meter roads. Districts with this characterisation include Districts 10, 11, 12, 14, 15, 16 and 17.

2.2.11. Bridges

For the analysis of bridge vulnerability, detailed data were compiled by TETCO. Data for a total of 160 bridges were collected.

In addition, the Study Team carried out individual site survey on missed bridges and flyovers located within the 22 municipal district boundaries and added a detailed list of 79 bridges and flyovers. As a result of these additional surveys, the total number of bridges and flyovers is 239, where as 168 bridges and flyovers are located within the Study Area Locations of these are clearly identified.

Table 2.2.7 Number of bridges in Tehran (collected for the study)

Type of Bridge	No. of bridges	Within the Study Area and Location Identified
Road Bridge (TETCO)	56	50
Railroad Bridge (TETCO)	51	0
Metro Bridge (TETCO)	53	39
JICA Study Team Identified	79	79
Road-Road		50
Road-Metro, Railways		16
Road-River		11
Metro, Railways-River		2
Total	239	168

The bridge data consist of:

1) Name
2) Location
3) Construction Year
4) Girder Type
5) Type of Bearing
6) Maximum Height of Abutment / Pier
7) Material of Abutment / Pier
8) Foundation Type

2.2.12. Hazardous Facilities

Hazardous Facilities can be identified as the facilities (mainly petrol stations, factories, etc.), which handle hazardous and dangerous substances. These facilities may cause secondary disasters such as fire outbreaks, explosions, etc. At the time of earthquake, listing and knowing the location of these facilities can minimise or prevent damage.

For collection of hazardous facilities data, the fire-fighting department of the Tehran Municipality cooperated to create the database. In Tehran, a total of approximately 1,500 facilities are considered hazardous facilities, according to their categorisation. The department prepared the location map of 840 facilities in total, and the Study Team digitised the location for use in the GIS database and included necessary attributes data.

In the database prepared by the fire-fighting department, many outdated data were found through a random check. For instance, many kerosene distributors included in the database are no longer in business or have changed location. The data, which is outdated, cannot be trusted and it may lend to a serious disaster in the event of an earthquake. Therefore, it is urgently recommended to update the data as soon as possible.

Since lack of address and inaccuracies were found in the data supplied, a location map could not be completed. Also, there were many facilities included in the database, which were not considered as hazardous facilities and were eliminated for the damage analysis.

Chapter 3:

Earthquake Analysis

Chapter 3. Earthquake Analysis

3.1. General

A flowchart for the analysis is shown in Figure 3.1.1. The first step is to decide on a scenario earthquake. The next step is to construct a fault model for the numerical calculation. For the analysis of the earthquake motion, the empirical Green' s function method is used. The waveform at the engineering bedrock is synthesised at this stage. The subsurface amplification factor is indispensable in order to assess the earthquake motion at the ground surface. For this purpose, the ground of the whole area is classified into several models. The ground model for numerical calculation is constructed from the ground classification and its soil properties. The subsurface amplification factor is analysed by response analysis. The waveform at the ground surface is calculated from the waveform at the engineering bedrock and the subsurface amplification function.

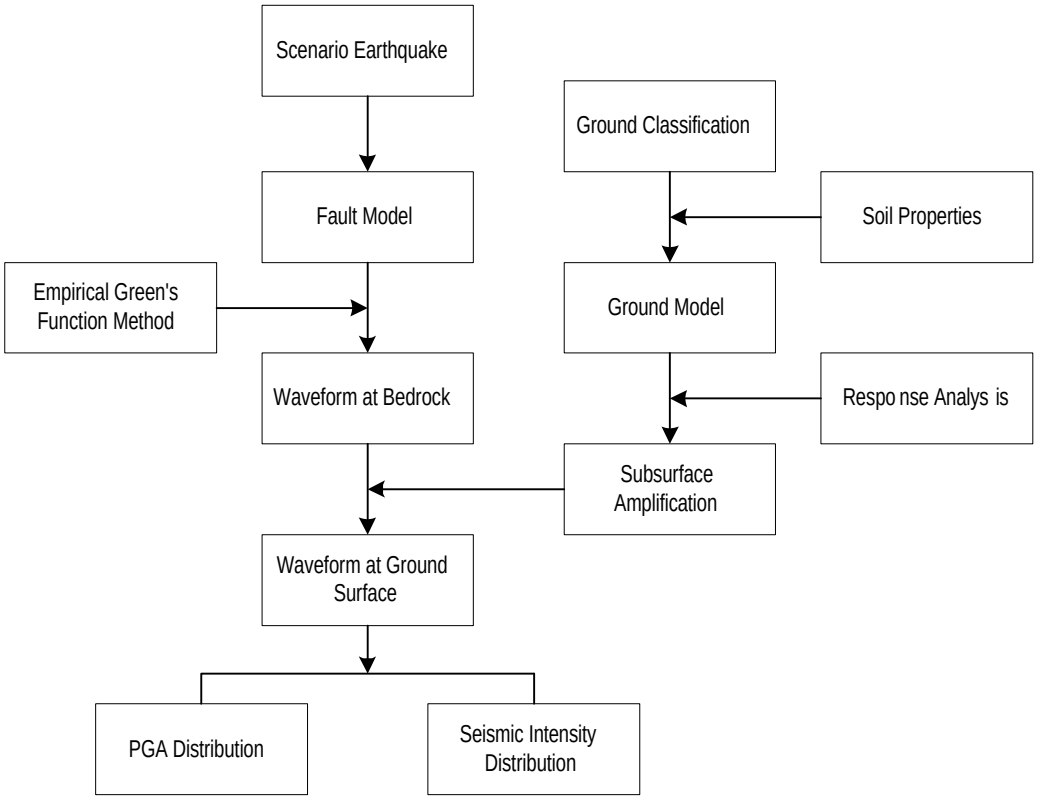


Figure 3.1.1 Flowchart for Earthquake Analysis

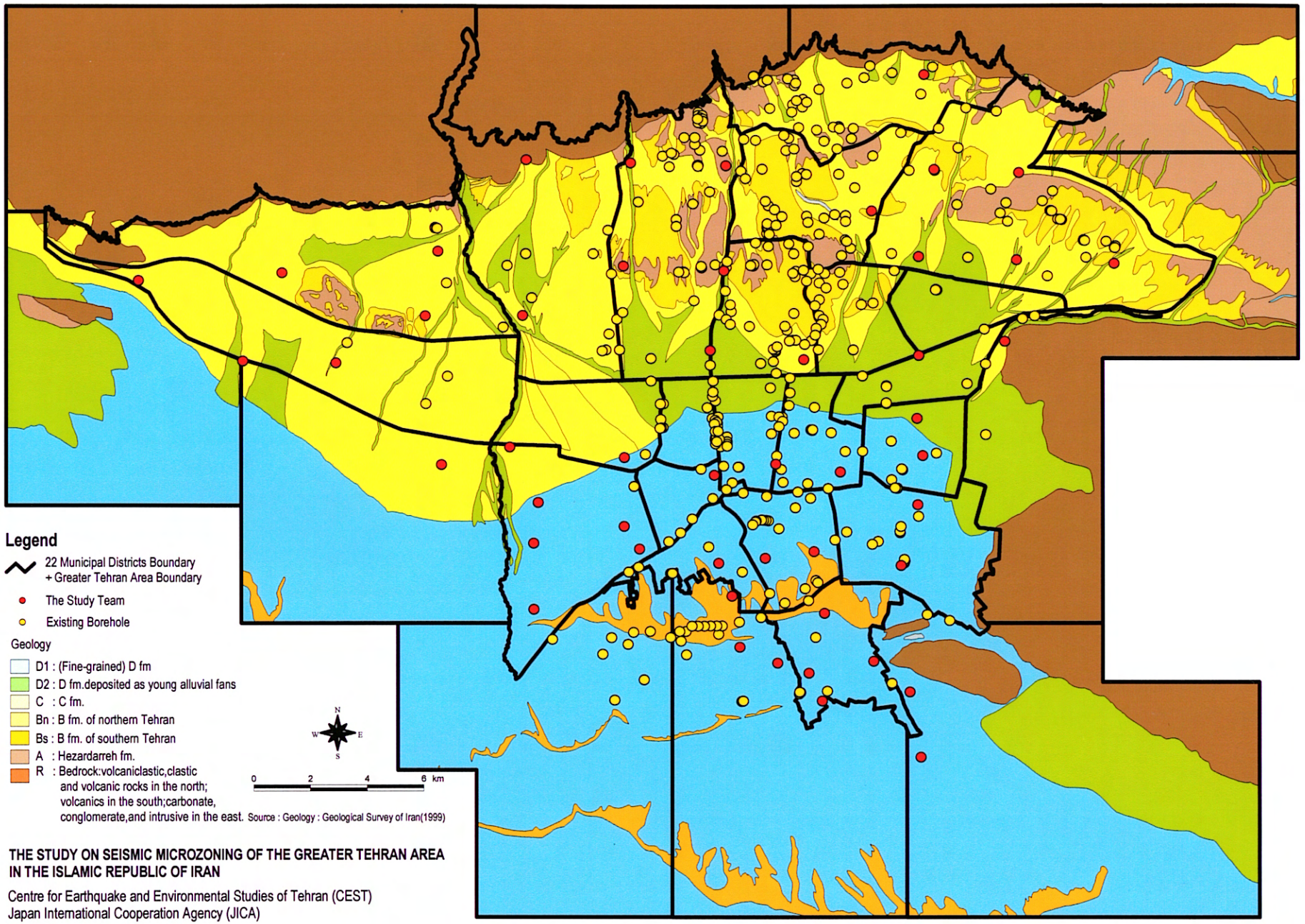
3.2. Ground Classification

3.2.1. Data used for the Ground Classification

Fifty boreholes were drilled in the Study Area in order to collect essential ground information. Details of the investigation were summarised in the Field Report. Shear wave velocities of ground were measured using the suspension PS logging method and downhole PS logging method. This borehole data served as the framework for the ground classification. The location of these boreholes is shown in Figure 3.2.1. The general geological cross section of the Study Area is shown in Figure 3.2.2.

Figure 3.2.1

Location Map of Boreholes



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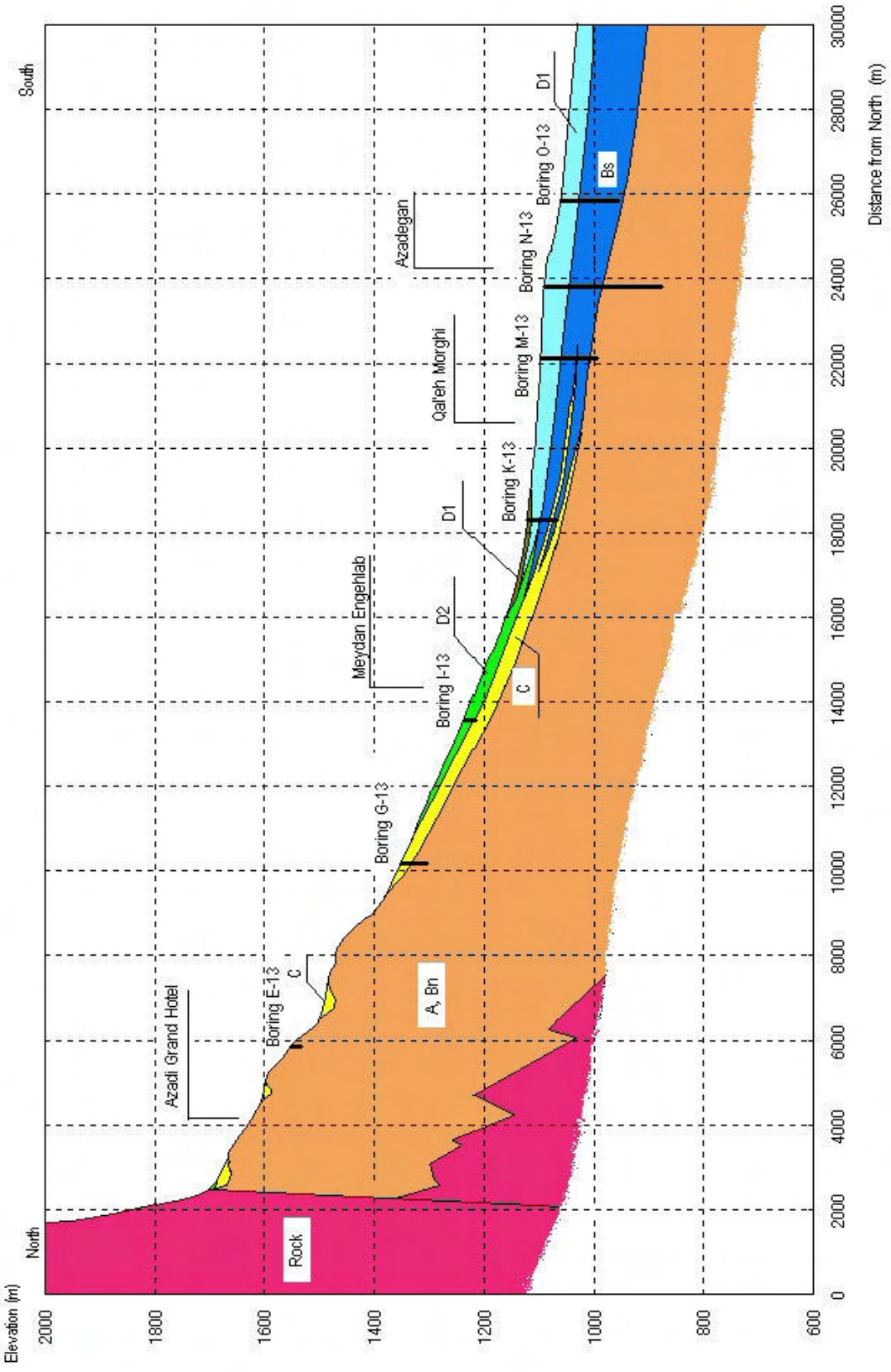

Figure 3.2.2 Geological Cross Section