Republic of Armenia
Rescue Service, Ministry of Emergency Situations (RS)

The Project for Seismic Risk Assessment and Risk Management Planning in the Republic of Armenia

Final Report

Vol. II Main Report 1

Risk Assessment of Yerevan City

December 2012

Japan International Cooperation Agency (JICA)

OYO International Corp.
Nippon Koei Co., Ltd.
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Structure of Volume of Final Report

Vol.	Title	Language
I	Summary	Armenian English Japanese
II	Main Report 1 Risk Assessment of Yerevan City	Armenian English Japanese
III	Main Report 2 Yerevan Earthquake Disaster Management Plan	Armenian English Japanese
IV	Data Book	Armenian English

Exchange rate used in this report

1.00 US Dollar (US$) = 407.43 Armenia Drams (AMD)
1.00 Japanese Yen (JPY) = 5.19 Armenia Drams (AMD)
(as of October 8, 2012)

Outline of the Project

1. Background

Title:	The Project for Seismic Risk Assessment and Risk Management Planning in the Republic of Armenia
Counterpart Agency:	Rescue Service, Ministry of Emergency Situations (RS)
Project Period:	August 2010 - December 2012

The goal of this project is "Reduction of Disasters due to a large scale earthquake which has a possibility of occurrence in Yerevan City". The three purposes of the project are the followings;

1) Generation of seismic risk map and establishment of earthquake disaster management plan for Yerevan city
2) Capacity development of relevant organizations on seismic risk evaluation, earthquake disaster management planning, and these capacities for applying to other cities in Armenia.
3) Establishment of cooperation structures and cooperation relations among Ministry of Emergency Situations (including RS), Yerevan Municipality, and relating organizations regarding to earthquake disaster management.

The project is composed by two phases. Phase 1 is by September 2011 and mainly for seismic hazard and risk assessment. Phase 2 is after then and mainly on earthquake disaster management planning.

2. Risk Assessment of Yerevan City

2.1 Ground Survey

The Tertiary sedimentary rocks widely distribute in Yerevan. The volcanic rocks and the Terrace deposits cover it in north and in southwest respectively. As the information of the ground is insufficient for risk assessment, following ground survey were carried out. The ground models for each 250m square grids are made based on the acquired information.

1) Drilling Survey (30m depth x 10 points)
2) PS Logging (30m depth x 10 logs)
3) Surface Wave Exploration (60 points)
4) Micro Tremor Survey (50 points)
5) Surface Geology Mapping and Cross Section Mapping (1:10,000 scale)

2.2 Active Fault Survey

The trench investigation was carried out across the active faults near Yerevan to set up the scenario earthquakes.

1) Active fault was confirmed along Garni Fault. The time of seismic event of the active fault which was confirmed at east of Yerevan was supposed around BC 1,000.
2) Trench survey was carried out at Metsamor in the west of Yerevan City to confirm the Yerevan fault, however no fault was found. Active fault was confirmed at Nor Ughi trench across Vedi Fault in

southeast of Yerevan. The Vedi Fault might not be geology fault as it was estimated before but moved as a secondary along with the movement of Yerevan Fault (may be in 893 by Dvin Earthquake).

2.3 Seismic Hazard Assessment

Following two scenario earthquakes are established along Garni Fault which runs in eastern direction of Yerevan from north-northwest to south-southeast.

- GF2 Scenario: east of Yerevan, magnitude 7.0
- GF3 Scenario: southeast of Yerevan, magnitude 7.0

The calculated seismic intensity by GF2 Scenario is 8 to 9 in MSK scale (5+ to 6- in JMA scale) and almost 8 (5- to 5+) by GF3 Scenario. The possibility of liquefaction is low. The re-activation of existing landslides in eastern Yerevan may occur.

2.4 Risk Assessment

The structural classification and distribution of residential buildings are studied by sampling survey and inventory survey. The current condition of bridges and flyovers are investigated by the existing register and onsite survey. The lifeline database of network and the pipe materials was compiled from existing drawings. The damage functions were prepared mainly based on the damage during the 1988 Spitak Earthquake considering the aging effect and the existing inventory in Yerevan also.

The damage was estimated as follows based on the inventory database, damage functions and the earthquake motion by the scenario earthquakes.

(1) Damage of residential buildings (Total collapse and heavily damage)

Inventory			GF2 Scenario			GF3 Scenario		
Multi-story Apartment	Individual House	Housing Unit	Multi-story Apartment	Individual House	Housing Unit	Multi-story Apartment	Individual House	Housing Unit
4,371	42,633	264,928	860 (20%)	13,870 (33%)	54,800 (21%)	350 (8%)	6,660 (16%)	22,500 (8%)

* Half of multi-story apartments are 4 - 5 storied stone masonry. Same type buildings to the damaged by Spitak Earthquake also exist many. Most individual houses are stone masonry.

(2) Casualty damage

Population	GF2 Scenario		GF3 Scenario	
	Death	Injured	Death	Injured
1,119,200	31,800 (2.8%)	76,500 (6.8%)	11,200 (1.0%)	31,100 (2.8%)

* More than 70% of citizens are living in multi-story apartment.

(3) Damage of infrastructure

No damage was estimated for bridges and flyovers.

(4) Damage of lifelines (Worst case)

Length of pipes/ lines (km)				GF2 Scenario				GF3 Scenario			
Water	Sewage	Electricity	Gas	Water	Sewage	Electricity	Gas	Water	Sewage	Electricity	Gas
1,300	1,050	2,600	1,090	27 points	81 points	22 km	265 km	12 points	36 points	5 km	121 km

* Water and sewage pipelines are buried underground but most gas pipelines are set on the ground surface.

2.5 Related Study on Earthquake Disaster Management Plan

The urban planning, environment, social conditions and educational aspects were surveyed and studied to contribute the earthquake disaster management planning. Followings are the summary.

- There are a few parks and green spaces available to access on disaster in the northeastern part of the city. The open space in the densely built-up area is mostly occupied by private warehouse or garage.
- In order to promote earthquake-resistant urban development requiring the earthquake-resistant housing, improvement of legal framework for urban development will be the priority issue.
- Some reference and recommendations on earthquake disaster mitigation needs to be added in Master Plan.
- There is no hazardous waste disposal site in Yerevan City. About 17 years are needed to dispose whole disaster waste by GF2 Scenario in current management ability.
- The capacity of Temporary Distribution Points is enough but Long-term Settlement Points are less. On the contrary, questionnaire survey suggested that half of the victims will prefer to remain in Yerevan in case of a violent earthquake.
- The evacuation plan in case of the accident of nuclear power plant is prepared. However, the accident envisaged in this plan is independent case, not due to severe seismic disaster.
- The school disaster education is systematically carried out mainly related to the emergency response activities. The interactive and participatory learning is insufficient.
- Education for citizen provided by government organizations focuses on enhancing disaster management capacity of each citizen. The Community Based Disaster Risk Management is not covered.

2.6 Establish of the System for Earthquake Disaster Management

Two systems are established making use of the outcomes in Phase 1.

(1) Realtime seismic intensity distribution information system

This system displays the estimated earthquake intensity distribution of whole Yerevan City immediately after the earthquake on the display in Rescue Center of MES. The earthquake motion is estimated from observed data at the 5 strong motion stations in Yerevan in accordance with the ground amplification factor which was evaluated in the hazard assessment study in Phase 1. The information distribution function through SMS service of mobile phone is also added.

(2) Earthquake disaster estimation system

This is the GIS based software which estimates the earthquake motion distribution by the arbitrary scenario earthquake and the damage due to the natural hazard in quantitative manner. The simplified risk evaluation methods which were used in the risk assessment study in Phase 1 are loaded. As the main users of this system are the members of RS or the Yerevan branch of RS, this system is designed that can be used without professional knowledge of the earthquake hazard and damage analysis. The effect of reconstruction of residential buildings can be included as an option.

3. Formulation of Earthquake Disaster Risk Management Plan of Yerevan City

In consideration of evaluation of earthquake hazards and risks in Yerevan City and result of preparation of earthquake disaster scenario, the earthquake disaster risk management plan of Yerevan City was developed, together with Rescue Service, Ministry of Emergency Situations; a counterpart of this project.

For the formulation of the plan, disaster consequence scenario on 19 matters of emergency response was developed, and then, issues and measures for improvement of the present situations were picked up. Concerning mitigation, direction and outline of the measures for improvement were identified through clarification of the present situations and important issues.

Selection of priority measures was done by means of Analytical Hierarchy Process (AHP), and implementation plans for the priority projects were developed. The highest-priority measure "Development of evacuation plan and approval by Mayor for dissemination of the contents" has been implemented in this project. Business Continuity Plan (BCP) of Rescue Service was also prepared in the course of the preparation of the Earthquake Disaster Risk Management Plan.

The Earthquake Disaster Risk Management Plan is on process for approval of Mayor of Yerevan City.

3.1 Goal, policies, priorities for the plan

Under "promotion of comprehensive disaster management" as goal of earthquake disaster risk management, earthquake disaster management activities are promoted from the following perspectives.

(1) Long-sighted disaster management (setting ultimate goals)

To mitigate risks related to earthquake disaster, promotion of earthquake disaster management activities is recommended upon definition of ultimate goals, which are 1) Saving human lives, 2) Securing the livelihood of citizens, 3) Maintaining social/ economic systems and 4) Maintaining the governance of the City and the nation.

(2) Overall disaster management (responsibilities shared under vertical and horizontal organization schemes as well as collaboration of activities by all stakeholders with a sense of ownership)

Disaster management activities should be promoted by all the personnel and organizations. In order to facilitate earthquake disaster management activities, it is necessary for all personnel/ organizations to clarify their own roles and to engage in activities with a sense of ownership through coordination with one another.

(3) Systematic disaster management (Sequencing activities within the disaster management cycle)

In order to reduce earthquake disaster risks, it is important that activities on mitigation and preparedness for emergency response activities are initiated ahead of the occurrence. Emergency response immediately after the occurrence should be followed by subsequent rehabilitation/reconstruction activities. Furthermore, the rehabilitation/reconstruction should take a

consistent approach for quake-resistant development by not only recovering to the pre-earthquake state but also linking with disaster mitigation and preparedness for future earthquakes.

(4) Specific/ efficient disaster management (activities upon risk awareness)

In order to efficiently implement disaster management activities, one needs to, upon learning hazard and vulnerability primarily as well as risks, formulate a disaster management plan and implement measures accordingly to mitigate risks selected in consideration of importance, urgency and efficiency of response measures.

(5) Precise and feasible disaster management (activities aligned with one's capacity and accumulation of activities)

It is recommendable to implement feasible measures, considering needs of residents and financial conditions, and then, to realize a quake-resident city with the accumulation of the feasible measures. Together with the implementation of measures, it is required to update the result of risk assessment and revise the Plan, based on the updating of assessment.

The following policies for formulating the Plan were defined in conjunction with the issues identified through the study.

a) Utilizing scientific risk assessment and earthquake disaster scenarios
b) Focusing on mitigation for efficient activities
c) Lowering vulnerability by enhancing prior measures such as building reinforcement, considering the feasibility
d) Enhancing disaster management awareness of all citizens ranging from administrative officers to residents
e) Formulating a sustainable plan that emphasizes system/budget/governance enhancement through coordination with related organizations and the communities (groups of residents)
f) Promoting disaster management activities through disaster education and dissemination of disaster information, utilizing real-time seismic intensity display system

The key elements described in the above policies will facilitate mitigation activities for earthquake disasters under the priorities for the Plan. The priority mattes were selected through review and evaluation of the present situation are summarized below.

a) Raising awareness/ dissemination of information on disaster management
b) Promotion of urban redevelopment and securing open space in urban areas
c) Improvement of road network
d) Seismic strengthening of buildings
e) Research and study for damage estimation
f) Collaboration and co-working with volunteers
g) Prevention of fire outbreak and explosion and increasing safety of dangerous materials

3.2 Earthquake disaster risk management plan of Yerevan City

The structure and contents of the earthquake disaster risk management plan formulated in this project are shown in following table.

Structures and contents of the Plan

Structures		Contents
Part 1	Basic Considerations	Chapter 1 Basic considerations Chapter 2 Overview and damage estimation Chapter 3 Basic responsibilities of risk management entities
Part 2	Mitigation Plan	Chapter 4 The city'governance related to implementation of mitigation measures Chapter 5 Quake-resistant human development Chapter 6 Quake-resistant community development Chapter 7 Quake-resistant urban Development Chapter 8 Aseismic reinforcement of buildings, facility structures, etc. Chapter 9 Seismic study and research
Part 3	Preparedness Plan	Chapter 10 Process for preparedness and assistance by the city Chapter 11 Preparedness by the citizens and communities Chapter 12 Preparedness related to initial response Chapter 13 Preparedness related to communication Chapter 14 Preparedness for fire and hazardous materials Chapter 15 Preparedness for rescue and evacuation Chapter 16 Preparedness for emergency transportation Chapter 17 Preparedness for emergency medical care Chapter 18 Preparedness for missing person search / body recovery Chapter 19 Drinking water and food procurement / supply process Chapter 20 Preparedness for rehabilitation of lifeline / communication / mudslide prevention facilities Chapter 21 Preparedness for handling of garbage, human waste, and debris
Part 4	Emergency Response Plan	Chapter 22 Basics of emergency response Chapter 23 Establishing and managing Crisis Management Center Chapter 24 Collection and offering of information Chapter 25 Security, traffic control, emergency transport Chapter 26 Mutual coordination with disaster risk management bodies Chapter 27 Evacuation and rescue Chapter 28 Emergency medical care, sanitation Chapter 29 Search and rescue of missing persons, handling of remains Chapter 30 Fire-fighting, countermeasures against hazardous materials Chapter 31 School measures Chapter 32 Supply of drinking water and food Chapter 33 Emergency rehabilitation of lifelines, telecommunications, traffic, and debris flow protection facilities Chapter 34 Handling of garbage, human waste, and debris Chapter 35 Emergency response to housing and livelihood
Part 5	Rehabilitation / Reconstruction Plan	Chapter 36 Basic ideas for reconstruction Chapter 37 Reconstruction Headquarters Chapter 38 Formulating reconstruction plans Chapter 39 Stability of civilian life Chapter 40 City reconstruction
Part 6	Assistance Plan	Chapter 41 Assistance plan

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Abbreviations

Armenian	English	Japanese
^{14}C 14 զանգվածային թվով ածխածնի իզոտոպ	**^{14}C** Carbon Isotope Mass Number 14	炭素の放射性同位体 (原子量 14)
ADSL Ասիմետրիկ թվային բաժանորդային գիծ	**ADSL** Asymmetric Digital Subscriber Line	非対称デジタル加入者回線
ՀՎՄ Հիերարխիայի վերլուծության մեթոդ	**AHP** Analytic Hierarchy Process	分析階層処理
ALOS Հողի դիտարկման առաջադեմ արբանյակ (Ճապոնիա)	**ALOS** Advanced Land Observing Satellite (Japan)	陸域観測技術衛星
AMS Արագացումային զանգվածասպեկտրաչափում	**AMS** Accelerator Mass Spectrometry	加速器質量分析
ՀԿԽԸ Հայկական կարմիր խաչի ընկերություն	**ARCS** Armenian Red Cross Society	アルメニア赤十字社
Հայպետհիդրոմետ Հայաստանի հիդրոօդերևութաբանության և մոնիտորինգի ծառայություն	**ArmHydromet** Armenian State Hydrometeorological and monitoring Service	アルメニア水文気象観測サービス
ԱՇՊ Աշխատանքների շարունակականության պլան	**BCP** Business Continuity Plan	事業継続計画
CAD Ավտոմատացված նախագծում	**CAD** Computer-aided design	コンピュータ支援設計
Կադաստր ՀՀ կառավարությանն առընթեր անշարժ գույքի կադաստրի պետական կոմիտե	**Cadastro** State Committee of the Real Property Cadastre of the Government of the RA	地籍局
ՀՎՀԱՌԿ Համայնքի վրա հիմնված աղետի ռիսկի կառավարում	**CBDRM** Community based disaster risk management	コミュニティ防災
ՔԿՃՄՊՆ Քիմիական, Կենսաբանական, Ճառագայթային, Միջուկային, Պայթուցիկ նյութեր	**CBRNE** Chemical, Biological, Radiological, Nuclear, Explosives	化学、生物、放射性物質、核、爆発物
ՔՊ Քաղաքացիական պաշտպանություն	**CD** Civil Defence	民間防衛
ԱՊՀ Անկախ պետությունների համագործակցություն (անկախ պետությունների մի խումբ, որոնք մինչև 1991թ. մտնում էին Խորհրդային Միության կազմի մեջ)	**CIS** Commonwealth of Independent States (a group of independent countries that were part of the Soviet Union until 1991)	独立国家共同体

ՓԲԸ Փակ Բաժնետիրական Ընկերություն	**CJSC** Closed Joint Stock Company	非公開型株式会社
ՃԿԿ Ճգնաժամային կառավարման կենտրոն	**CMC** Crisis Management Center	危機管理センター
ՃԿՊԱ Ճգնաժամային կառավարման պետական ակադեմիա	**CMSA** Crisis Management State Academy	国家危機管理アカデミー
DEM Բարձրության թվայնացված մոդել	**DEM** Digital Elevation Model	数値標高モデル
ՂԿ Ղեկավար կազմ	**DISTAFF** Directing Staff	訓練指示担当管理官
ԿՍԿ ՍՊԱԾ կառուցվածքների սեյսմակայունության կենտրոն	**EEC** Earthquake Engineering Center of NSSP	地震工学センター (NSSP)
EERI Ինժեներական սեյսմալոգիայի հետազոտական ինստիտուտ	**EERI** Earthquake Engineering Research Institute	地震工学会（米国）
EMS Եվրոպական մակրոսեյսմիկ սանդղակ	**EMS** European Macroseismic Scale	ヨーロッパ震度階級
ԱԻ Արտակարգ իրավիճակներ	**ES** Emergency Situations	非常事態
ՀՓՋ Հրշեջ փրկարարական ջոկատ	**FRD** Firefighting Rescue Detachment	消防救難部隊
ՄՄ Մարտական միավոր	**FU** Fighting Unit	消防部隊
ԳԽ Գառնիի խզվածք	**GF** Garni Fault	ガルニ断層
GIS Աշխարհագրական տեղեկատվական համակարգ	**GIS** Geographic Information System	地理情報システム
ԵԳԻ Երկրաբանական գիտությունների ինստիտուտ, ՀՀ գիտությունների ազգային ակադեմիա	**IGS** Institute of Geological Science, National Academy of Science	地質学研究所
ՃՄՀԳ Ճապոնիայի միջազգային համագործակցության գործակալություն	**JICA** Japan International Cooperation Agency	国際協力機構
ՃՕԳ Ճապոնիայի օդերևութաբանության գործակալություն	**JMA** Japan Meteorological Agency	気象庁（日本）
ՃՀԽ ՃՄՀԳ հետազոտական խումբ	**JST** JICA Study Team	JICA 調査団
ԵԲՎ Երկարատև բնակության վայր	**LTSP** Long Term Settlement Place	長期避難場所

ԱԻՆ Արտակարգ իրավիճակների նախարարություն	**MES/MoES** Ministry of Emergency Situations	非常事態省
MSK սանդղակ Մեդվեդև-Սպոնհեուրեր–Կարնիկի սեյսմիկ ինտենսիվության սանդղակ	**MSK scale** Medvedev Sponheuer Karnik Seismic Intensity Scale	MSK 震度階級
ԼՓՋ Լեռնափրկարարական ջոկատ	**MRD** Mountain Rescue Detachment	山岳救助部隊
NGA Գրունտի շարժման մարման մոդելների հաջորդ սերունդ	**NGA** Next Generation of Ground-Motion Attenuation Models	新世代地震動減衰モデル
ՀԿ Հասարակական կազմակերպություն	**NGO** Non-Governmental Organization	非政府組織
ՍՊՀԾ Սեյսմիկ պաշտպանության հյուսիսային ծառայություն	**NorSSP** Northern Department of NSSP	NSSP 北部支部
ԱՎԾ Ազգային վիճակագրական ծառայություն	**NSS** National Statistical Service	国家統計局
ՍՊԱԾ Սեյսմիկ պաշտպանության ազգային ծառայություն	**NSSP** Armenian National Survey for Seismic Protection	国家地震防災調査所
ԲԲԸ Բաց բաժնետիրական ընկերություն	**OJSC** Open Joint Stock Company	公開型株式会社
ԳՄԱ Գրունտի մաքսիմալ արագացում	**PGA** Peak Ground Acceleration	最大加速度
ԲՊ Բնակչության պաշտպանություն	**PP** Population Protection	住民保護
ՓՍՍԽ Փամբակ-Սևան-Սյունիք խզվածք	**PSSF** Pambak-Sevan-Sunik Fault	パンバック・セバン・チュニック断層
ԲՏՊՎ Բնակչության և տարածքների պաշտպանության վարչություն	**PTPD** Population and Territories Protection Department	市民／国土保護部
ՀՀ Հայաստանի Հանրապետություն	**RA** Republic of Armenia	アルメニア共和国
ՀՀՇՆ Հայաստանի Հանրապետության շինարարական նորմեր	**RABC** Republic of Armenia Building Code	アルメニア国建築基準
ԵԲ Երկաթբետոն	**RC** Reinforced Concrete	鉄筋コンクリート
ՓՈՒՎ Փրկարար ուժերի վարչություն	**RFD** Rescue Forces Department	救助隊部
ԸԿ Ընդունման կետ	**RP** Reception Point	受付場所

ՄՓՎ Մարզային փրկարարական վարչություն	**RRD** Regional Rescue Department	Marzes（地方政府）のレスキュー部隊
ՓԾ փրկարար ծառայություն	**RS** Rescue Service	レスキューサービス
ՈՓ Որոնողափրկարարություն	**SAR** Search and Rescue	捜索救難
ՀՀՋ Հատուկ հրշեջ ջոկատ	**SFD** Special Firefighting Detachment	特殊消防部隊
ՊՈԱԿ Պետական ոչ-առևտրային կազմակերպություն	**SNCO** State Non-commercial Organization	国家非営利組織
ՀՓՋ Հատուկ փրկարարական ջոկատ	**SRD** Special Rescue Detachment	特殊救助部隊
ԺՏԿ Ժամանակավոր տեղաբաշխման կետ	**TDP** Temporally Distribution Point	一時避難場所
ՄԱԶԾ Միացյալ Ազգերի Զարգացման Ծրագիր	**UNDP** United Nations Development Program	国連開発計画
ՄՆԵՀ Միացյալ Նահանգների երկրաբանական հետազոտություն	**USGS** United States Geological Survey	米国地質調査所
ՄՈՒԼ պրոյեկցիա Մերկատորի ունիվերսալ լայնական պրոյեկցիա	**UTM projection** Universal Transverse Mercator projection	ユニバーサル横メルカトル投影法
ԱԽ Աշխատանքային խումբ	**WG** Working Group	ワーキンググループ
ՋՈՋ Զանգվածային ոչնչացման զենքեր	**WMD** Weapons of Mass Destruction	大量破壊兵器
ՋՓՋ Ջրափրկարարական ջոկատ	**WRD** Water Rescue Detachment	水難救助部隊
ՍՊԱրմԾ Սեյսմիկ պաշտպանության արևմտյան ծառայություն	**WSSP** Western Department of NSSP	NSSP 西部支部
ԵԽ Երևանի խզվածք	**YF** Yerevan Fault	エレバン断層
ԵՓՎ Երևանի փրկարարական վարչություն	**YRD** Yerevan Rescue Department	RS エレバン支部

Chapter 1 Background

1.1 Background of the Project

(1) Outline of Yerevan City

Armenia as an independent country existed with interruptions from BC 9-6th centuries till AD 11th century. The Republic of Armenia was established in 1918 and was in the structure of the Soviet Union during 1920-1991 (some very brief description is shown in Table 1.1-1). Therefore, Armenia is similar to other CIS countries that it still remains the educational and social environments of the Soviet Union. As the capital of Republic of Armenia, Yerevan city has its population of one third of the country. Urban area of Yerevan city has not yet been catching up the development and shows heavy traffic jams every day. In the central part of the city, middle to high rise buildings and apartments are concentrated, and in the suburbs multi storied residential buildings and low rise individual house are the main.

Table 1.1-1 Very Brief History of Armenia

Armenia lies in the highlands surrounding the Biblical mountains of Ararat. The original Armenian name for the country was Hayk, later Hayastan (Armenian). The name Armenia was given to the country by the surrounding states, and it is traditionally derived from Armenak or Aram (the great-grandson of Haik's great-grandson, and another leader who is, according to Armenian tradition, the ancestor of all Armenians). In the Bronze Age, several states flourished in the area of Greater Armenia, including the Hittite Empire (at the height of its power), Mitanni (South-Western historical Armenia), and Hayasa-Azzi (1600–1200 BC). Soon after the Hayasa-Azzi were the Nairi (1400–1000 BC) and the Kingdom of Urartu (1000–600 BC), who successively established their sovereignty over the Armenian Highland. Each of the aforementioned nations and tribes participated in the ethnogenesis of the Armenian people. Yerevan, the modern capital of Armenia, was founded in 782 BC by king Argishti I. The Iron Age kingdom of Urartu (Assyrian for Ararat) was replaced by the Orontid dynasty. Following Persian and Macedonian rule, the Artaxiad dynasty from 190 BC gave rise to the Kingdom of Armenia which rose to the peak of its influence under Tigranes II before falling under Roman rule. In 301, Arsacid Armenia was the first sovereign nation to accept Christianity as a state religion. In 405, the Armenian alphabet was invented. The Armenians later fell under Byzantine, Persian, and Islamic hegemony through 5th to 9th centuries, but reinstated their independence with the Bagratuni Dynasty kingdom of Armenia in 9th century. The capital city Ani had “200,000 people with 1001 churches”. After the fall of the kingdom in 1045, and the subsequent Seljuk conquest of Armenia in 1064, the Armenians established a kingdom in Cilicia, where they prolonged their sovereignty to 1375. In the 15th century, Cilicia fell under Ottoman dominion and officially became known as the Adana Vilayet. Due to its strategic significance, Armenia was constantly fought over and passed back and forth between the dominion of Persia and the Ottomans. At the height of the Turkish-Persian wars, Yerevan changed hands fourteen times between 1513 and 1737. In the aftermath of the Russo-Persian War, 1826-1828, the parts of historic Armenia under Persian control, centering on Yerevan and Lake Sevan, were incorporated into Russia. Greater Armenia was later divided between the Ottoman Empire and Russia. In 1909, Cilician Armenians were subjected to a massacre in Adana and during World War I after which, in 1915, they suffered in the genocide that was inflicted on them by the Ottomans. Armenia, from then on corresponding to much of Eastern Armenia, once again gained independence in 1918, with the establishment of the Democratic Republic of Armenia, and after 1922-1991 of Armenian USSR period, then in 1991, with the Republic of Armenia. (after Bagrat A. Ulubabyan (1991), “Collection of stories Essays for middle and high school pupils”, 670p. “Literary-art publication” Arevik”1991, and Wiki-Pedia English version.)

(2) Earthquake Disasters in Yerevan City

The two historical earthquakes are known as mentioned below. For Armenia, the famous 1988 Spitak Earthquake and others have happened. However, in Yerevan city, in these 300 years, no disastrous earthquakes which provided deaths happened.

- 1679 June 4th, Garni Earthquake (M=7.0): epicenter is 20km east of Yerevan. Maximum estimated seismic intensity is 'X' in MSK-64 scale. It is said that the fortress and at least 12 churches and two bridges were collapsed, and 1,228 people were killed at northern part of the current Yerevan city. Totally 7,600 people were killed including surrounded area.
- 1937 January 7th, M=5.2: It is estimated as a local earthquake near Yerevan city. The estimated MSK-64 seismic intensity scale is 'VII' in the city. A couple of hundred houses in the city had cracks. No casualties are told.

(after "V.A. Stepanyan – Earthquakes in the Armenian highland and its surrounding. Armenia, Yerevan, 1964, 248 pages", Appendix 5-56 of "Historical description for 863, 893 and 1679 Earthquakes in Dvin and Yerevan", and "Appendix 5-6 of "The Churches affected in the surroundings of Yerevan city by the 893 and 1679 Earthquakes".)

(3) Vulnerability of Yerevan City against Earthquake Disasters

The grounds in the northern part of Yerevan are relatively stiff, but in its lowland of the southern part a certain thick soft soil layers deposited. Some information said that an active fault exists below the Yerevan City, but the confirmation is necessary by an investigation by experts.

The populations are concentrating in the central area and the hilly developing region of the city with multiple storied residential building constructed during the Soviet Union era of 1950s to 80s. It has made urban environment more serious. Numerous multi storied residential buildings that were constructed by the old standard are structurally vulnerable and getting older. If such earthquake like the 1988 Spitak event may happen, tremendous and miserable situation might occur in Yerevan. And according to the narrow intervals between buildings, road blockage is worried during disaster.

Further, since Yerevan city is the center of governmental, economical and social functions of Armenian country, when it is hit a destructive damage, socio-economical functions will be stand still and all the development will be suspended, and it is alarmed to become a country wide scale disaster.

(4) Problems to be solved in Yerevan City for Earthquake Disaster Management

Following problems will be pointed.

(a) Insufficient in scientific evaluation of seismic hazard, risk and earthquake scenario

Though earthquake investigation and various analyses are conducted by multiple organizations, mutual cooperation is insufficient. Fully resolution is not conserved in comprehensive evaluation in seismic hazard and risk for earthquake disaster management planning.

(b) Deficiency of Preparedness measures in Earthquake Disaster Management Plan of Yerevan city

After the 1988 Spitak Earthquake, country level earthquake disaster management activities have been conducted in Armenia. Regarding laws, acts and decision were enacted, but they were not yet so systematic. Also, though earthquake disaster emergency response plans were established, preparedness measures were not sufficiently considered. Further, in Yerevan municipality, department of disaster management does not exist and instead Yerevan branch of RS is taking over, though still concrete action plan and measures are not identified clearly.

(c) Insufficient in disaster reduction measures due to evaluation, inspection and conduction of measures for seismic resistant buildings

The Building Code in Armenia is enacted in 1994 and revised 2006. However most buildings in Yerevan city were constructed before the code, and now are showing low seismic resistance due to their age. Further, the high vulnerability of the major part of buildings is also due to low quality of designing process and construction. Since there are difficulties in agreement of residents and financial raising at condominiums where most citizens are living, strengthening of structures due to inspection, retrofitting and rebuilding is in difficult situation. Systematic building inspection, retrofit measures, and keeping and following the Building Code are necessary.

As explained above, due to imminence of earthquake and overage of buildings, earthquake disaster risk in Yerevan City has been increasing. Armenian Government recognizes this situation and has started to take actions to reduce urban vulnerability and earthquake disaster risks. However, the challenge to mitigate disaster impact to society, economy and finance caused by recurrent earthquakes in future requires holistic and multi-dimensional approach. Thus, international cooperation network has been sought.

Under such circumstances, the Government of the Republic of Armenia has requested the Government of Japan for technical cooperation. To respond to the request, the Government of Japan has decided to implement “The Project for Seismic Risk Assessment and Risk Management Planning In the Republic of Armenia” and the Japan International Cooperation Agency (hereinafter referred to as “JICA”), the official agency responsible for the implementation of technical and international cooperation programs of the Government of Japan, is instructed to undertake the Study. Based on this, JICA has decided to conduct the Project under the signature of Scope of Work for the Project on February 9, 2010.

1.2 Purpose of the Project

The goal of this project is "Reduction of Disasters due to a large scale earthquake which has a possibility of occurrence in Yerevan City". The three purposes of the project are the followings;

1) Generation of seismic risk map and establishment of earthquake disaster management plan for Yerevan city
2) Capacity development of relevant organizations on seismic risk evaluation, earthquake disaster management planning, and these capacities for applying to other cities in Armenia.
3) Establishment of cooperation structures and cooperation relations among Ministry of Emergency Situations (including RS), Yerevan Municipality, and relating organizations regarding to earthquake disaster management.

The target area of the Project is 227km^2, shown in Figure 1.2-1.

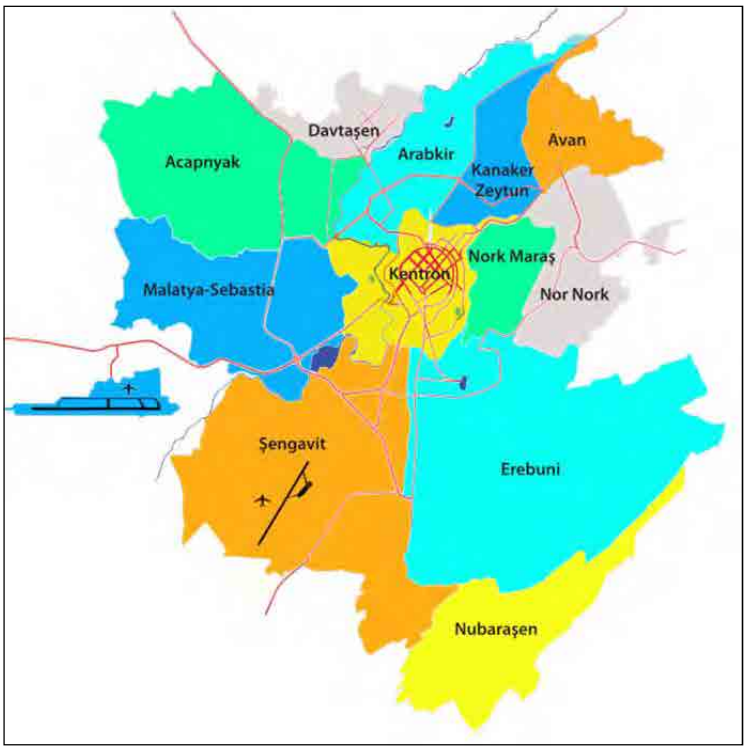


Figure 1.2-1 Whole Area of Yerevan City (227km^2)

1.3 Execution Structure of the Project

The project is executed by relating organization of counterpart of Armenian side, JICA Team. The JICA Team is consisted of OYO International Corporation, Nippon Koei Co. Ltd., and Kokusai Kogyo Co. Ltd. The counterpart organization of Armenian side is RS (Rescue Service, Ministry of Emergency Situations).

In Armenia, wide range of people of governments and institutions at national and city levels are relating to earthquake disaster management. Since these organizations are accumulating various data regarding to earthquake disaster management, advance in preparedness against earthquake disaster management is expected due to active participation of these organizations to the project. Therefore, steering committee and two working group of earthquake risk evaluation and earthquake disaster management planning consisted of these persons concerned to these organizations are formulated in order to establish the operation system for getting advices and suggestions.

Following Figure 1.3-1 shows the operation system of this project. Also the conducting people in operating group, consisting organizations of steering committee and working groups are shown in Table 1.3-1.

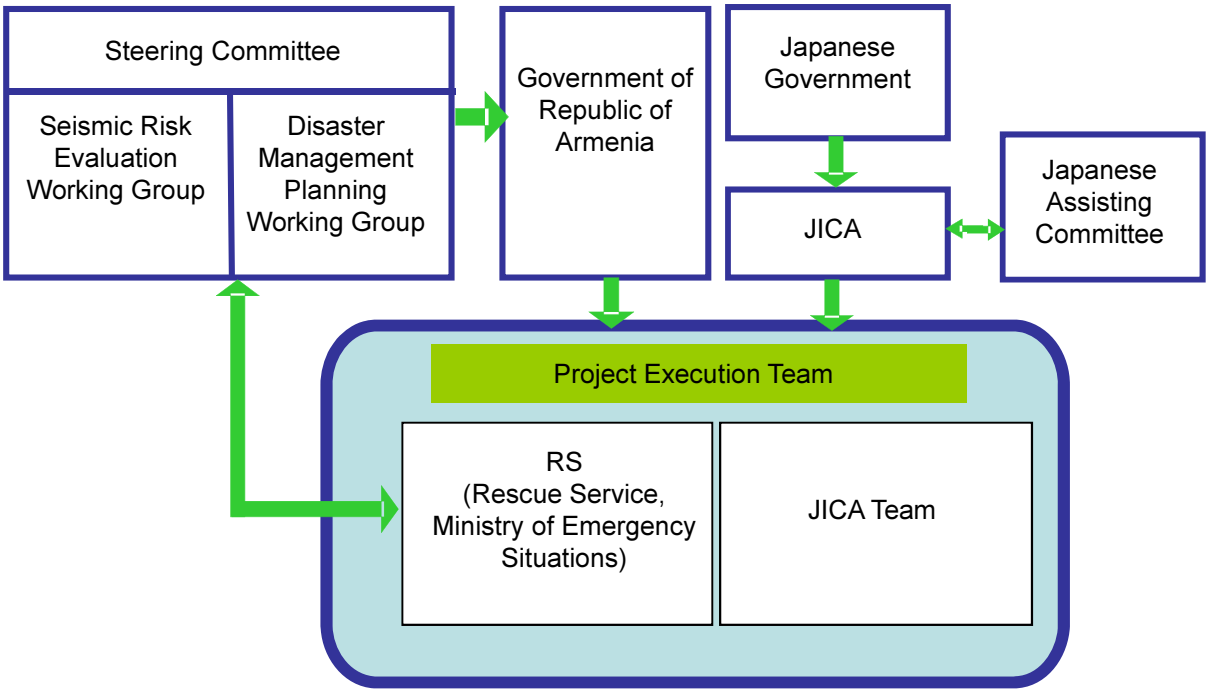


Figure 1.3-1 Operation System of the Project

Table 1.3-1 Operating Organizations and Members

<JICA Team Members>

NAME	Expertise
Fumio KANEKO	Leader
Kenji YANO	Sub Leader / Earthquake Disaster Management Planning / Earthquake Disaster Scenario
Shukyo SEGAWA	Sub Leader / Seismology / Earthquake Engineering
Michio MORINO	Topography / Active Fault
Satoru TSUKAMOTO	Geology / Land Slide
Jun MATSUO	Soil Investigation / Coordinator
Akira INOUE	Building Structure / Retrofit

Tsuyoshi YOSHIDA	Seismic Resistant Evaluation of Transport Infrastructure
Hideo SATO	Seismic Resistant Evaluation of Lifeline Facilities
Koichi HASEGAWA	GIS / Mapping
Kenji FUKUSHIMA	Land Use / Urban Planning
Tomoko SHAW	Disaster Education / Community Disaster Management
Le ZYENHAI	System Engineer
Kazuhiro KUKI	Establishment of Earthquake Observation System
Sinya KAWADA	Environmental and Social Consideration
Akiko ITO	Coordinator / Assistant of Earthquake Disaster Management Planning
Koichi SHIWAKU	Coordinator / Assistant of Disaster Education
Kumiko NOGUCHI	Translator

<Japanese Assisting Committee>

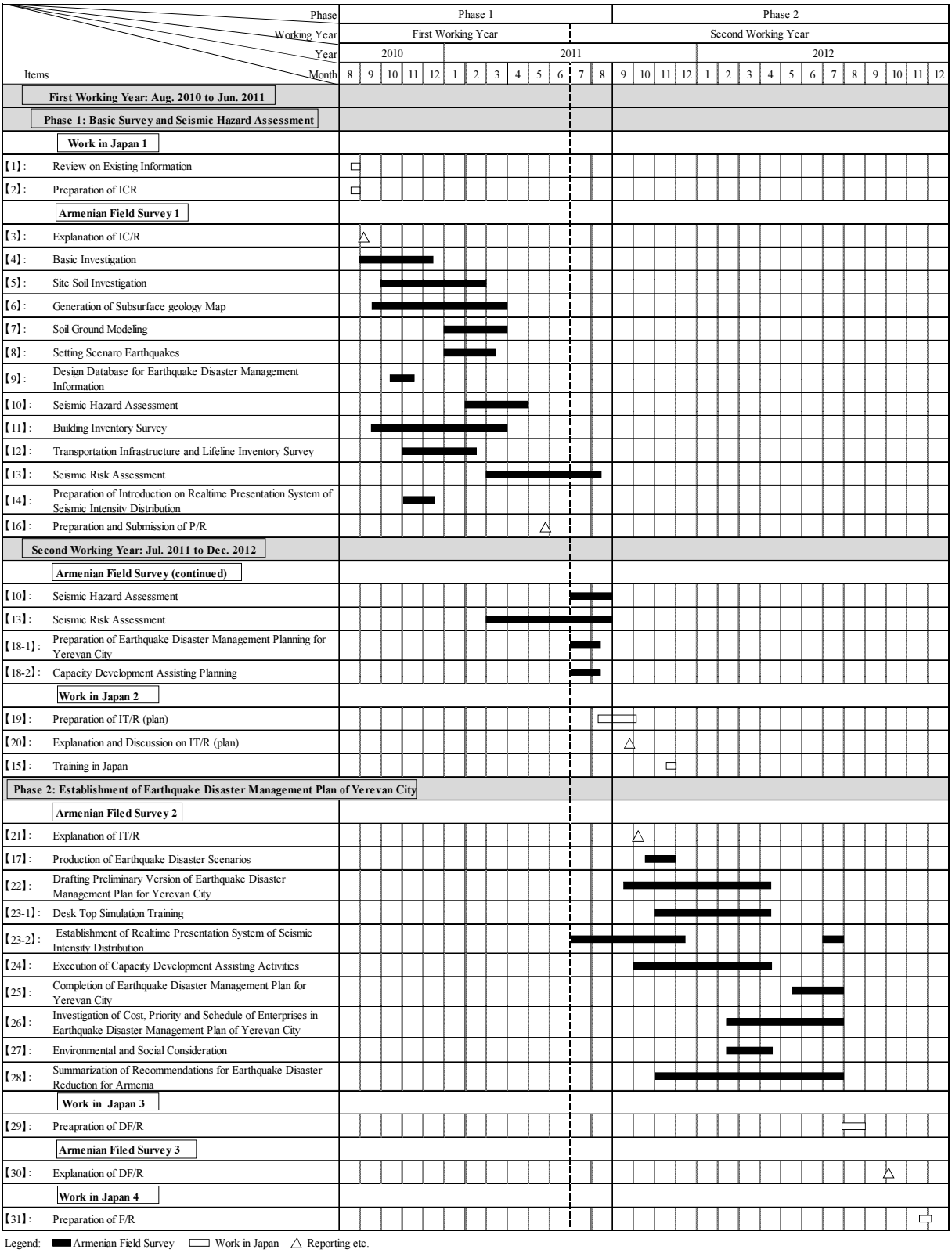
Name	Affiliation
Toshiaki YOKOI	Senior Researcher, International Earthquake Engineering Center, Building Research Institute of Japan
Tatsuo NARAFU	International Cooperation Expert, Japan International Cooperation Agency

<Composition Organizations of Steering Committee and Working Groups>

Organization
RS (Rescue Service, Ministry of Emergency Situations)
Ministry of Emergency Situations
NSSP (National Survey of Seismic Protection, Ministry of Emergency Situations)
Armenian Research Institute of Earthquake Engineering, Ministry of Urban Development
Yerevan Municipality (Mayor)
Institute of Geological Science, Armenian Academy of Science
Cadastro
Lifeline Companies (Water, Sewerage, Gas, Electricity, Telephone)

The duration of the project is around 29 months from August 2010 to December 2012. Phase 1 is by September 2011 and mainly for seismic hazard and risk assessment. Phase 2 is after then and mainly on earthquake disaster management planning. The schedule and the contents of work of the project are shown in Table 1.3-2 and Figure 1.3-2 respectively.

Table 1.3-2 Working Schedule of the Project



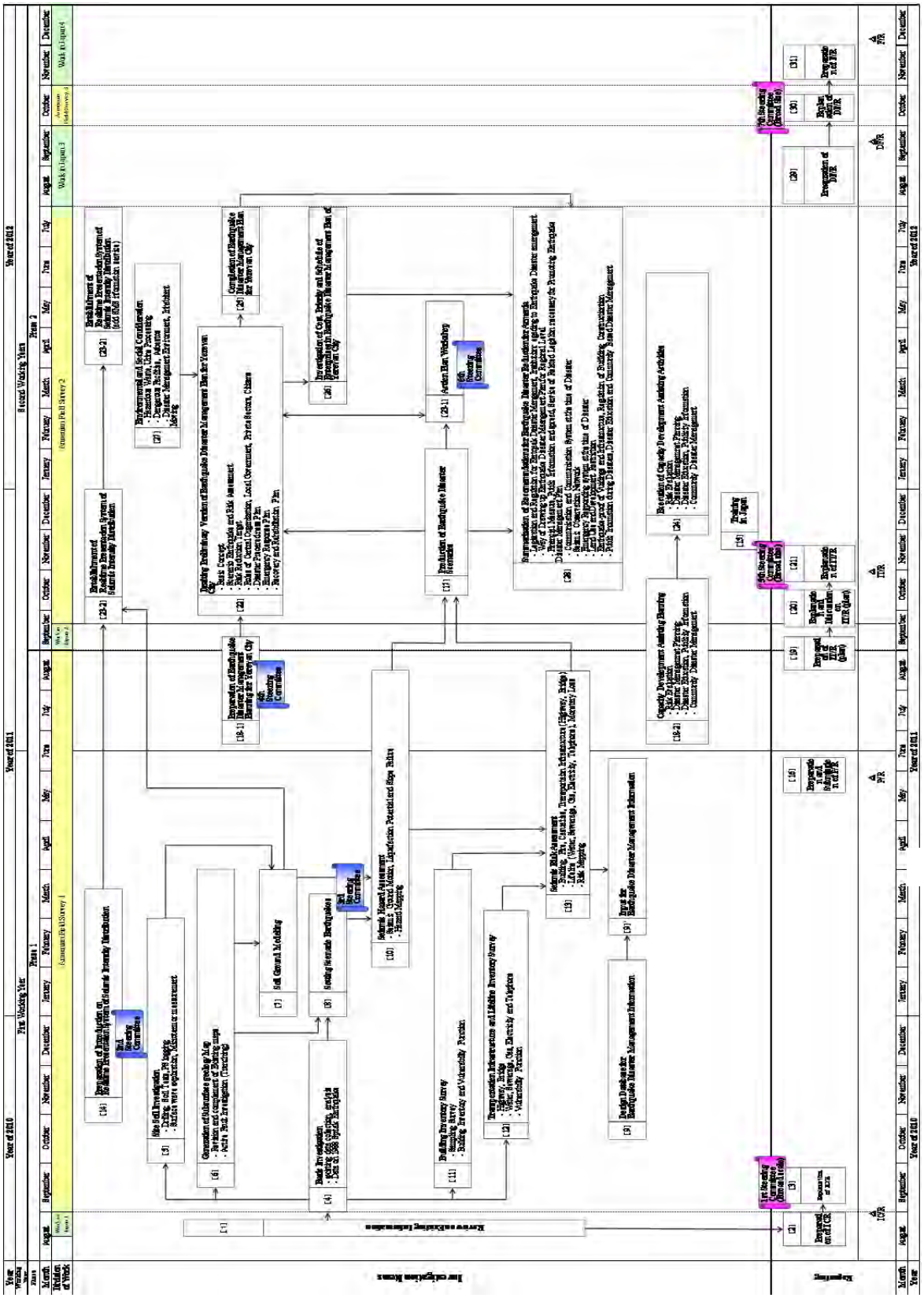


Figure 1.3-2 Flowchart of the Project

Chapter 2 Data Collection and Evaluation

The collection and arrangement were conducted for the data which is necessary for the seismic hazard and risk analyses, generation of earthquake scenarios and establishment of earthquake disaster management planning. These data are compiled in the GIS database for future utilization. The outline of treated data is the followings;

Table 2-1 Outline of collected Data and contents

Item	Contents
Disaster Management Plans for Armenia and Yerevan city	Plans for emergency response against earthquakes, action plans, civil defense plans etc.
Laws and Regulations regarding to disaster management	Laws and regulations, decisions regarding to earthquake disaster management
Emergency Response Institutions	Disaster management institutions in Armenia and Yerevan city, information exchange
Existing Projects regarding to disaster management	Projects regarding to disaster management in and around Armenia by International donors etc.
Maps and GIS data	Maps, topography data, GIS data, aero photo, satellite imagery
Geology, ground conditions, earthquakes, meteorology	Geology map, active fault map, drilling data, soil test data, Earthquake catalogue, records, earthquake damage reports, Climate, wind, temperature etc.
Urban development and plans, land use	Urban plan, land use map, master plan
Buildings	Residential buildings, public buildings, inventory data of buildings, buildings code and regulations, building construction restrictions
Infrastructures	Structure and networks of roads, bridges, railways, airports, etc.
Lifelines	Structure and networks of water, sewerage, electricity, Gas and telephone.
Hazards materials, critical industries	Gas stations, gas tanks, chemical factories, hazardous waste treatment, critical industries, large shopping centers
Socio-economic and demographics	Census and statistic data for Population, family, economic, industries, community etc.
Disaster education, and publicity	Disaster education at School, disaster management activities, knowledge in disasters, awareness of citizen, publicity of disaster management etc.
Resources for disaster management, and environment(ecological) related issues	Parks, hazardous treatments, disaster management facilities like fire station, police station, etc.

2.1 Regulation, Organization, and Plan

The Republic of Armenia suffered serious damage from the Spitak earthquake in 1988, just before the independence from the Soviet Union. The Republic consequently made vigorous exertion in developing frame work such as regulation, organization, and planning in earthquake disaster management, even in years of confusion after the independence, and the efforts have being continuing until this day.

2.1.1 Regulation

In the Republic of Armenia, the Law on Protection and the Law on Martial Law were in force in 1997. These laws mainly ordain matters responding to armed attack.

The following four laws are major laws concerning disasters, including earthquake disasters, and major accidents.

1) Law on Population Protection, being in force in 1998
2) Law on Civil Protection in 2002
3) Law on Seismic Protection in 2002
4) Law on Fire Security in 2001

The Law on Population Protection and the Law on Civil Defense ordain matters responding in emergency situations to major accidents and disasters as well as armed attack, and these laws are base for responding earthquake disasters. These laws cover issues on emergency response and its preparation, but do not include much provision on mitigation.

The Law on Seismic Protection is a comprehensive law ordaining matters on earthquake disaster management, including provision on over-all disaster management cycle including mitigation, and provision on the right and obligation of all-level actors including public bodies, organizations, and population.

For the implementation of the above-mentioned laws, several regulations are in force as shown below.

1) Regulating activities of the government of RA in case of a severe earthquake or the threat of it (Decision N152, 1997)
2) The procedure on population evacuation from dangerous areas (Decision N746, 1999)
3) The procedure on population sheltering (Decision N592, 2000)
4) Regulation on provision of population with individual protection means (N679, 2000)
5) Order of preparedness of state and local authorizes and organizations and training of population of the Republic of Armenia in the fields of emergency situation and civil defense (Decision N134, 2003)
6) Establishment of the list of Critical, important and general purposes facilities in the field of seismic protection (Resolution #237-N, 2003)
7) Order of reception of information and warning about occurrence of emergency situations in the territory of the Republic of Armenia (Decision N1304N, 2003)
8) Order of development of Civil defense plan (DecisionN633N, 2004)
9) Order of warning of population and governing bodies (N1494, 2004)

10) Order on warning of population about the occurrence of emergency situations in the territory of the Republic of Armenia (Decision N1925N, 2005)
11) Approving the plan of main actions of Yerevan City master plan execution (Decision N1402N, 2006)
12) The regulation of involving the rescue forces into the emergency situation prevention and disaster consequence elimination (Decision N1403, 2006)
13) Procedure and conditions for organization of qualification for rescue units and rescuers (Decision N1391N, 2006)
14) Order of the adoption of seismic micro zoning map (Decision N1581N, 2006)
15) Earthquake resistant construction design codes (RABC II-6.02-2006, 2006)

In the above-mentioned regulations for implementation, some laws (such as N157 and N746) seem to need to be updated for reflecting change of government organizations, and laws relating to warning (N1304, N1494, and N1925) require to unify the procedure and show the procedure in a plan.
Regulations, relating to organizations on earthquake disaster management are defined as follows.

1) Charter of the emergency management administration under the Government of the Republic of Armenia (Decision N67-D, 2003)
2) The procedure on civil protection formations creation, preparation and activities (Decision N1532N, 2003)
3) Order of establishment, preparation and activities of civil defense services (Decision N384N, 2003)
4) Law on rescue forces and status of rescuers (Law HO85, 2004)
5) Charter of the "National Survey for Seismic Protection" agency of the Ministry of Territorial Administration of the Republic of Armenia (Decision, 2005)
6) Legislation and structure of the Armenian Rescue Service(N634N,2005)
7) Law on "the Armenian Rescue Service" (Law 30-171N, 2005)
8) Order and conditions of conducting the attestation of rescue officer (N1799N, 2005)
9) Legislation of the Ministry of Emergency Situations of the Republic of Armenia (Decision N531N, 2008)

Several plans relating to earthquake disaster management have been ratified and been in force as government decision or other official documents as shown in sub-section 2.1.3.
Yerevan City also defines the framework of disaster management on the following Mayor's decision, based on regulations and plans ordained by the Republic.

1) Establishing evacuation committee in Yerevan City (Mayor's decision 397A, 2007)
   Ditto modification (Mayor's decision N1832, 2003 and Mayor's decision 397A, 2007)
2) Establishment of committee of emergency situations in Yerevan City (Mayor's decision N920, 2000)

Ditto modification (Mayor's decision1830, 2003, Mayor's decision N747, 2007, and Mayor's decision, 2010)

3) Changes in the structure of civil defense system of Yerevan City (Mayor's decision 1418A, 2003) Ditto modification (Mayor's decision 398A, 2007)
4) Approval of the charter of urban development of Yerevan (Mayor's decision A2228A, 2006)

2.1.2 Organization

According to the Law of Civil Defense, which ordains the framework of disaster management, including earthquake disaster management, the head of civil defense in the Republic is the Government of Armenia, the deputy is the Minister of Emergency Situations, and responsible governmental body is Ministry of Emergency Situations. The President of the Republic has a power to determine and modify the framework as the executor of sovereign responsibility of the Republic.

Ministry of Emergency Situations; MES governs the following subsidiary organizations relating to earthquake disaster management.

"Rescue Service; RS", "National Survey for Seismic Protection; NSSP", "National Reserves Agency", "State Crisis Management Academy", "State Hydrometeorology and Monitoring Service", and "Technical Security Services".

Among these organizations, Emergency Management Administration; EMA (the predecessor of RS, which is the counterpart organization of this Study), was established as "Emergency Management State Administration; EMSA" in 1992 with "Civil Defense at the time of the Soviet Union" as its parent organization, and then, changed to be "Civil Protection" in 1993, "Emergency Management Administration; EMA" in 1995, "Armenian Rescue Service; ARS" in 2005, and "Rescue Service; RS" in 2012. RS is the authorized body on emergency response to emergency situations, including earthquake disasters, and its preparation, as well as the formulation of disaster management plans, including earthquake disaster management plan, and the management/super vision of the implementation of the measures.

NSSP was established in 1991 by the Government of Republic of Armenia with the task of which was the organization of seismic protection of the population, buildings and structures. In addition to earthquake monitoring, NSSP has responsibility in the preparation of seismic hazard maps, formulation of reduction plans of earthquake disaster risks, implementation of programs for mitigation such as earthquake disaster education and examination of vulnerability of buildings.

Both RS and NSSP were established as agencies under Prime Minister, and belonged to Ministry of Territorial Administration in 2005 at the establishment of the ministry, and then, moved to Ministry of Emergency Situations in 2008 at the establishment of the ministry.

At the time of emergency situations, the management of the situation should be done with national-level committee of emergency situations, headed by Prime Minister as well as local committee of emergency situations, headed by Mayor of Yerevan or the head of marzes (prefectures) as shown in Figure 2.1-1.

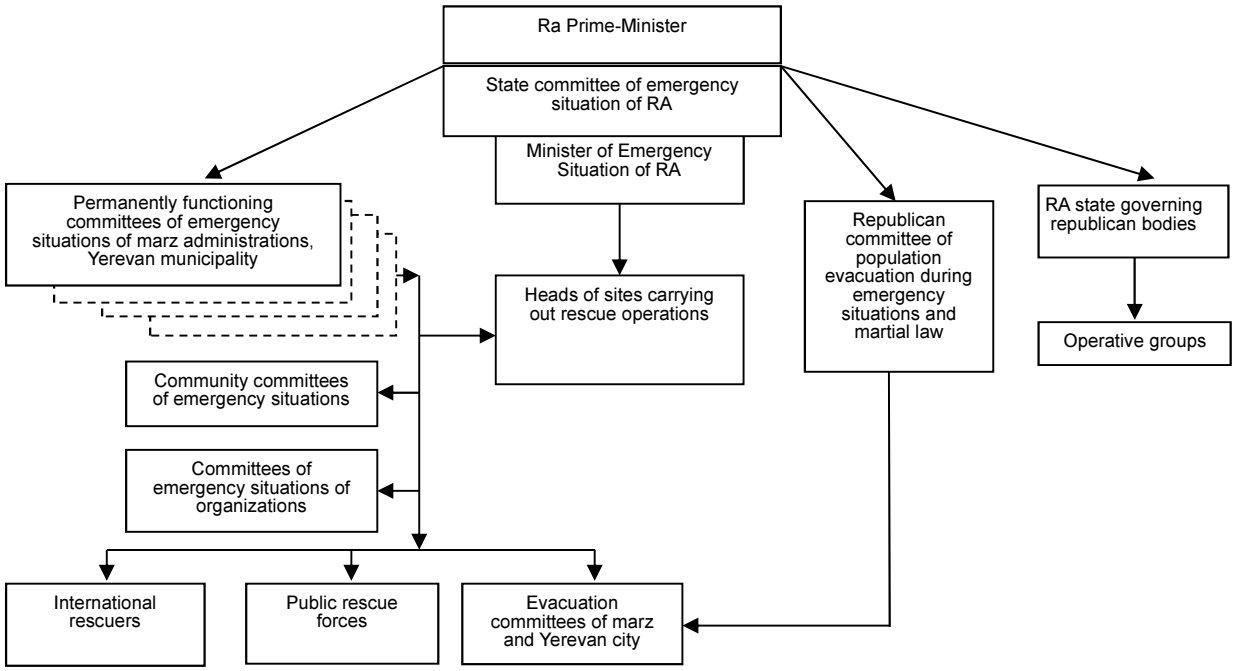


Figure 2.1-1 Chart of management bodies for civil protection in emergency situations

Yerevan City has created several services for formulating plans and organizing institutional base as well as activities for rescue and emergency response in martial law and emergency situations by Mayor's decision N1418L. The decision also ordains fundamental organizations for the created services and the heads of the services.

1. Communication and warning service, 2. Evacuation committee, 3. Public order keeping service, 4. Medical service, 5. Engineering service, 6. Utilities-technical service, 7. Energy and black-out service, 8. Transport service, 9. Commerce and service unit, 10. Nature and environment protection service, 11. Information and public affairs service, 12. Unit of special service of population.

The Mayor's decision N398 in 2007, which amended the above-mentioned Mayor's decision N1418L, ordains the followings for population protection.

- The head of each service should submit the re-elaborated structure, staff, and charter to the Mayor for his approval in one month period.
- The head of district communities should review the previous decisions and orders on the establishment of civil defense services, elaborate the charters, agreed with the rescue department of Yerevan City of RS, and in one month period.
- Rescue department of Yerevan City of RS is the working body of management of system of emergency situations and civil defense of Yerevan City.
- The head rescue department of Yerevan City of RS has responsibility of organization and implementation of the present decision.

2.1.3 Plan

As a plan relating to earthquake disaster management, "Complex Programs of Seismic Risk Reduction ("Reduction Plans")", mainly for pre-disaster measures (mitigation and preparedness), were formulated for Yerevan City and the Republic in 1999, considering the results of seismic hazard assessment done by NSSP, and the programs were approve as Resolutions #392 and #429.

As a plan for emergency response, "Comprehensive disaster response plans ("Response Plans")", which include response to natural disaster and armed attach, were formulated for each marz (prefecture) in 2001 and the plans are updated as needed.

As an emergency response plan for Yerevan City, "Plan of Action of Yerevan City in Emergency Situations (Action Plan)" was formulated in 2007, and the way of response to major accidents and disasters was defined in the plan.

In 2010, "The Concept of Development of Seismic Security System of the Republic of Armenia ("Concept")", which aims at comprehensive earthquake disaster management, was officially announced as Presidential order NH140N. The "Concept" sets similar target in comprehensive earthquake disaster management to what sets in this study with the following main points.

- Important matters in seismic security system are risk reduction based on strong and stable institutional base, task shearing and collaboration, identification and evaluation of risk, reduce its components and factors, establishing early warning system, strengthening international and regional cooperation.
- Main issues requiring solutions are as follows.
  1) Absence of state joint mechanism of seismic risk reduction due to frequent structural and functional changes of the republican authorized body
  2) The way of implementation, coordination, and supervision of complex projects for seismic risk reduction is not clear. This issue has been improved.
  3) Necessity to reform the Republican "Law on Seismic Protection" and review complex projects both for the Republic and Yerevan City.
  4) Necessity to initiate relevant reforms in bodies having supervisory functions.
  5) Necessity to improve the legal field
  6) Issues of distinguishing of competencies among related organizations.
  7) Sub-legislative filed defining the order of land use, design, acceptance of finished buildings, and their further exploitation.
  8) Factors of seismic risk and seismic hazard are not completely reflected in urban development.
  9) Legal regulation on use of built-up area is incomplete from a viewpoint of seismic security.
  10) Necessity to modernize seismic observation network, enhancement of the accuracy of measurement, and increase the effectiveness of evaluation of seismic hazard
  11) Necessity of international and regional cooperation.

- The strategic objectives and component of the concept are shown in order to solve the above-mentioned issues.

- The main tasks of all related organizations are shown for the establishment of the seismic security system.
- Policy, financial sources, and target years are shown for the development of the system.
- As a result of development of the system, main issues on the assessment of seismic hazard and risk will be solved in five years, state projects for risk reduction will be elaborated, and seismic risk will be reduced considerably in ten years.

In 2010, "Plan of Organization of Protection of Population of the Republic of Armenia in Case of a Severe Earthquake (Organization Plan)" was in force as Decision N919. The "Organization Plan", ordains and explains on the following matters.

- Tasks and functions of government bodies, including all ministries, and related organizations
- The summary of natural and seismic conditions, evaluation result of human and physical damages by an earthquake (human loss in Yerevan City is evaluated to be 162,243), and required number of several kinds of rescue forces and their activities for the response
- Stipulation on organizations and activities for management, medical care, information transmission, damage reconnaissance, and evacuation
- Stipulation on organizations and implementation for rescue, medical care, social security, logistics, foods, transportation, and information dissemination
- Stipulation on method and order of reception, acceptance, and distribution of international assistance

An earthquake disaster management plan to be prepared in phase 2 in this Study will be a comprehensive management plan, based on the above-mentioned "Concept" and "Organization Plan" and it will include the result of review and updating of "Reduction Plans" and "Response Plans".

2.2 Maps and GIS data

2.2.1 Maps

(1) Topographic Map

The base maps to get inventory for seismic risk assessment or conduct several kinds of survey are the existing topographic maps from Cadastre. The scales of the topographic map are 1/2,000, 1/10,000, and 1/50,000, which covers all the region of Yerevan city. The number of CAD files for three scales are shown at the Table 2.2-1. Figure 2.2-1 shows an example of the CAD drawing of the scale 1/2,000. Coordinate system of these topographic maps is the following Projection: Gauss-Kruger, Datum: Pulkovo1942 (Zone8).

Table 2.2-1 Collected Topographic CAD data

Scale	Year	Number of files
1/2,000	2005	376
1/10,000	-	18
1/50,000	-	4

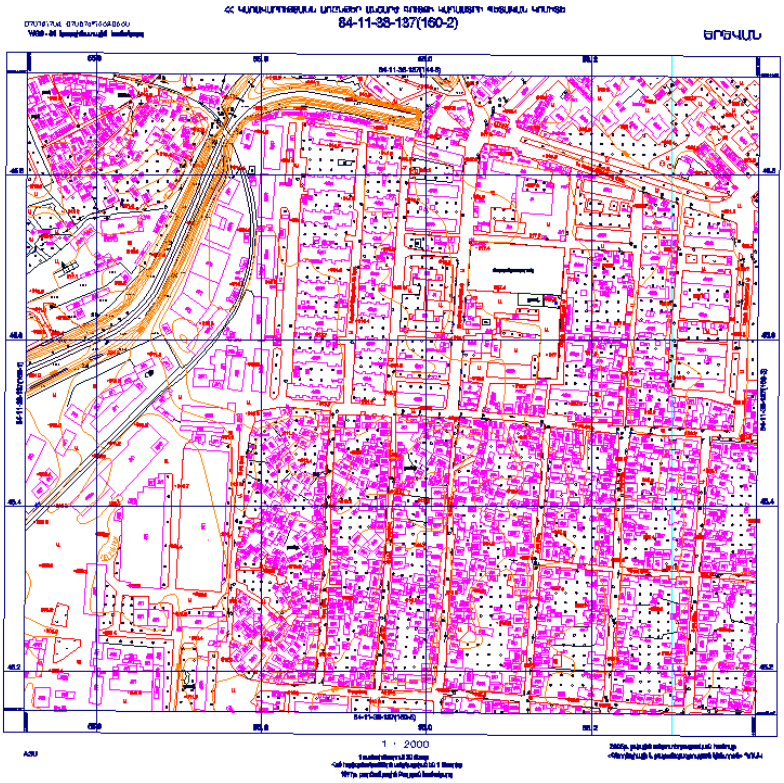


Figure 2.2-1 Example of the topographic CAD drawing of scale 1/2,000

(2) Aero Photo Image Map

As one of the free online map services of Arc GIS, ESRI which is selected for this project (Figure 2.2-2), Bing Maps, aero photo image maps offered by Microsoft is available in Armenia. Therefore, the Bing Maps were used to make inventory data or confirming the location of survey locations.

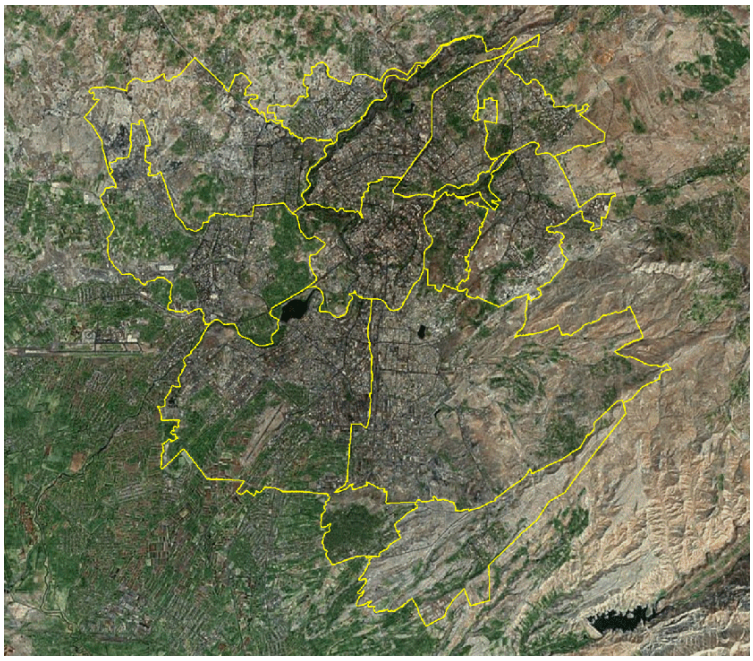


Figure 2.2-2 Bing Maps and Yerevan community border line

2.2.2 GIS (Geographic Information System)

GIS (Geographic Information System) is the important tool for constructing the database from collected or surveyed data. As RS has already introduced the ESRI's GIS, that is one of the worldwide standard GIS, we introduced ESRI's Arc GIS Desktop 9.3.1.

In order to construct a geographic database in a GIS, it is better to unify the coordinate system. In this project, Projection: Universal Transverse Mercator (UTM), Datum: WGS1984, Zone 38N is selected. On the other side, most GIS or CAD data files offered from Cadastre or other institute are based on the Projection: Gauss-Kruger, Datum: Pulkovo1942. Thus it is necessary to convert the datum from one another. As the parameter set of ESRI doesn't offer the parameter for Armenia, we decided to use an original parameter shown in the Table 2.2-2.

Table 2.2-2 Geographic Transformation Parameter from Pulkovo1942 to WGS1984

Method	Parameter
Geocentric Translation	X Axis Translation: 4.5(meters) Y Axis Translation: -8.5 (meters) Z Axis Translation: 0 (meters)

2.3 Earthquake Related Data

2.3.1 Earthquake Catalogue

The survey of the earthquake, determination of the hypocenter and the magnitude are conducted by NSSP using the 31 seismometer installed in Armenia. The obtained data are compiled to the earthquake catalogue including the date/time, hypocenter and magnitude of the earthquake. The distribution of the

earthquakes in and around Armenia after 1932 based on the earthquake catalogue of NSSP is shown in Figure 2.3-1. This figure shows that the 1988 Spitak Earthquake is the only one event larger than magnitude 6 in Armenia during recent 75 years that occurred in Armenia. The seismicity is active in northern part of Armenia including Lori State to Georgia across the border, but the earthquakes larger than magnitude 5 is less around Yerevan. Several earthquakes of magnitude 4 class can be found in southwest of Yerevan, which caused no damage at all. There have occurred some magnitude 5 class earthquakes near Ararat Mountain in Turkey.

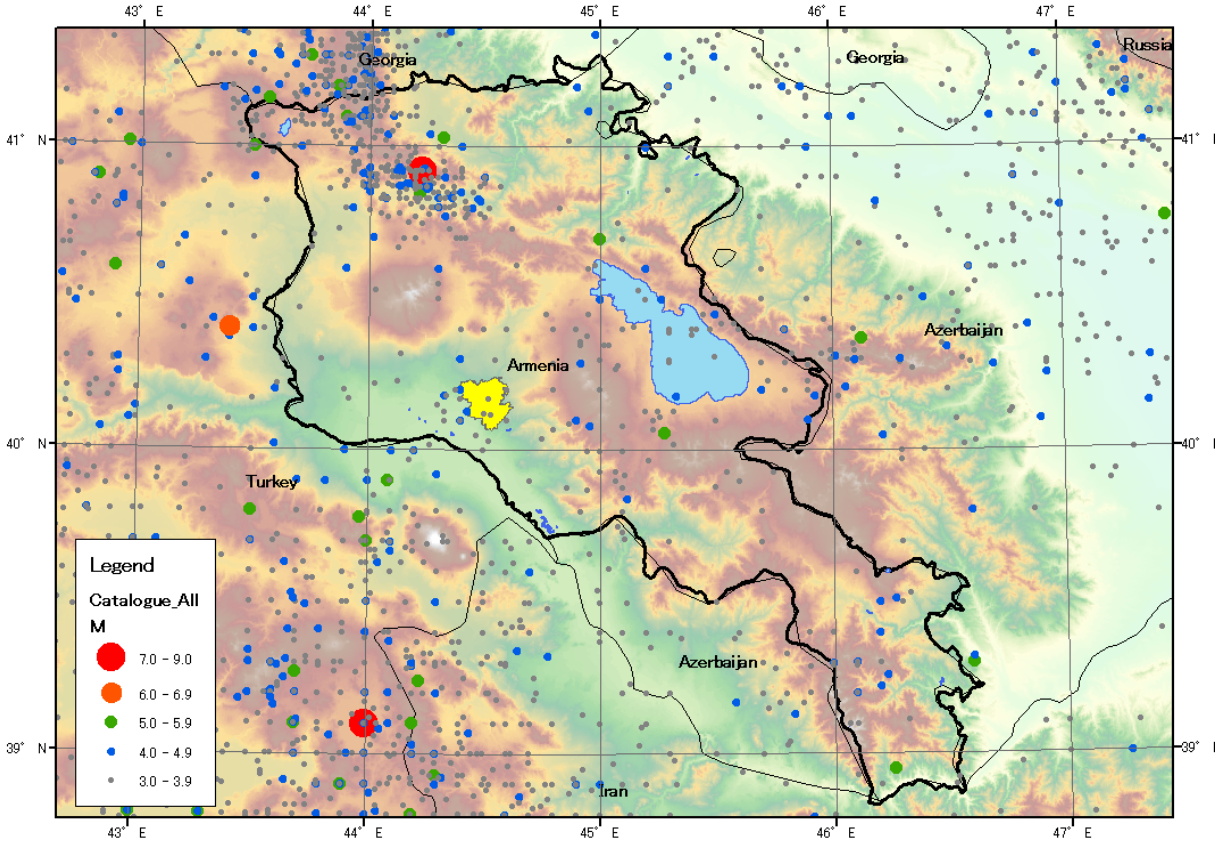


Figure 2.3-1 Seismicity from 1932 to 2008 by NSSP Earthquake Catalogue

NSSP also made the so-called historical earthquake catalogue which includes the event before starting the instrumental earthquake observation based on the existing material and literature. The distribution of the historical events from BC is shown in Figure 2.3-2. Several earthquakes of magnitude 7 or larger have occurred in southern and eastern area in Armenia, therefore it is known that seismic active area is not limited to the northern area in Armenia from this figure.

Near Yerevan City, magnitude 7 class Garni Earthquake has occurred in 1679 in the east, and magnitude 6 class earthquake has occurred in 9th century in the south near Dvin.

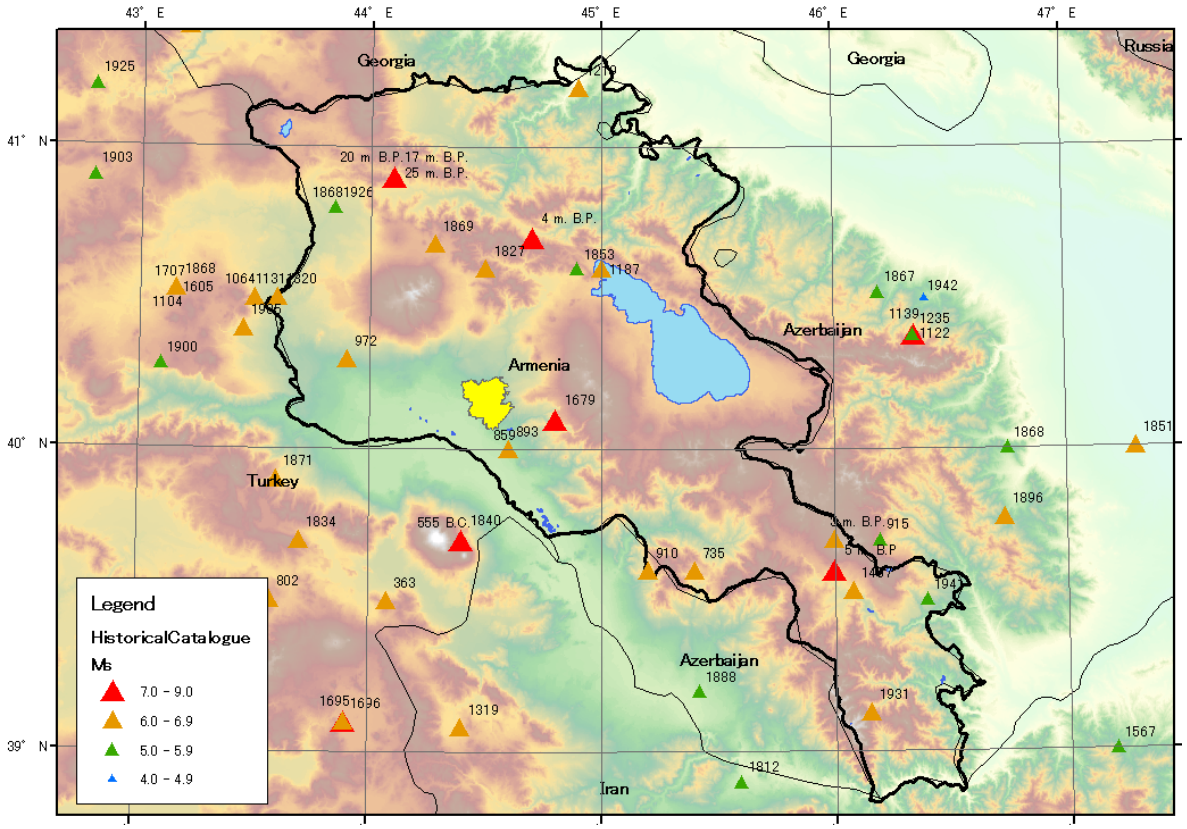


Figure 2.3-2 Historical Seismicity by NSSP Catalogue

2.3.2 Strong Motion Records

Strong motion observation started 1970's in Armenia, and in 1991 NSSP started the strong motion observation after 1988 Spitak Earthquake using the digital strong motion seismometer under the assistance of Swiss. The current 9 observation points of them are shown in Figure 2.3-3. NSSP also collaborates with Georgia in the data exchange and using the observed data in Georgia for their analysis. The observed digital strong motion records of the earthquakes in Figure 2.3-3 are made into the database. No events larger than magnitude 5 have been occurred in Armenia since 1988, while some earthquakes of magnitude 7 or larger occurred in Georgia and the observed records of these events are utilized in their analysis

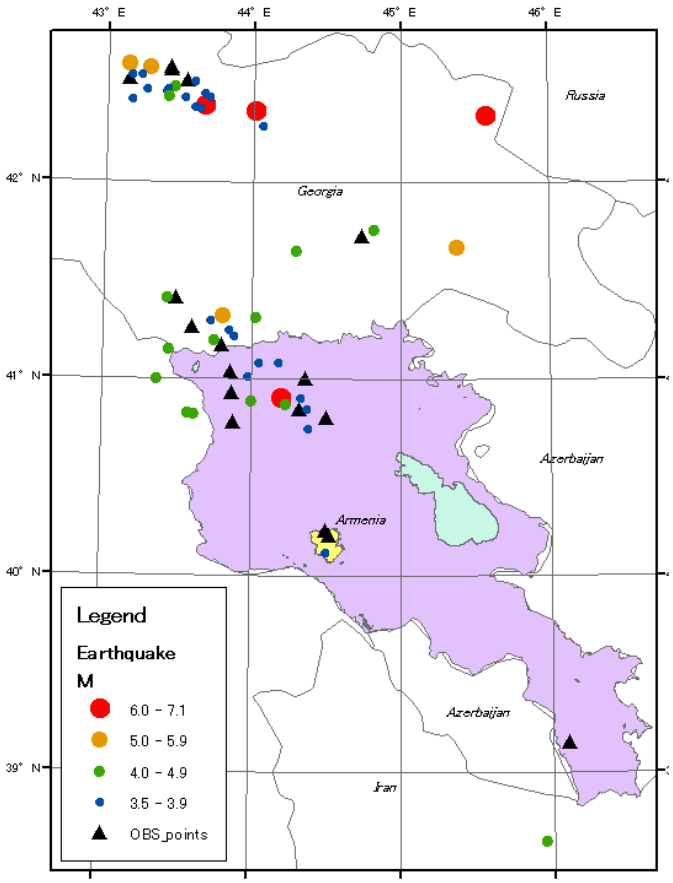


Figure 2.3-3 Strong Motion Observation Points of NSSP and the Observed Earthquakes

2.3.3 Data of Earthquake Damage

Armenia is the seismically active region and there have been experienced many damage by earthquake in prehistory period and historical period. At the same time, Armenia is the highly civilized area from ancient times and there are many literatures referred to the earthquake hazards. The estimation of the situation of historical events based on the literature containing information, or known or existing information on damage degree of the church is tried by IGS and their group.

As shown in Figure 2.3-2, 1679 Garni Earthquake and Dvin Earthquake in 9th century are known for the earthquakes that have affected to Yerevan. Dr. Balassanian, who was the leader in seismology and earthquake engineering in Armenia, described about these earthquakes in his book (Balassanian et al. (2004)) as follows.

893. 3. 27 (M=6.5) "Dvin Earthquake"

An earthquake occurred near Artashat in the Ararat valley, south of Yerevan. The estimated maximum MSK intensity is 9. More than 70,000 people may have died by this earthquake.

1679. 6. 4 (M=7.0) "Garni Earthquake"

An earthquake occurred at Garni, where is 20km east of Yerevan. The estimated maximum MSK-64 intensity is 10. The fort in Yerevan collapsed and mosques and minarets came down. In Kanaker village (currently north of Kanaker-Zeytun in Yerevan), 1,228 people died and 7,600 people in total.

As for Dvin Earthquake, many researchers offer several opinions and even the year of the occurrence has not been fixed. Some researchers mention that not only the 893 year but large earthquake occurred in 863 year and affected damage to Dvin (e.g. Guidoboni (1997)). There is a source mentioning 12,000 victims by 863 year events.

The population of Yerevan was about 10,000 at the time of 1679 Garni Earthquake and historical literatures described the damage of the churches as follows.

- In 1679, a calamitous earthquake leveled much of the city and destroyed many structures in the neighboring regions.
- The following churches were destroyed: Aghchots temple, Ayri temple, Havuts-Tar, Trdakert, Khorvirap, Jrvezh, Dzagavanq, three churches of Yerevan, Noragavit, Noragegh, Dzoragegh, Norq, Gamrez.
- St. Sarkis Church, together with the hermitage-monastery, destroyed.
- Yerevan fortress: (left edge of canyon of Hrazdan river includes 800 houses) completely destroyed
- Katoghike church: (Abovyan & Sayat-Nova str.) Partly destroyed
- Paul-Peter church: (Abovyan & Tumanyan str.) destroyed particularly the southern wall
- Getseman chapel: (current state opera house) cupola was destroyed
- Chapel and cemetery of Kozern: (South of Baghramyan ave.) oldest cemeteries of Yerevan old chapel was destroyed
- St. Hovhannes church of Kond: (Paronyan str.) collapsed
- Zoravor church: (Pushkin str.) eastern wall was highly damaged
- The old bridge of Hrazdan: (South of Haghtanak bridge): with 4 (2 are big) arch spans, rebuilt after earthquake of 1679
- St. Astvatsatsin church of Norq: (in Norq) destroyed
- Simon Tseruni church of Norq: (old Norq) destroyed
- Bridge of Norq: (Norq canyon) resisted
- St. Hakob church of Kanakar: (Fanarjyan street) destroyed
- Avan temple: totally destroyed together with its 5 cupolas and major part of eastern wall
- St. Hovhannes church of Avan: (N. Safaryan street) roof together with the southern wall collapsed.
- St. Astvatsatsin church of Avan: (Marshal Babajanyan street) totally demolished

IGS also compiled the damage in Yerevan by the 1840 and 1937 earthquakes as follows.

1840.7.2 (M=6.5 to 7.4) "Ararat Earthquake"

An earthquake occurred at the vicinity of Ararat Mountain in Turkey, where is 50 km south of Yerevan. The maximum MSK-64 intensity is estimated to be 8 to 10. The death toll in the territory

of Russian Empire was 3,500 and reached 100,000 in total including the victims in Turkey and Iran. The phreatic eruption accompanied with earthquake at the northern slope near the top of Ararat Mountain and pyroclastic flow swallowed the villages at the base of the mountain. The landslide and liquefaction were also found. The estimated direct human casualty is 6,000 and victims by secondary damage is supposed to be 4,000.

1937.1.7

This earthquake may be a local earthquake near Yerevan. The estimated maximum MSK-64 intensity is 7. Some 100 buildings in Yerevan suffered minor crack.

References:

Balassanian, S., S. Nazaretyan and V. Amirbekyan, 2004, Seismic Protection and its Development, Eldorado, p.p. 436 (in Russian),.

Guidoboni, E., 1997, Historical Seismology Research in the Caucasus: Methodological Aspects and Some Results, Historical and Prehistorical Earthquakes in the Caucasus, NATO ASI Series 2. Environment Vol.28.

2.4 Tectonics, Active Faults, Landforms, Geology and Ground Conditions

2.4.1 Tectonics and Active Faults

Literatures on the tectonics and active faults around Armenia were collected and summarized as follows:

(1) Tectonics

Armenia is situated on the north of the collision boundary between the Arabian plate and the Eurasian plate (Figure 2.4-1). This region is one of typical collision boundaries in the world, though the Himalayan region is most famous.

The Arabian plate is moving northward at the rate of 20-30 mm/year and collides with the Eurasian plate. Consequently the Caucasian region is compressed and uplifted. The Black Sea and the Caspian Sea were connected during the geological time. However, the Caucasian region was uplifted and the sea was divided into the Black Sea and the Caspian Sea (Yeats et al. edited, 1997). As shown in Figure 2.4-1, the Anatolian block and the Iranian block are squeezed westward and eastward respectively. The northern margin of the Anatolian block corresponds with the North Anatolian Fault (NAF). Historically the seismicity is high along the NAF.

Due to the compression with N-S direction, the tectonics around Armenia is characterized as follows: 1) WNW-ESE trending reverse and strike-slip faults, and 2) formation of extensional axes with N-S oriented direction (Figure 2.4-2). The former is represented by the Pambak-Sevan-Sunik Fault (PSSF in Figure 2.4-1) which shows the northward convex configuration as well as collision

boundary. The east side and west side of the convex are composed of a right-lateral fault and a left-lateral fault respectively.

The latter is called as the extension behind the collision boundary (Yeats et al. edited, 1997). Volcanoes are aligned with NNW-SSE direction along the extensional axes. According to Karakhanian et al. (2004), the Garni Fault (GF in Figure 2.4-1 and refer Figure 2.4-2) demonstrates a typical right-lateral fault. However, the geomorphic features for a right-lateral fault are not distinct. The GF exhibits the features for a normal fault in the trench which was carried out for this project. Because the GF is parallel to the extensional axes, it seems that the GF is a normal fault with right-lateral component except for the northern edge.

(2) Active Faults

The active faults and epicenters of historic earthquakes around Armenia are shown in Figure 2.4-3 (Philip et al., 2001). Also the active fault map after Gerrisk report is shown in Figure 2.4-4. The data of historic and observed earthquakes after NSSP are overlapped on Figure 2.4-4.

The major active faults in Armenia are composed of the Pambak-Sevan-Sunik Fault (PSSF), the Mrav Fault, the Akhourian Fault, Garni Fault (GF), and Yerevan Fault (YF) etc.

The PSSF which is a longest active fault in Armenia (~410 km) is a right-lateral fault with reverse component, and exhibits clear geomorphic features for a right-lateral fault. The trench investigation along the PSSF was carried out at three sites (Philip et al., 2001). The recurrence period of the PSSF is inferred to be 3000-4000 years. However, the PSSF did not generate the large earthquake with magnitude more than Mw 7.0 in the last 2000 years or more. The PSSF is one of the active faults with high risk of future earthquake occurrence in Armenia.

The Mrav Fault is a reverse fault inclined to the north. The 1139 M 7.5 earthquake was generated by this fault.

The Akhourian Fault is a left-lateral fault. The historic earthquakes with magnitude of M 6.5 to 7.0 occurred along this fault.

The Garni Fault passes from Nakhigevan, Azerbaijan, via the east of Yerevan City, and merges into the PSSF (Figure 2.4-3). The length is ~200 km. According to Karakhanian et al. (2004) and Georisk report on the Garni Fault, the GF is divided into 5 segments. Four large to moderate historic earthquakes have occurred along the GF, viz. the 906 earthquake (M 7.0), the 1679 Garni earthquake (M 7.0), the 1828 earthquake (M 7.0), and the 1988 Spitak earthquake (Ms 6.9). The 906 earthquake is shown as the 910 earthquake by the historic earthquake catalogue of NSSP. The historic earthquakes seem to be shifted from south to north.

The Yerevan Fault is a blind fault which is inferred on the south of Yerevan City based on the gravity anomaly data (Georisk report on the Yerevan Fault). However, a low-angle reverse fault (thrust) overlying the Mesozoic sediments on the unconsolidated Gravel was confirmed by the pilot trench at Nor Ughi that was performed for this project. The part of the YF may reach to the surface, though more detailed trench survey is necessary. According to the mechanism analysis of small to

moderate earthquakes, the prevailing type of motion observed within 30km from Yerevan is a reverse one (Tovmasyan, 2008). The 893 Dvin earthquake is well-known as Dvin of the ancient capital in Armenia has suffered severe damages. Dvin is located near the YF. However, the detailed epicenter of the 893 earthquake is not clarified. There is another opinion that the GF generated this earthquake (Georisk report on the Yerevan Fault). Besides, according to another opinion, Dvin earthquake occurred twice for AD 863 and AD 893 (Guidoboni, 1997).

References:

Guidoboni, E., 1997, Historical Seismology Research in the Caucasus: methodological aspects and some results. In: Giardini, D. and Balassanian, S. (Eds), Historical and Prehistorical Earthquakes in the Caucasus, Kluwer Academic Publishing, Dordreeht, Netherlands, 333-356.

Karakhanian, A.S., V.G. Trifonov, H. Philip, A. Avagyan, K. Hessami, F. Jamali, M.S. Bayraktutan, H. Bagdassarian, S. Arakelian, V. Davtian, and A. Adilkhanyan, 2004, Active faulting and natural hazards in Armenia, eastern Turkey and northwestern Iran. Tectonophysics, 380, 189-219.

Philip, H., A. Cisternas, A. Gvishiani, and A. Gorshkov, 1989, The Caucasus: an actual example of the initial stages of continental collision. Tectonophysics, 161, 1-21.

Philip, H., E. Rogozhin, A. Cisternas, J.C. Bousguet, A. Borisov, A.S. Karakhanian, 1992, The Armenian earthquake of 1988 December 7: faulting and folding, neotectonics and paleo – seismicity. Geophys. Int. J., 110, 141-158.

Philip, H., A. Avagyan, A. Karakhanian, J.-F. Ritz, and S. Rebai, 2001, Slip rates and recurrence intervals of strong earthquakes along the Pambak-Sevan-Sunik fault (Armenia). Tectonophysics, 343 (3-4), 205-232.

Tovmasyan, A. K., 2008, Focal Mechanisms of Yerevan Earthquakes. The modern main issues of Geology and Geography, 297-305.

Yeats, R. S., K. Sieh, and C. R. Allen, 1997, The geology of earthquakes. Oxford University Press, 568p.

Georisk Report

Report on the Garni Fault, 20p.

Report on the analysis of strong historical earthquakes located near to the ANPP (Armenian Nuclear Power Plant), 174-268.

Report on the Yerevan Fault, 43p.

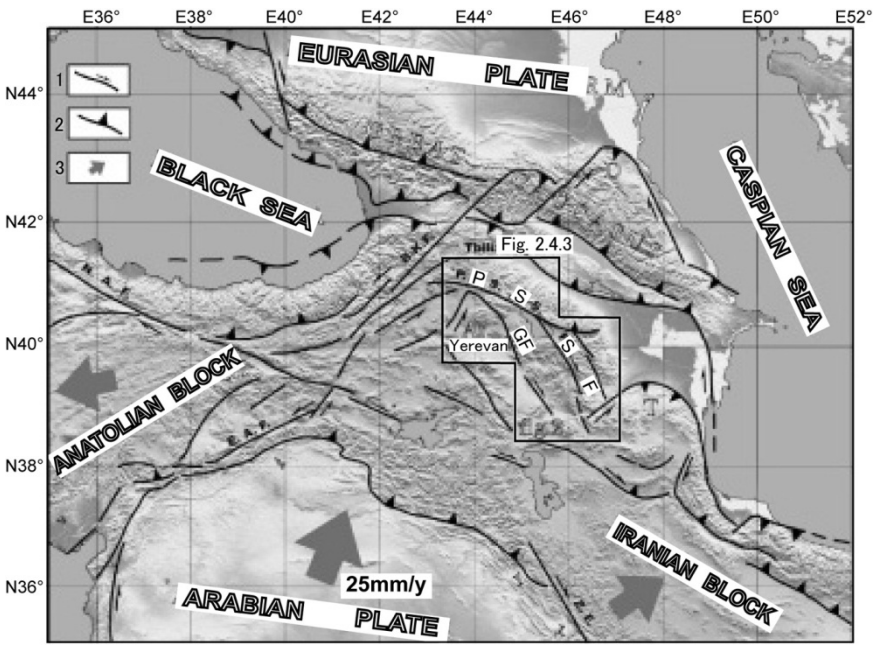


Figure 2.4-1 Tectonics around Armenia (Philip et al., 1989, 2001).

The Arabian plate moves northward and collides with the Eurasian plate. Consequently the Caucasia including Armenia is compressed, and reverse and strike-slip faults are developed. 1: major strike-slip fault, 2: major thrust, 3: the relative movement of the Arabian plate against the Eurasian plate. The Anatolian block and the Iranian block are squeezed westward and eastward respectively. PSSF: Pambak-Sevan-Sunik Fault, GF: Garni Fault.

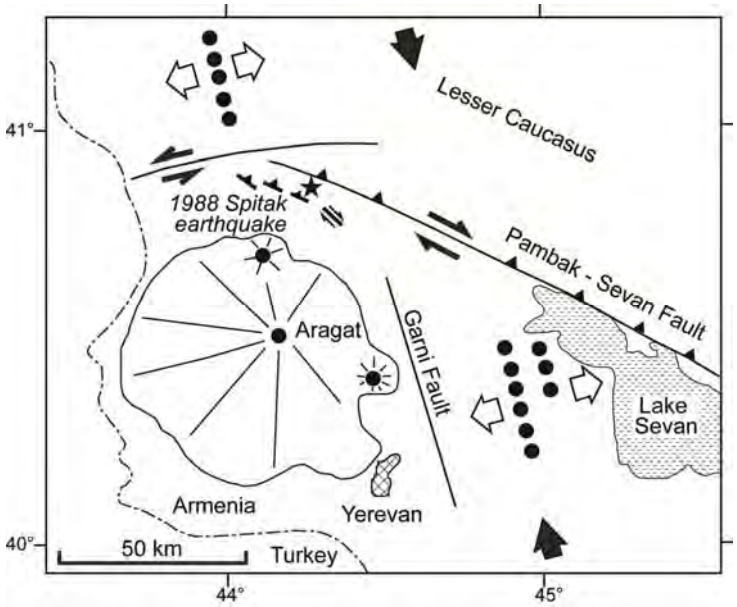


Figure 2.4-2 Tectonics of Armenia.

The Garni Fault is drawn into the figure after Philip et al. (1992). Black arrows: shortening direction, black circles:ranges of craters, white arrows: extensional direction, asterisk: epicenter of the 1988 Ms 6.9 Spitak earthquake, thick solid lines: faults activated during the 1988 earthquake. Due to N-S compression, the reverse and strike-slip faults with WNW-ESE direction are developed, and the extensional axes with N-S oriented direction are formed. The Garni Fault is parallel to the extensional axes.

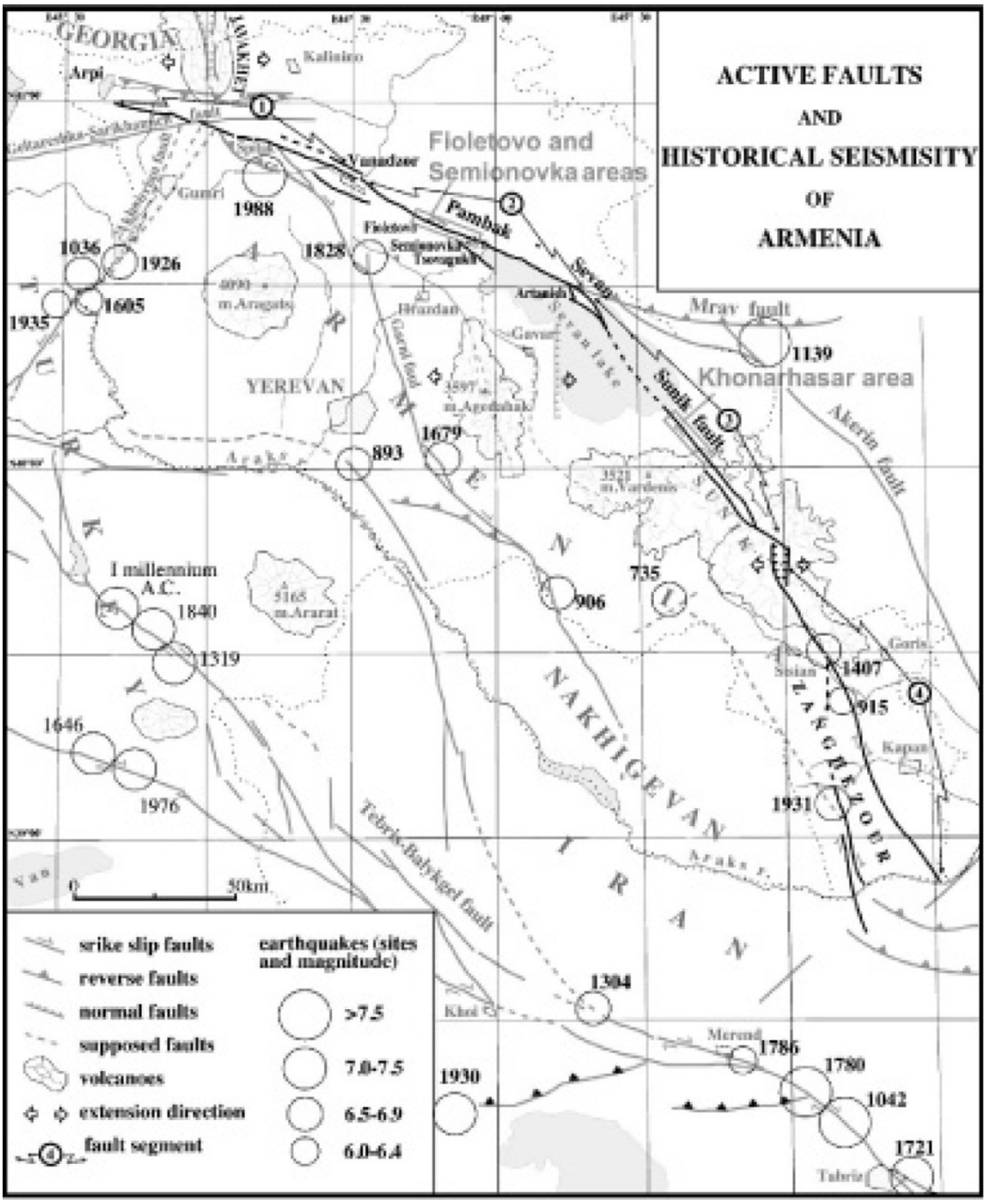


Figure 2.4-3 Active faults and epicenter distribution of historic earthquakes around Armenia after Philip et al. (2001).

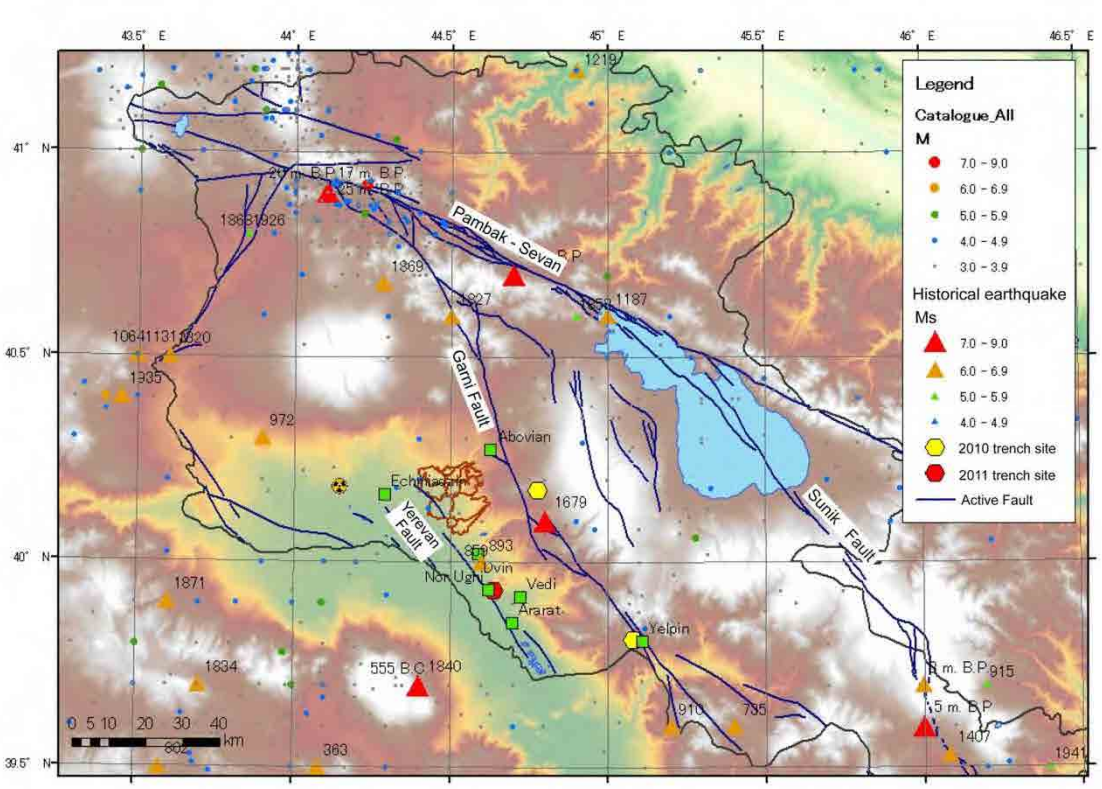


Figure 2.4-4 Active fault map after Georisk. The data of historic and observed earthquakes after NSSP are overlapped

2.4.2 Landforms

The territory of Yerevan city is situated at elevation ranging from 830 m (South-western part) to 1550 m (North-eastern part) above sea level (Figure 2.4-5). The elevation of Kentron is around 1000m high. The river systems in the territory of Yerevan city are Hrazdan river which flows from north-east, Getar river which flows from north-east and joins to Hrazdan river at Erebuni district, Jrvezh river and Shorakhpiur river which flow down from east mountain range and join to Getar river.

The territory Yerevan city consists of four landform divisions, which are;

1) Yeghvard volcanic plateau, Kotayk volcanic plateau , and Jrvezh-Nork volcanic plateau
2) Shorakhpiur-Nubarashen sloping plain and Erebuni mountain range
3) Fluvial plain of Hrazdan river, Getar river and Shorakhpiur river
4) Reclaimed land

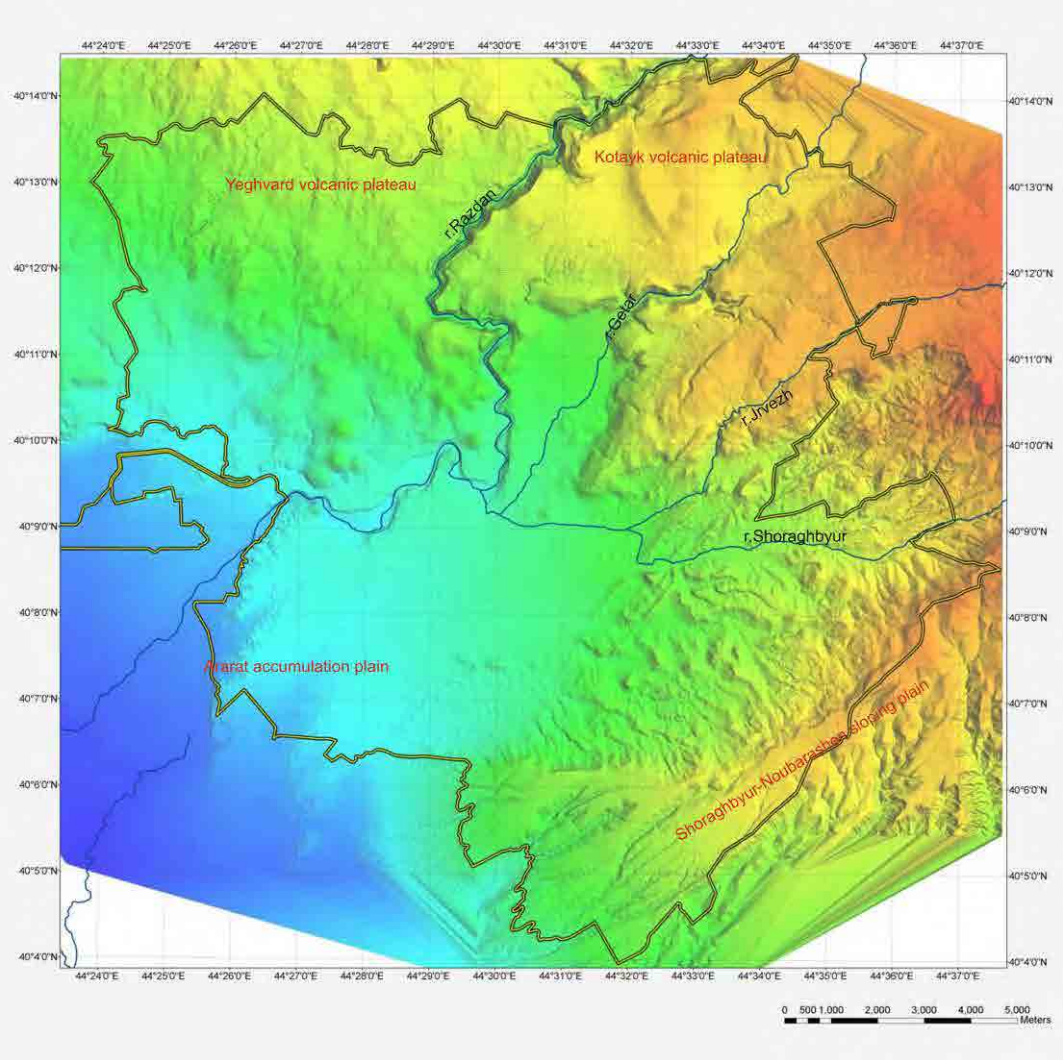


Figure 2.4-5 Relief map of Yerevan city, created from DEM（Georisk,2011）

1) Northern volcanic plateaus

The Yeghvard and Kotayk volcanic plateaus are located on the west side and east side slopes of the Hrazdan river gorge, respectively. Jrvezh-Nork volcanic plateau is located in the river basin of Getar river, as well as Jrvezh river valley. Top surface of the plateaus are reflected the original landform of the lava flows when those flowed and become solid, with undulations, mounds and depressions.

Erosion landforms after lava flew can be seen along the rivers. Hrazdan river gorge slopes composed of volcanic tuff are very steep, the valleys form 120 to 150 m-deep gorge. The depth of the gorge reduce to 100 to 50m at its down streams. Hrazdan river gorge is 1,000-1,200 m wide in the northern part, but reduces to the width of 200-300 meters southward. Hrazdan river gorge has complicated landscape with steep, and stepping slopes were formed not only by different lava flows, but also by landslides.

2) Shorakhpiur-Nubarashen sloping plain and Erebuni mountain range

The south-eastern outskirts of the city area are located within the Shoraghpiur-Nubarashen sloping plain and Erebuni mountain range. Original sedimentation surfaces are widely distributed at Nubarashen and Nor Kharverd, which are dissected fan inclined from north-east to south-west. The inclination of the dissected fan surface is 2.3°in the Yerevan city territory, which is steeper than recent valley. The sediments of the terrace consist mainly coarse gravel beds derived from mountains and old volcanoes, which located out of the territory of Yerevan city.

A lot of landslides cover the most of the slope of Shorakhpiur river basin, especially, on the slopes of from Erebuni to Voghjaberd (in Kotayk Region).

Some monadnock-like hills can be seen in the Shorakhpiur river basin, which are formed by erosion of Shorakhpiur suite and Hatsavan suite. Most representative one is the hill behind Erebuni museum.

3) Fluvial plain of Hrazdan river, Getar river and Shorakhpiur river

Fluvial plains are distributed along Hrazdan river, Getar river and Shorakhpiur river. Fluvial plain of Hrazdan river and its tributaries and Ararat accumulation plain spread in Kentron district, Erebuni district and Shengavit district, respectively.

Terraces above the floodplain are distinctly manifested in the relief in the region of Yerevan Lake and south of it. Erosion terraces that are also observed in the Hrazdan river gorge formed in basaltic andesite and are located 50 to 70 m high from the water level in the river.

4) Reclaimed land

Land reclamation is developing in some part of the territory of Yerevan city. Some of the sloping plains and erosion valleys of upland are cut and filled with soils, and some parts of southern lowland are buried. Some slopes are cut and dug as quarries and mines, a part of slopes disappeared.

2.4.3 Geology

Oldest geological unit in the territory of Yerevan city is the Shorakhpiur suite (P_3^1sh) of Lower to Middle Oligocene, and youngest one is flood plain deposits of Holocene (Recent period) .The table of stratigraphy of this area is shown the Table 2.4-1.

Older sedimentary rocks in this area are the ones of Oligocene-Miocene and volcanic sedimentary rocks which are mainly distributed in southern and eastern areas.

Effusive, pyroclastic and fragmental materials, which are represented by tuff breccias, tuff conglomerates, tuff sandstone, tuff, and pumice-ashy units distributed at the lower part of Voghjaberd Suite under Kotayk volcanic plateau and Yeghvard volcanic plateau.

The rocks of the Shorakhpiur Suite exposed there are related to the Early Eocene-Oligocene and are represented by aleurolites, tuff sandstone, sandstone, and conglomerates with inter-layers of gypsiferous clays and lenses of reef limestone in Shorakhpiur –Nubarashen sloping plain.

Table 2.4-1 Stratigraphy of the territory of Yerevan city

Geological Ages			Names of layers
Cenozoic	Quaternary	Holocene	Flood plain deposits
		Upper Pleistocene	Getamech-Arghavand lava flow
		Middle to Upper Pleistocene	Argavand terrace deposits
		Middle Pleistocene	Arzni lava flow
		Middle Pleistocene	Charbakh terrace deposits
		Middle Pleistocene	Tuff of Yerevan type
		Lower to Middle Pleistocene	Ararat suite
		Lower Pleistocene	Yeghvard plateau lava and Kotayk plateau lava
		Lower Pleistocene	Nubarashen terrace deposits
	Tertiary Neogene	Upper Pliocene to Lower Pleistocene	Yeghvard plateau lava and Kotayk plateau lava
		Upper Pliocene	Doleritic basalts
		Upper Miocene Sarmatian Part	The Hrazdan suite
		Middle Miocene	The Jrvezh suite
	Tertiary Paleogene	Upper Oligocene to Lower Miocene	The Hatsavan suite
		Lower to Middle Oligocene	The Shorakhpiur suite
		Middle Eocene	Clay, aleurolite, gravelite, tuff sandstone
Proterozoic to Paleozoic		Upper Proterozoic to Lower Cambrian	Metamorphic basement
			Rock salt

Neogene rocks are Hatsavan suite and Jrvezh suite. Hatsavan suite is composed of unconsolidated conglomerates, sandstones, red-colored clays, aleurolites. Jrvezh suite is composed of cloddy sandy clays, sandstones, and argillites with strata and inter-layers of rock salt and gypsum and is developed extensively over the Kotayk plateau lava flow. Hrazdan Suite is associated with the sites of exposed clay and marly rocks, on which thick basaltic lavas are bedded at Hrazdan valley in the northern part of the territory of Yerevan city.

Volcanic rocks in this area are of the various ages of lavas distributing in the central and northern volcanic plateau. Yeghvard and Kotayk volcanic plateau were overlain with a few flows of the Late Pliocene-Early Quaternary basalts, and olivine basaltic andesites, making all a single extensive cover. Within the plateau, basalts and basaltic andesites developed a thick layer (up to 150 m). Those thick lavas cover over the surface of the dolerite basalts.

New age lavas effused and flew to Hrazdan valley, as the flows of basaltic andesite and andesite lavas. The one is Arzni lava flow of breccia-shaped basaltic andesite, which can be traced along both sides of the Hrazdan valley from Arzni village north of Yerevan city to Yerevan lake. The other is Getamech-Arghavand lava flow (8 to 25 m thick) with columnar joint is traced along Hrazdan river.

Ararat accumulation plain is filled with sedimentary formations of the Early-Middle Quaternary Ararat suite, represented by lake and lake-alluvial sediments.

Argavand terrace gravel bed of the Hrazdan river is developed in the suburb district of Argavand village(Ararat region), where it has a relative height of 11-13 m, the terrace is built of pebble size rounded gravel, sand and clay.

Recent sediments within the central and southern parts of the city are represented by channel deposits of the Hrazdan river, Jrvezh river, Getar river, and Shorakhpiur river. Channel and flood plain deposits of those rivers, like pebble, sand, loamy sand and clays, are well developed in their downstream at the northern part of the Ararat accumulation plain.

2.4.4 Existing geological information / borehole database

The existing borehole database of Yerevan is collected. It is composed by 5,094 borehole data in total. The altitude of the surface of rock formation was studied using this database. The defined rock in Yerevan is studied as follows.

a) Volcanic rocks (Basalt, Slag, welded Tuff, Clinker)

The welded Tuff is a sedimentary rock in exact meaning but included in this category from petrogenetic view.

b) Sedimentary rocks (Marl, Limestone, Sandstone, Conglomerate)

The estimated rock surface is shown in Figure 2.4-6. The altitude of rock surface is high in the north to south east and low in the center to south west.

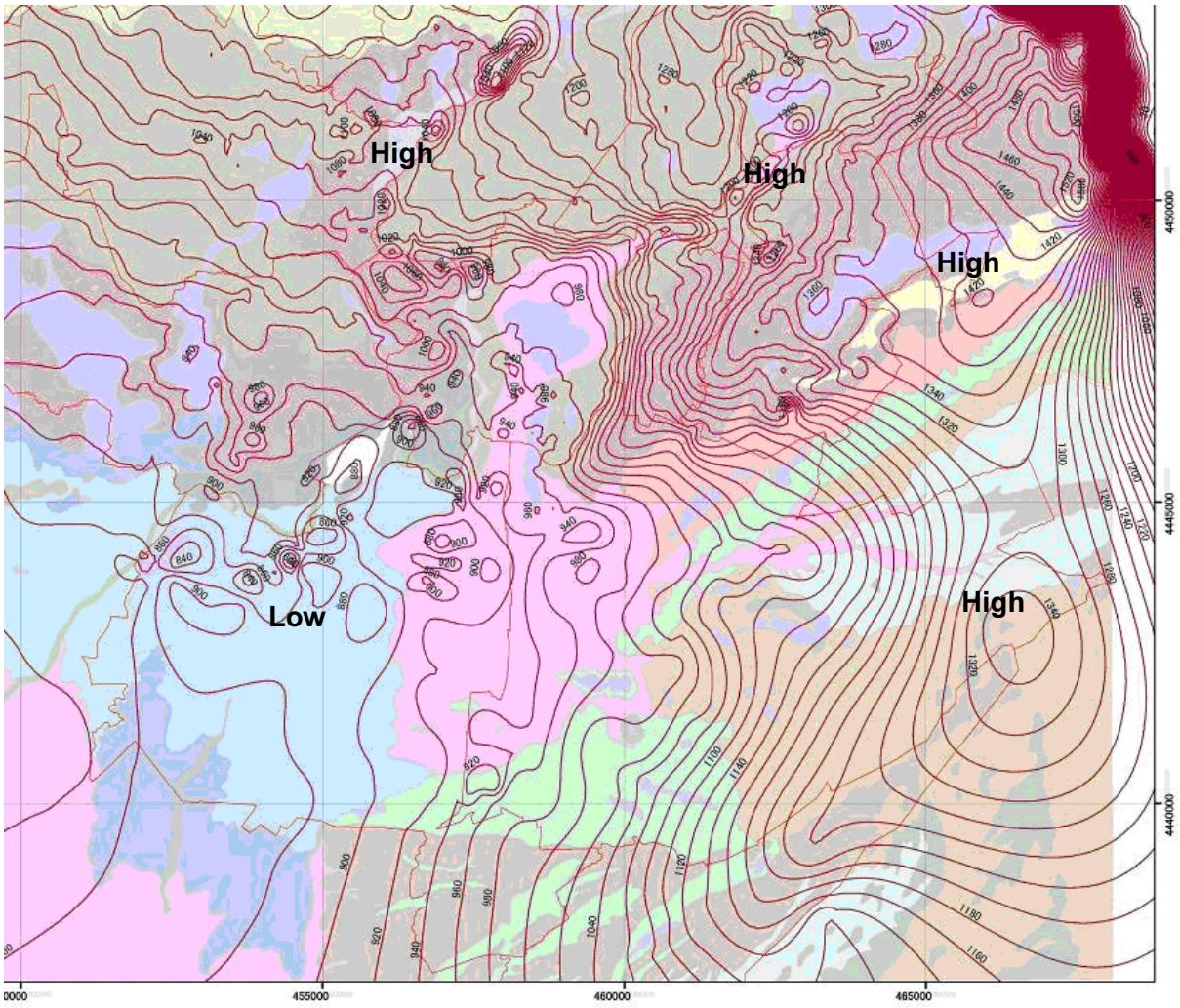


Figure 2.4-6 Estimated altitude of rock surface by borehole database

2.5 Population, Land-use and Urban Development

2.5.1 Population

Yerevan city has an area of 226.6km^2 with 12 districts, and its scale such as area and population is extremely similar to Saitama city near Tokyo in Japan as shown in Figure 2.5-1.

The district is a minimum size of administrative body with a district office and a district hospital independently. The lower level of administrative body such as sub-district or community does not exist in Armenia, but block number or local name are occasionally seen in some districts.

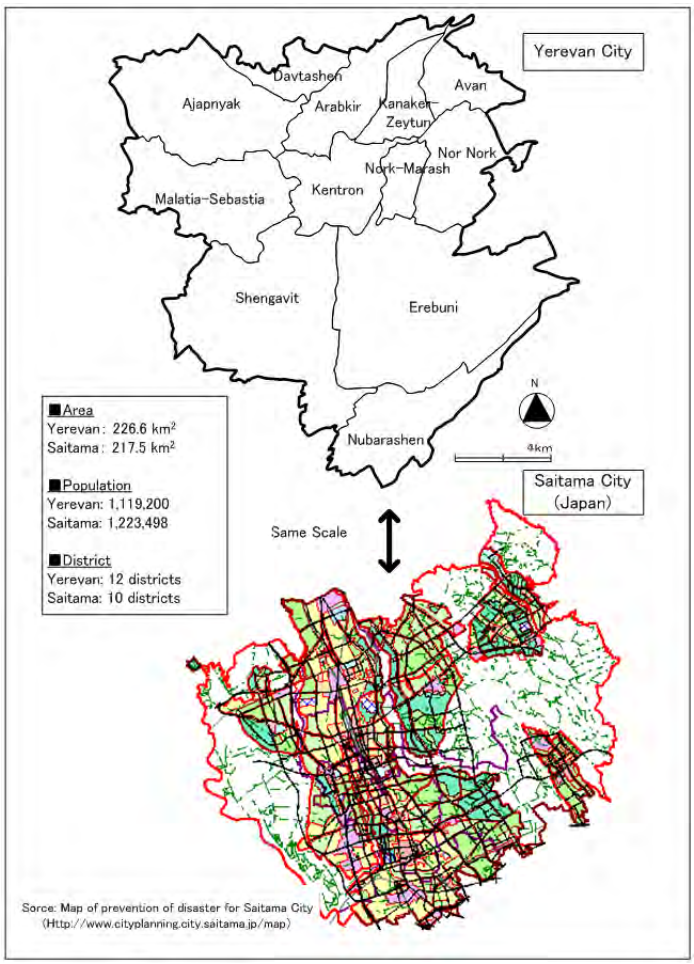


Figure 2.5-1 Yerevan city with 12 districts

Based on the statistic data, including estimated data of the Master Plan as a target year of 2020, area, population and population density by district are indicated in Table 2.5-1 and in Figure 2.5-2.

The spread of population in Yerevan city is characteristic of geographical reason and land-use, and population density is relative high at the northern to the central part of the city.

The housing estate development at the north-western to the south-western part of the city has become active recently, and future population will be expected to slightly increase in these areas.

The movement of population by district is also indicated in Table 2.5-2 and Figure 2.5-3. Since the population of Yerevan city is slightly increasing from 1,102,000 people in 2003 to 1,119,000 people in 2010 over a long time period, an increase in population is not expected in the future.

Regarding age structure of Yerevan city in 2010, 141,737 people of over 63 years old occupy 12.7% of total, 769,319 people of 16 to 62 years old as employed population occupy 68.9%, and 205,592 people of 0 to 15 years old occupy 18.4%, respectively.

Table 2.5-1 Population and Population Density by District

District	Area[1)] (ha)	Population[2)] (×1,000)	Population Density (Pop./ha)
Ajapnyak	2,600	108.2	42
Avan	820	51,0	62
Arabkir	1,320	130.8	99
Davtashen	650	41.1	63
Erebuni	4,940	121.9	25
Kentron	1,340	130.6	97
Malatia-Sebastia	2,530	141.8	56
Nor-Nork	1,450	147.0	101
Nork-Marash	470	11.3	24
Nubarashen	1,720	9.7	6
Shengavit	4,060	146.5	36
Kanaker-Zeytun	760	79.3	104
Total	22,660	1,119.2	49

Source：1) Yerevan city Master Plan (2005)

2) National Statistical Service(2010)： Marzes of the Republic of Armenia in Figures

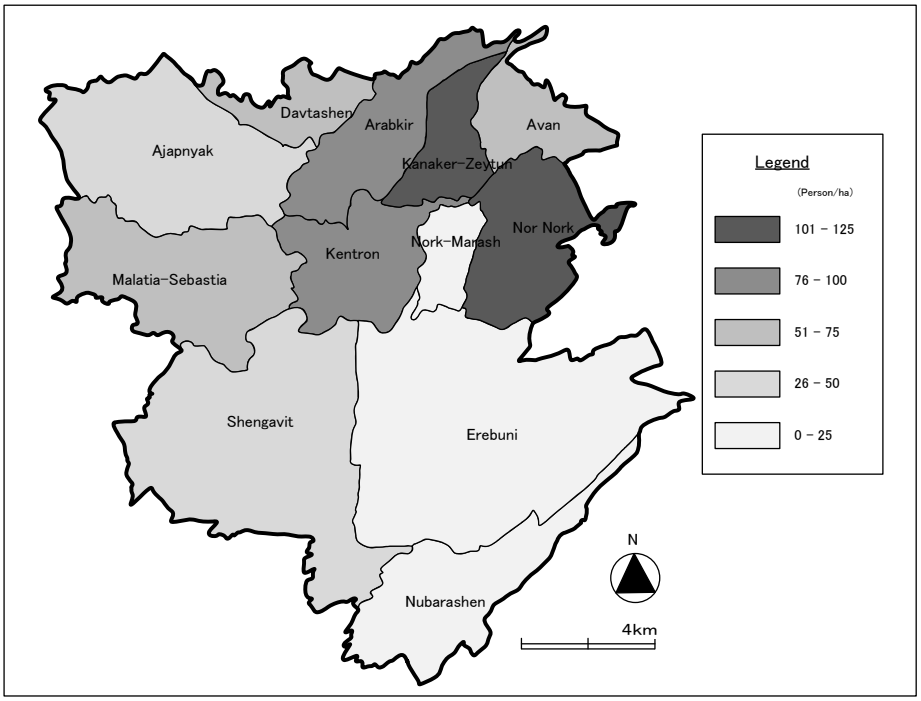


Figure 2.5-2 Population Density by Districts

Table 2.5-2 Movement of Population by Districts

District	Population (×1,000)								
	2003	2004	2005	2006	2007	2008	2009	2010	2020
Ajapnyak	106.5	106.5	106.6	106.7	106.8	107.1	107.5	108.2	147.8
Avan	50.1	50.2	50.2	50.4	50.5	50.8	50.9	51.0	55.3
Arabkir	132.2	132.0	131.7	131.6	131.4	131.3	131.1	130.8	129.9
Davtashen	40.4	40.4	40.4	40.4	40.4	40.6	40.8	41.1	45.1
Erebuni	119.0	119.0	119.3	119.5	119.8	120.1	120.6	121.9	123.8
Kentron	130.2	129.9	129.9	129.7	129.7	129.7	130.0	130.6	127.5
Malatia-Sebastia	141.6	141.3	141.0	140.9	140.6	140.6	141.0	141.8	160.9
Nor-Nork	142.2	142.6	142.9	143.3	143.8	144.5	145.2	147.0	144.9
Nork-Marash	11.9	11.8	11.8	11.6	11.5	11.4	11.3	11.3	13.0
Nubarashen	9.3	9.3	9.4	9.5	9.5	9.5	9.6	9.7	14.8
Shengavit	140.8	141.1	141.7	142.2	142.8	143.8	144.6	146.5	160.6
Kanaker-Zeytun	77.8	77.8	77.9	78.0	78.1	78.4	78.7	79.3	76.5
Total	1102.0	1101.9	1102.8	1103.8	1104.9	1107.8	1111.3	1119.2	1200.0

Source : National Statistical Service(2010) : Marzes of the Republic of Armenia in Figures
Yerevan city Master Plan (2005)

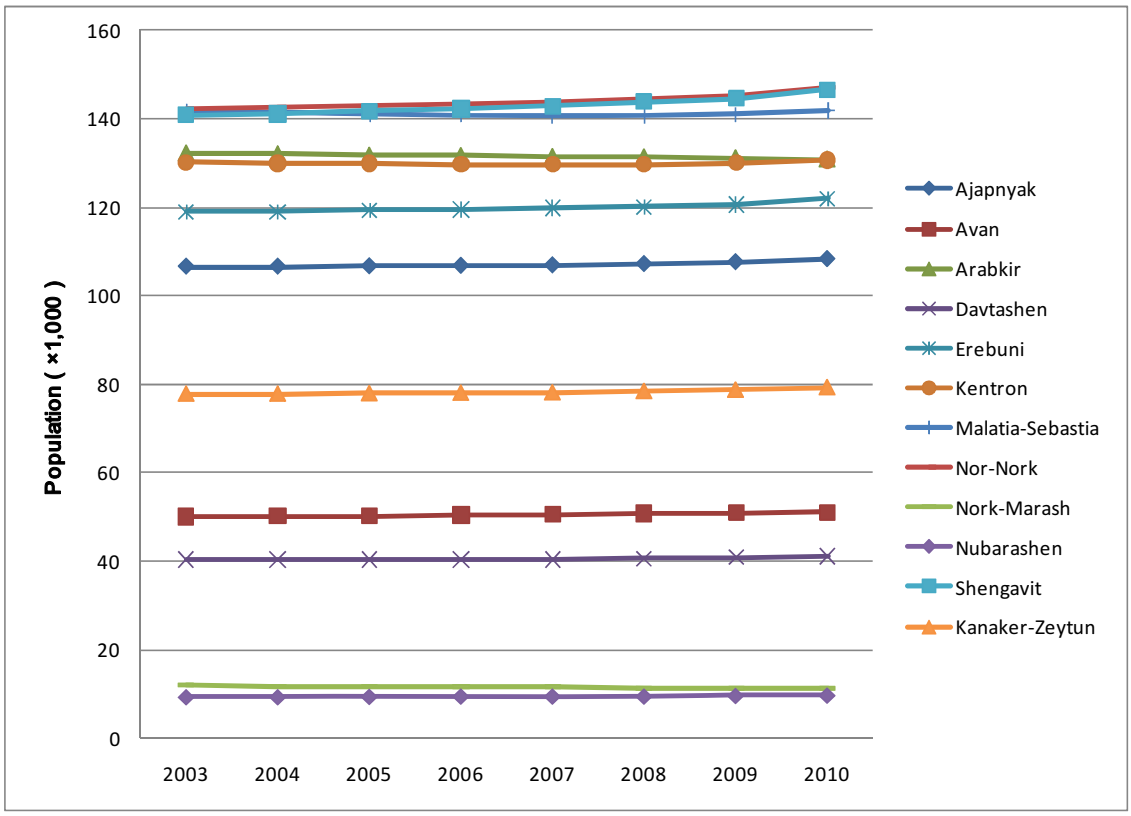


Figure 2.5-3 Movement of Population by Districts

2.5.2 Land-use

The Master Plan of urban development for Yerevan city (hereinafter referred to as "the Master Plan") was elaborated in 2005. The target year of the Master Plan is from the year 2006 to the year 2020. At the present time, the Master Plan has been re-examined by Yerevan municipality and the Yerevan Project, CJSC since 2010.

According to the recent statistic data of Yerevan city (in 2010), land-use of Yerevan city is composed of ; Agricultural land: 42.55km2 (18.7%), Available agricultural land: 14.435km^2 (6.4%), Settlements' lands including public buildings: 67.02km^2 (29.5%), Industrial lands: 27.66 km^2 (12.2%), Green space, including parks: 11.13km^2 (4.9%), Groves: 12.39km^2 (5.5%).

Present land-use map, indicated in the Master Plan, is shown in Figure 2.5-4. Due to the secret matter on land-use data, detailed information of land-use, including GIS data, was not obtained within the project period.

Land-use zoning map, indicated in the Master Plan, is also shown in Figure 2.5-5. The zoning map is elaborated in the Master Plan, according to the requirements, defined in the Article 14 of the Armenia law about Urban Development. The land-use control is carried out based on the new Land Code in 2001 that is divided into nine (9) classes of land-use as indicated in Table 2.5-3.

The law and regulation, related to land-use, are under control of the Ministry of Urban Development. After the approval of the Master Plan of Yerevan city by the Government, concrete land-use control and its procedures were carried out based on the Mayor's Decision with legal force. Related and responsible organization of Yerevan city was in charge of implementation of the Master Plan.

With significant progress of land privatization in recent years, land-use control and redevelopment of urban area confirmed in the Master Plan are not always improved smoothly in Yerevan city. With respect to permission on transaction in real estate and development activities, Department of urban development and related organization of municipality are dealing with them within the legal power.

Table 2.5-3 Land-use Code of Armenia

No.	Categories and types of lands (according to the RA Land Code)	Functional sub-zone
1	Urbanized Lands (Settlements' lands)	
1.1	Dwelling building	
1.1.1		Private house building
1.1.2		Building with multi-flat dwelling houses
1.1.3		Mixed dwelling building
1.2	Mixed building	
1.2.1		Administrative-functional
1.2.2		Trade-household building
1.2.3		Cultural-illuminating
1.2.4		Sport-recreation
1.2.5		Health-resort
1.2.6		Multi-functional
1.2.7		Educational
1.2.8		Historical-archeological
1.3	Land of common use	
1.3.1		Gardens, parks
1.3.2		Streets and squares
1.4	Public building	Objects of public significance
1.4.1		Worship (cult)
1.4.2		
1.5	Other lands	
2	Territories of industrial, lithosphere use and other production significance	
2.1		Production zone
2.2		Public-production zone
3	Territories of special protection of agricultural significance	
4	Objects of energy	
5	Communication, transport, communal infrastructures	
6	Special significance	
7	Forest territories	
8	Water surfaces	
9	Reserve lands	

Source: Yerevan city Master Plan (2005)

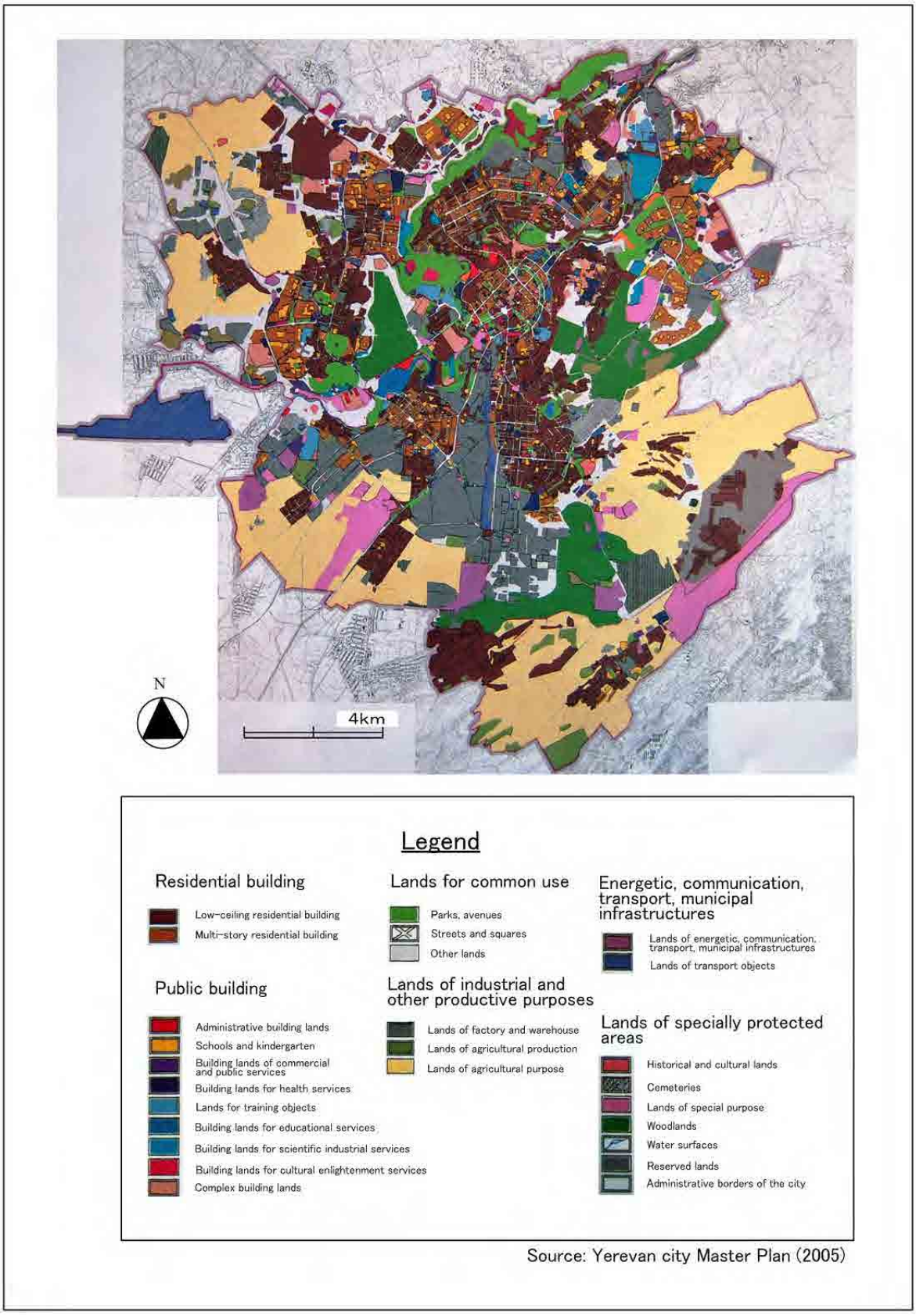


Figure 2.5-4 Present Land-use map of Yerevan city

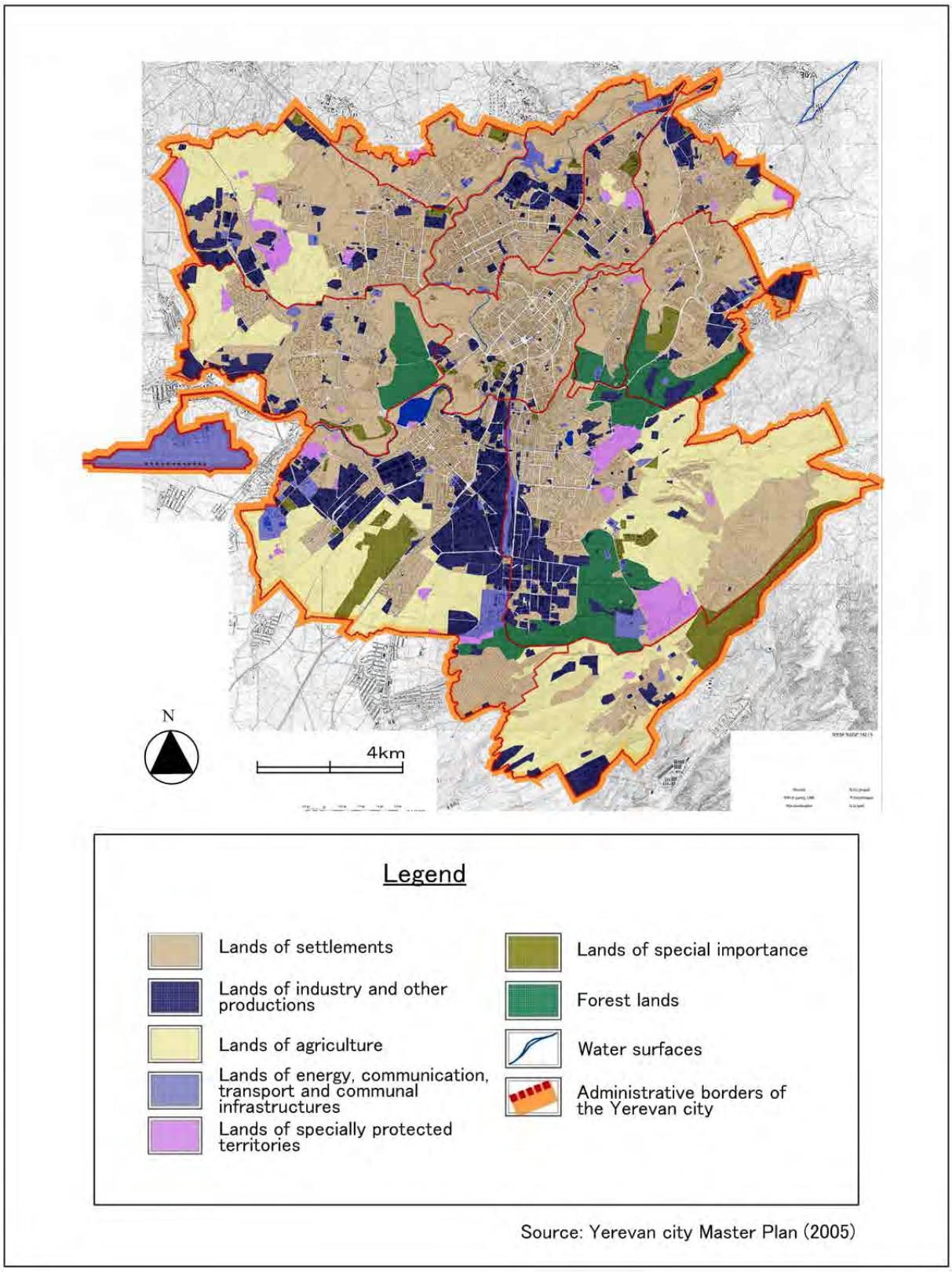


Figure 2.5-5 Land-use zoning map of Yerevan city（for control of land-use)

2.5.3 Urban Development

Before Soviet Union annexation of Armenia at the beginning of the 20th century, urban center of Yerevan city was developed only in the Kentron District, and pasture or agricultural land was spread around a ring road and green space of the District. Urbanization of Arabkir District in the north part of Yerevan city, adjacent to Kentron District, Shengavit District in south, and northern part of Erebuni have been developed in the period before and after the second world war. In 1960s to 1970s, at the stage of economic development, related to the socialism, a lot of industrial factories and apartment buildings were intensively constructed in these districts and its outward.

Regarding the industrial zone, extended to the southern part of Yerevan city, due to the recent movement and change in the field of industrial structure and market economy, increase of out-of-date factories, redevelopment of industrial base are the problems to be solved.

Urbanized area extends radially to outward of city center. Reconstruction of 30-40 years old buildings are also major tasks for Yerevan city. State of redevelopment area in the city center (Kentron District) is shown in Figure 2.5-6. With respect to the Master Plan, since damage and disaster mitigation of buildings against the earthquake are mentioned, a place of refuge and evacuation that should be secured at the time of disaster in the city are not mentioned at all.

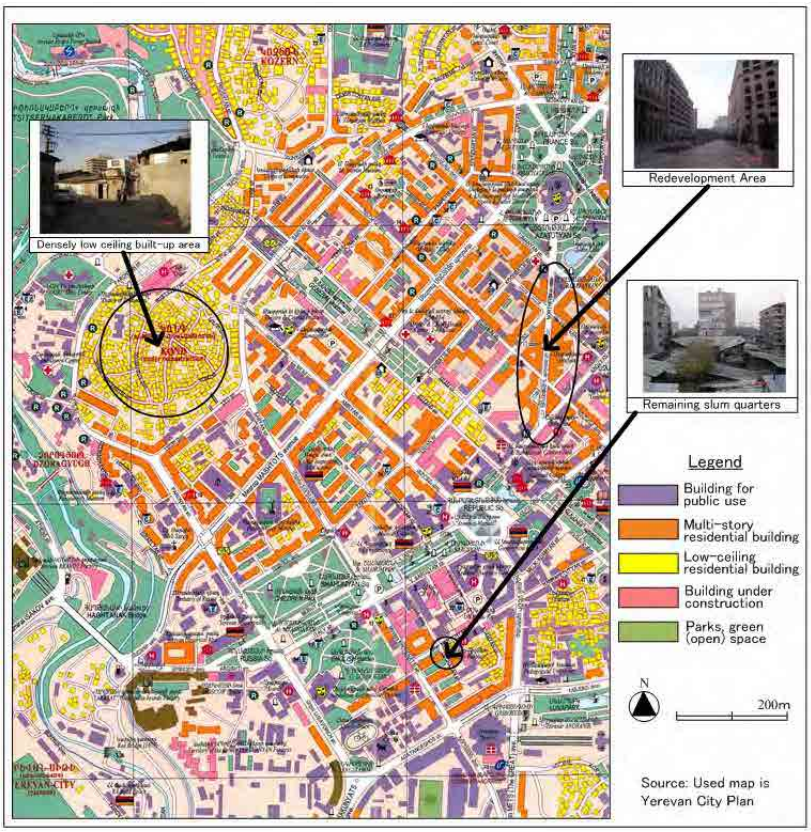


Figure 2.5-6 Redevelopment of the central part of Yerevan city (Kentron District)

2.6 Buildings

2.6.1 Building inventory data

(1) Conditions of GIS and CAD data for Buildings

Data collection for building inventory such as multi-story residential buildings, individual houses, and schools and hospitals was executed from related institutions. Content of collected data by GIS and CAD is shown in Table 2.6-1 and maps in Figure 2.6-1, Figure 2.6-2 and Figure 2.6-4. There was no data of inventory for structural type of buildings. After the investigation of existing data, it was concluded to use CAD data of Cadastro and convert to GIS data. Related attributes were added to this GIS data.

As far as governmental buildings, these were not included for the damage estimation including commercial buildings, industrial facilities and others, since inventory data is difficult to get practically.

Table 2.6-1 Content of collected building data by GIS and CAD

Institution	Type	Content/ evaluation of data	Utilization of data
Cadastro	CAD (as of year 2005)	Classification of buildings as residential and non-residential is included as an attribute. There was no data for structural type. Polygons include small structures such as small warehouse, garages etc.	Existing CAD data was converted to GIS data, and was utilized incorporating attributes of multi-story residential buildings through the building inventory survey.
RS	GIS (as of year 2001)	Data based on Census 2001. There are data of number of stories for multi-story residential buildings, but some error was observed. There was no data for structural type. There are data of approximately 40% of exiting individual houses with respect to number of stories and constructed year.	Data of constructed year for individual houses (approximately 40% of existing houses) was utilized.
NSSP	GIS	There are data of attributes for Multi-story residential buildings with 3-story and above. Data of structural type has not been classified properly. There was some distortion on GIS map for some areas.	Data of constructed year for individual houses for the area not covered by data of RS was utilized.

(2) Building statistical data

There is data by 'National Statistical Service of the Republic of Armenia' for multi-story residential buildings classified by two categories of stone buildings and RC buildings for twelve districts as of 2009. This data was used for the comparison with the result of inventory survey.

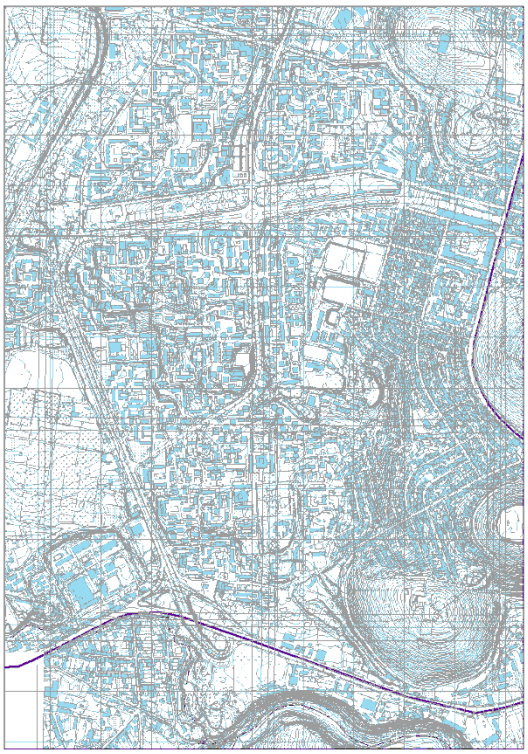


Figure 2.6-1 CAD map of Cadastro

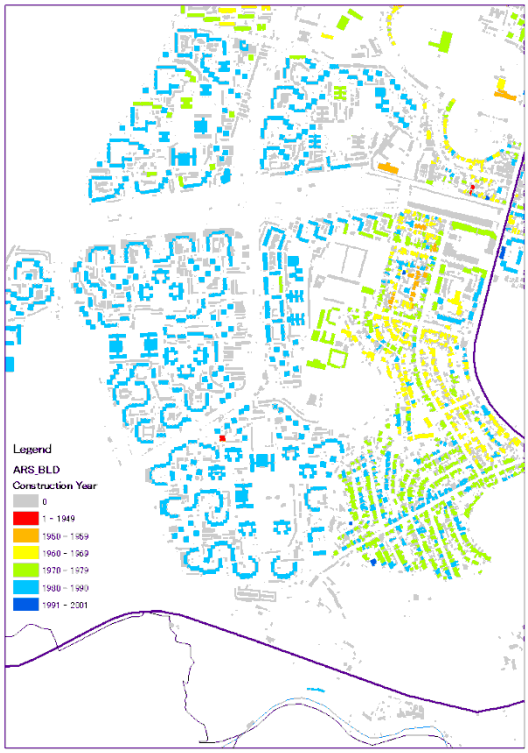


Figure 2.6-2 GIS map of RS

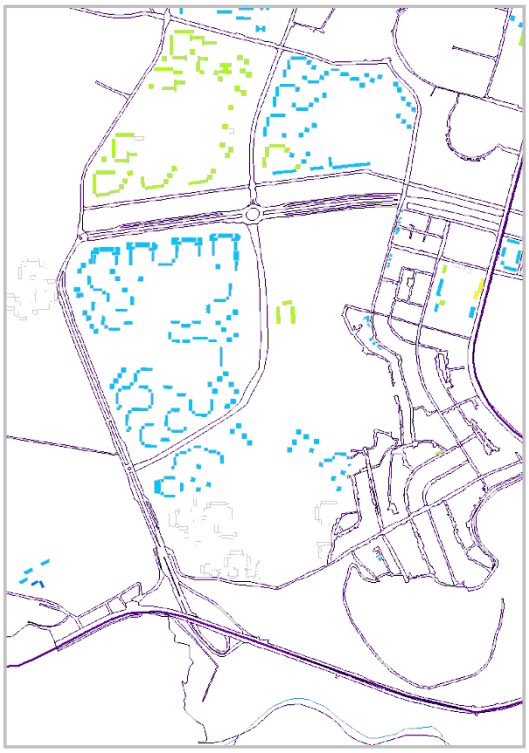


Figure 2.6-4 GIS map of NSSP

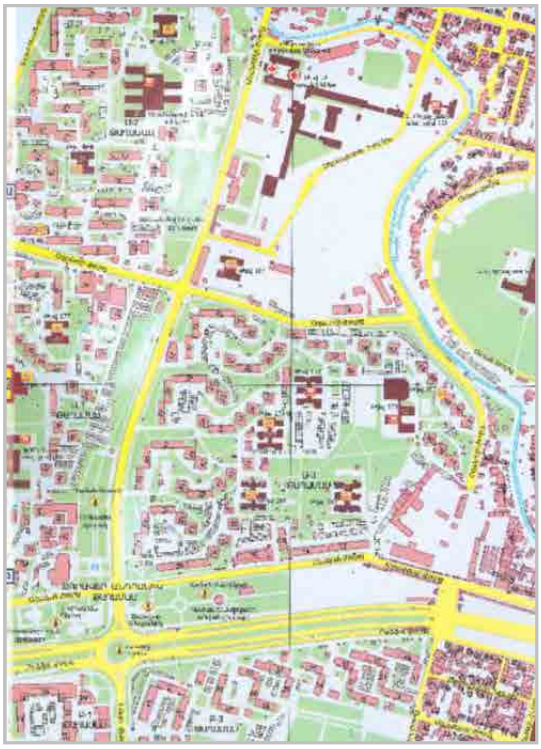


Figure 2.6-3 Atlas of Cadastro (A4 size)

(3) Atlas

An atlas showing building configuration (polygon) together with main usage of buildings has been issued by Cadastro (Figure 2.6-4). Location information of schools and hospitals shown in the Atlas was utilized as inventory data together with data of constructed year.

(4) Master plan 2005

In the Master plan 2005 of Yerevan city, data of population (Sec.3.1), houses (Sec.3.1.1) are included, and data of number of multi-story residential buildings, total floor areas and population for multi-story residential buildings and individual houses for each district were utilized.

2.6.2 Data related to vulnerability and retrofitting

There was no Armenian own data concerning the estimated seismic intensity and observed damage ratio of buildings at the Spitak earthquake in 1988. Then, reports by researches of USA and Japan for the Spitak earthquake were utilized.

Experimental and analytical study for the structure of existing buildings is limited in Armenia. Measurements of vibration period and vibration tests for buildings have been conducted within the elastic range. There is no general map showing category of four type of soil by RABC covering the city, which is required for the seismic design of buildings.

As far as seismic retrofitting of existing buildings, there are a few retrofitted stone buildings by base isolation system in Gyumri. There is also a RC building applying upper flexible floor to control seismic vibration at Vanadzor. There are no retrofitted existing buildings in Yerevan up to the present, according to the building sampling survey.

2.6.3 Collection of building data

(1) Building sampling survey

Building sampling survey for multi-story residential buildings, individual houses, and schools and hospitals was conducted (total 120 buildings), to get necessary information for the structural classification of buildings and vulnerability assessment. Result is introduced in Sec. 5.1.

(2) Building inventory survey

Building inventory survey was conducted for multi-story residential buildings, since there was no data for inventory of structural types. Result is introduced in Sec.5.2.

As far as inventory data of individual houses for constructed year, approximately 40% of existing houses are covered by data of RS and a ratio of constructed year was applied properly to other areas.

2.7 Infrastructure, Lifeline

2.7.1 Earthquake-proof Evaluation of Infrastructure

Transportation infrastructures such as roads and bridges are important factor in terms of evacuation, damage survey, and rescue/research in emergency response. Particularly from a viewpoint of

maintaining the function of road and railway transportation, it is crucial to prevent traffic hindrance caused with damages to structure such as collapse of bridges. Therefore, the study team carried out the estimation of earthquake damage to structures by site inspection and existing data.

2.7.2 Main Arterial Road of the Yerevan City

Yerevan city, which includes Kentron with the Opera House and Republic Square, Arabkir, Kanaker-Zeytun, Avan, Nork-Marash, Nor-Nork, Erebuni, Shengavit, Malatia-Sebastia, Ajapnyak, Davtashen, Nubarashen, a total of 12districts. The main route, has been extending radially from the periphery road of the Kentron district, towards the national highway M-1, M-2, M-4, M-5, M-15 and the state highway H-4, H-8 are connected. Yerevan city's major roads are shown in Table 2.7-1 and Figure 2.7-1.

Table 2.7-1 Yerevan City's Major Road List

No.	Name	No.	Name	No.	Name
1	ASHTARAK highway	18	David ANHAGHT street	35	TAMANTSINER street
2	Gevorg CHAUSH street	19	RUBINIANTS street	36	BAGRATUNIATS avenue
3	Houvhannes SHIRAZ street	20	Hrachya ATCHARIAN street	37	Admiral ISAKOV avenue
4	LENINAKAN street	21	GAI avenue	38	SEBASTIA street
5	MELKUMOV street	22	TEVOSIAN street	39	Marshal BAGHRAMIAN avenue
6	FUCHIK street	23	B.MURADIAN street	40	Mesrop MASHTOTS avenue
7	MARGARIAN street	24	David-BEK street	41	MOSKOVIAN street
8	HALABIAN street	25	Tigran METZ avenue	42	KHANJIAN street
9	LENINGRADIAN street	26	ARATSAKH street	43	AGATANGEGHOS street
10	KIEVIAN street	27	ARIN-BERD street	44	Grigor LUSAVORUCH street
11	KASYAN street	28	ROSTOVIAN street	45	PARONIAN street
12	KOMITAS avenue	29	NUBARASHEN street	46	SARALANJ street
13	YEGHVARD highway	30	EREBUNI street	47	KORYUN street
14	SASNA TZRER street	31	Kh.DASHTENTS street	48	HERATSI street
15	VAGHARSHIAN street	32	NUBARASHEN highway	49	Alexander Myasnikyan avenue
16	AZATUTIAN avenue	33	ARSHAKUNIATS avenue		
17	TBILISIAN highway	34	Garegin NZHDEH street		

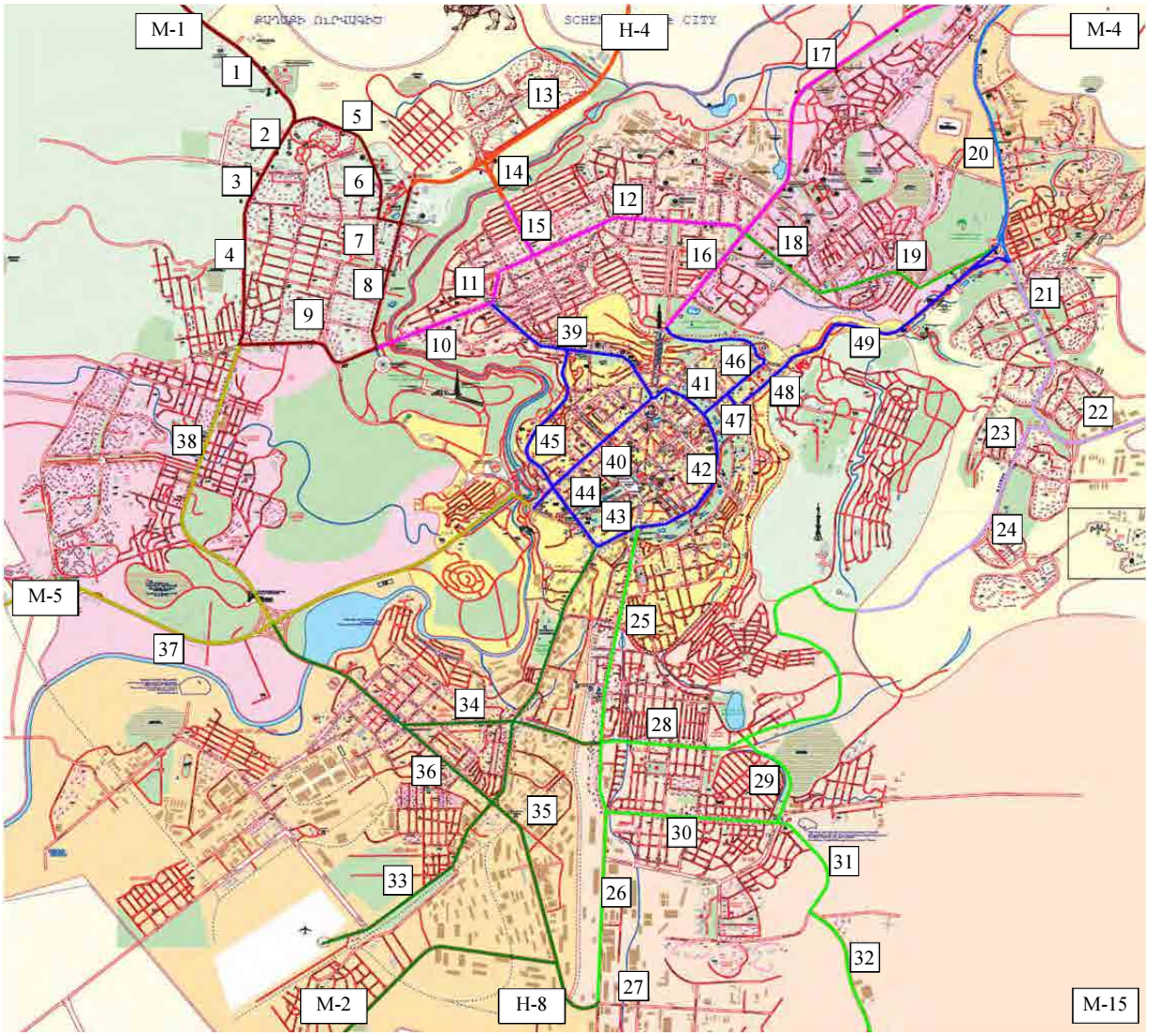


Figure 2.7-1 Yerevan City's Major Road

2.7.3 Main Structure of the Yerevan City

Particularly from a viewpoint of maintaining the function of road and railway transportation, it is crucial to prevent traffic hindrance caused with damages to structure, to evaluate the seismic performance of structures located around the city connecting road to the airport and the city of Yerevan. The study was based on a structure list (Table 2.7-2) obtained from Yerevan city. However, the structure list includes three pedestrian bridge and 5 removal structure based on site survey. These are excluded from this study. For the record such as structure length, structure passport has been lost about half of the list. The remaining 25 points are missing some of the state drawing or pictures. Therefore, this study policy will focus primarily inventory survey.

Table 2.7-2 Structure List

No.	Name	District	Passport			Target	ID
			Summary	Drawing	Photo		
1	Overpass bridge on the Friendship Square	Arabkir	---	---	---	OK	ARB-1
2	Bridge on Vatutin str.	Arabkir	Confirmed	Confirmed	---	OK	ARB-2
3	Bridge on Riga str.	Arabkir	Confirmed	Confirmed	---	OK	ARB-3
4	Bridge on Saralanji HW near Riga str.	Arabkir	---	---	---	OK	ARB-4
5	Bridge on Komitas ave.	Arabkir	---	Confirmed	---	OK	ARB-5
6	Avan 1st bridge	Avan	---	---	---	OK	AVN-1
7	Avan 2nd bridge	Avan	Confirmed	Confirmed	---	OK	AVN-2
8	Bridge on Yerevan - Sevan HW	Avan	Confirmed	Confirmed	---	OK	AVN-3
9	Bridge of 2nd road	Davtashen	Confirmed	Confirmed	---	OK	DVT-1
10	Central bridge of Davtashen transport	Davtashen	Confirmed	Confirmed	---	OK	DVT-2
11	Bridge of 7th road	Davtashen	Confirmed	Confirmed	---	OK	DVT-3
12	Bridge on Arin-Berd str.	Erebuni	Confirmed	Confirmed	---	OK	ERB-1
13	Bridge on Nubarashen str. near graveyard	Erebuni	Confirmed	Confirmed	---	None	---
14	Davtashen bridge	---	---	---	---	OK	HRA-1
15	Kiev bridge	---	Confirmed	Confirmed	Confirmed	OK	HRA-2
16	Bridge near the Kiev bridge	---	Confirmed	Confirmed	---	OK	HRA-3
17	Bridge near the Yerevan HES	---	Confirmed	Confirmed	---	OK	HRA-4
18	Haghttanak bridge	---	Confirmed	---	---	OK	HRA-5
19	Bridge of Korea valley	---	---	---	---	None	---
20	Overpass bridge of new highway	Kentron	---	---	---	OK	KNT-1
21	Overpass bridge of new highway	Kentron	---	---	---	OK	KNT-2
22	Bridge on Heratsi str.	Kentron	---	---	---	OK	KNT-3
23	Bridge on Charents str.	Kentron	---	---	---	OK	KNT-4
24	Bridge on Khanjyan str.	Kentron	---	---	---	OK	KNT-5
25	Bridge on Tigran Mets ave.	Kentron	---	---	---	OK	KNT-6
26	Bridge on Khorenatsi str.	Kentron	---	---	---	OK	KNT-7
27	Subway bridge over Kristapor str.	Kentron	---	---	---	OK	KNT-8
28	Bridge on G. Lusavorich str.	Kentron	Confirmed	Confirmed	---	OK	KNT-9
29	Overpass bridge near the Hrazdan Stadium	Kentron	Confirmed	Confirmed	---	OK	KNT-10
30	Bridge over Getar river	Kentron	---	---	---	None	---
31	Pedestrian over Heratsi str.	Kentron	---	---	---	Pedestrian	---
32	Pedestrian near the cablecar station	Kentron	---	---	---	Pedestrian	---
33	Pedestrian over Heratsi str.	Kentron	---	---	---	Pedestrian	---
34	Pedestrian over Khorenatsi str.	Kentron	---	---	---	Pedestrian	---
35	Bridge on Isakov ave.	M. Sebastia	Confirmed	Confirmed	---	OK	MLS-1
36	Argavand bridge	M. Sebastia	Confirmed	Confirmed	Confirmed	OK	MLS-2
37	Bridge on Isakov ave. to Echmiadzin HW	M. Sebastia	---	---	---	OK	MLS-3
38	Pedestrian over Isakov ave.	M. Sebastia	---	---	---	Pedestrian	---
39	Bridge near Nubarashen	Nubarashen	Confirmed	Confirmed	---	OK	NBR-1
40	Bridge on Galshoyan str.	Nor Nork	Confirmed	Confirmed	---	OK	NNR-1
41	Jrvejh river bridge	Nor Nork	Confirmed	Confirmed	---	OK	NNR-2
42	Bridge on Garegin Nzhdeh str.	Shengavit	Confirmed	Confirmed	---	OK	SHN-1
43	Subway bridge over Shahamiryanner str.	Shengavit	---	---	---	OK	SHN-2
44	Subway bridge over Tamantsineri str.	Shengavit	---	---	---	OK	SHN-3
45	Subway bridge over railway	Shengavit	---	---	---	OK	SHN-4
46	Shirak str. 1st bridge	Shengavit	Confirmed	Confirmed	---	OK	SHN-5
47	Overpass bridge on Araratyan str.	Shengavit	Confirmed	Confirmed	---	OK	SHN-6
48	Shirak str. 2nd bridge	Shengavit	Confirmed	Confirmed	---	OK	SHN-7

2.7.4 Public Transport around the Yerevan City

General air cargo and passengers are using the Zvartnots international airport in the western city of Yerevan (approx. 8km west-southwest from the city center). Erebuni Airport was diverted to military use is located about 5km from the city center. General passenger terminal is not used.

General passenger rail line has been developed from Yerevan station towards the direction of Georgia to pass through the city's west side. Other railway lines are operated by private cargo company. Metro has been in service from Ajapnyak district to Shengavit through Kentron area. Major airports and railway around the city of Yerevan in Figure 2.7-2, the city's subway lines are shown in Figure 2.7-3.

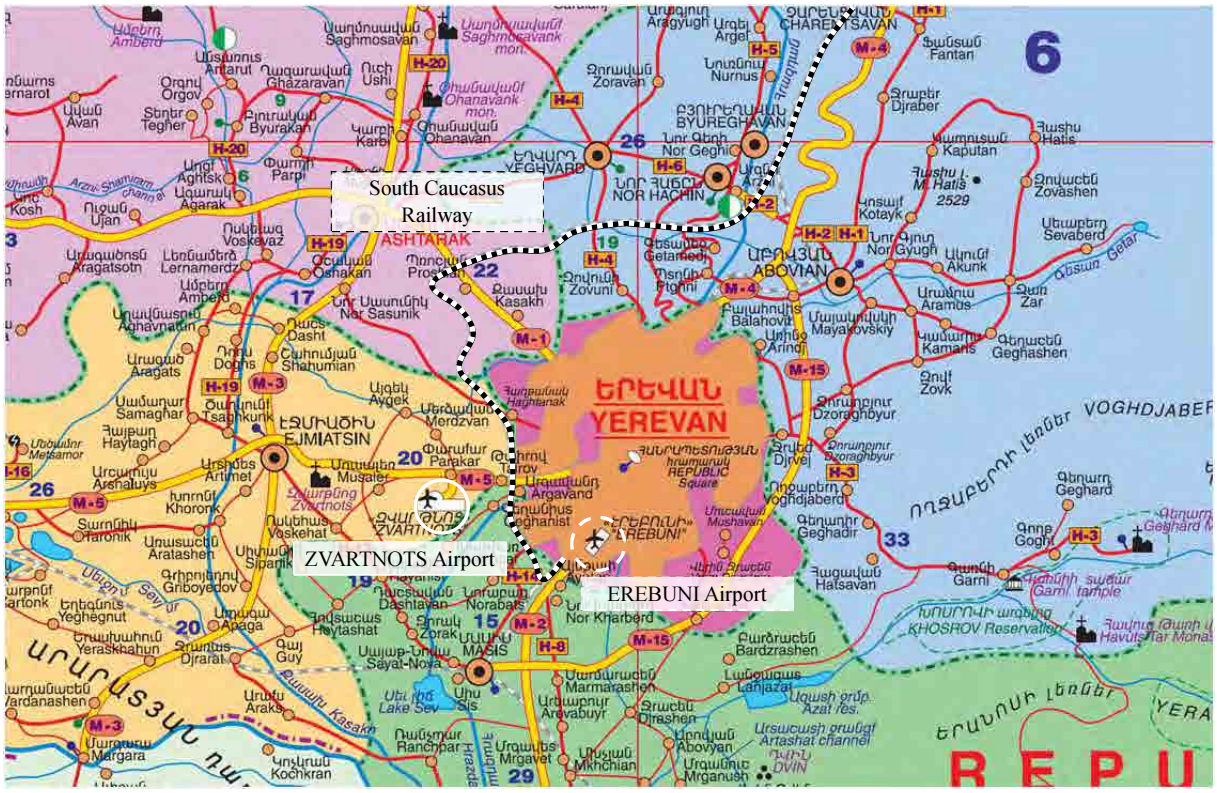


Figure 2.7-2 Major Airports and Railway

Figure 2.7-3 Yerevan Subway Route and Station

2.7.5 Traffic Trends

(1) Auto mobilization

The percentages of highway lengths per congestion are shown in Table 2.7-3. Traffic congestion is the ratio of daily traffic volume design volume. Mesrop MASHTOTS avenue or KOMITAS avenue etc., road congestion for the city center is more than 100%. Toward long-distance trunk roads such as Admiral ISAKOV avenue, 80-100% shows the traffic congestion.

Table 2.7-3 Congestion of Major Road

Traffic Congestion	Percentage of Road Length
More than 100%	15
80 - 100%	18
70 - 80%	17
50 - 70%	15
Less than 50%	35

Source: Master Plan of Yerevan City

Forecast the number of vehicles in the Yerevan city shown in Table 2.7-4. The number of car ownership in 2020, is more than 1.4 times in 2010. Thus, traffic congestion in the Yerevan city, will be further increased.

Table 2.7-4 Forecast of the Motor Car's Number (2010, 2020)

Year	Population	Number of Passenger Car	Level	Yearly Growth	
	thousand	unit	unit/1,000 per.	unit	%
2000	1,098	75,522	69	-----	-----
2001	1,100	80,253	73	4,731	6.3%
2002	1,104	84,985	77	4,732	5.9%
2003	1,102	100,348	91	15,363	18.1%
2010 (forecast)			130		
2020 (forecast)			186		

Source: Master Plan of Yerevan City

(2) Public transportation

The Yerevan city has been operated on four kinds of public transportation (subway, trolley-bus, bus and mini-bus). This forecast future demand for transportation is shown in Table 2.7-5. Average daily passengers of public transportation will be 1,256 thousand in 2010 and 1,414 thousand in 2020, The average yearly passengers will be 458 million in 2010, 516 million in 2020. The minibus user will be switched to trolley-bus or bus. The subway is expected to increase the number of passengers.

Table 2.7-5 Future Volume of Public Transportation (2010, 2020)

Type of Transportation	2004			2010 (forecast)			2020 (forecast)		
	million passengers /yearly	thousand passengers /daily	Ratio	million passengers /yearly	thousand passengers /daily	Ratio	million passengers /yearly	thousand passengers /daily	Ratio
Subway	16.6	45.5	4.0	30.7	84.0	6.7	61.0	167.3	11.9
Trolley-bus	4.5	12.3	1.1	53.7	147.1	11.7	124.4	340.8	24.1
Bus	8.0	21.9	1.9	144.7	396.4	31.6	232.2	636.2	45.0
Mini-bus	381.9	1,046.3	93.0	229.4	628.6	50.0	98.4	296.6	19.0
Total	411.0	1,126.3	100.0	458.5	1,256.2	100.0	516.0	1,414.0	100.0

Source: Master Plan of Yerevan City

2.7.6 Data survey for Lifelines

Survey contents and the collected material are shown in Table 2.7-6. The detailed network diagram (GIS data) was requested to each company, however such data were not provided because they were confident, unprepared or under preparation. Therefore, the inventory data of lifeline facilities was prepared based on the available information on the network which was obtained from the relevant several organizations other than the lifeline company as shown in Table 2.7-7.

Table 2.7-6 Contents of Survey

Item (Company name)		Survey item	Collected Material
Water supply and sewerage systems (Yerevan Djur)	1	Water supply pipe network in Yerevan City	—
	2	Water source, water intake facility and water purification plant facility	—
	3	Sewerage pipe network in Yerevan City and	—

		its circumference	
	4	Sewage treatment facility and pump facility in Yerevan City	Location and capacity
	5	Water tank truck in Yerevan City and its circumference	Number of water tank truck
	6	Update scheme	None
	7	Entrepreneur's organizational framework	Organizational framework
	8	Building standards and drawing and specification of water supply facility and sewage facility	－ (There is a building standards)
	9	Administration and maintenance of water supply pipe and sewage pipe	Agency of maintenance
	10	Post for state of emergency	Organization
	11	Publication	Service method to user
Electricity (Electric Network of Armenia)	1	Electric line and distribution line network in Yerevan City	Location map of the main electric line and distribution line, total length(voltage, above ground／underground) and number of beneficiary
	2	Electric power plant and transformer station in Yerevan City	Location and capacity
	3	Update scheme	Plan
	4	Entrepreneur's organizational framework	Organizational framework and work contents
	5	Building standards and drawing and specification of electric power plant, steel tower and transformer station	Standard
	6	Administration and maintenance of electric power plant, steel tower, electric line and distribution line	Agency of administration and maintenance
	7	Post for state of emergency	Post, agency and chairman
	8	Publication	Person in charge of publication and enlightenment and educational content
Gas (ARMRUSGASPROM)	1	Gas pipe network in Yerevan City	Location map ; Only main pipe Length, pressure, above ground／under ground, number of consumer ; Total of each district
	2	Distribution station in Yerevan City	Distribution station list and location map
	3	Supply source and route from out of Yerevan city	－
	4	Entrepreneur's organizational framework	Organizational framework and number of employee
	5	Building standards and drawing and specification of gas supply facility, distribution station and gas pipe	Building standards
	6	Administration and maintenance of gas supply facility, distribution station and gas pipe	Manual related to gas supply and administration etc.
	7	Post for state of emergency	Organization, action plan and machine list for state of emergency
	8	Publication	－
Telephone (Armentel) (Viva-Cell) (Orange)	1	Telephone Line network in Yerevan City	Length of main network
	2	Bases facility in Yerevan City	Location and capacity
	3	Entrepreneur's organizational framework	Organizational framework and work contents
	4	Post for state of emergency	Post and chairman
	5	Publication	Person in charge of publication and publication device

Table 2.7-7 Collected map of lifeline network

Organization	Cadastro	Institute of Geological Science	Yerevan Project
Type of Material	GIS data	GIS data	Printed Map
Water supply	collected (except Kentron and Shengavit)	–	collected
Sewerage (waste water)	collected (except Kentron and Shengavit)	collected	collected
Sewerage (rain water)	collected (except Kentron and Shengavit)	collected	collected
Electricity	collected (except Kentron and Shengavit)	collected	collected
Gas	collected (except Kentron and Shengavit)	collected (only main pipes)	collected (only main pipes)
Telephone	–	–	collected

2.8 Design of Earthquake Disaster Information Database

A large classification of the database in this project was decided as the following five sections considering the progress of the project. The Base map is necessary to constructing several kinds of GIS data. Natural environment includes soil condition model, fault model, water levels, and so on. Built environment includes inventory of buildings, lifelines, population, and so on. Hazard is the result of applying some calculation formulae such as attenuation, response analysis of ground to the Natural environment, and Risk is the result of applying the fragility functions to Hazard and Built environment. Furthermore, Disaster Prevention Plan is advanced based on the seismic Hazard and Risk. We can understand the perspective of the project from the structure of the Database. The relation among those Databases and the Perspective of this project is shown in the Figure 2.8-1.

1. Base Map
2. Built Environment
3. Natural Environment
4. Hazard Risk
5. Disaster Prevention Plan

The above large classification is prepared as folder. In each folder the database files which are called as “Persona Geodatabase” are stored. And in each database file, GIS layers are stored. Details of these databases are described in the Section 6.5.

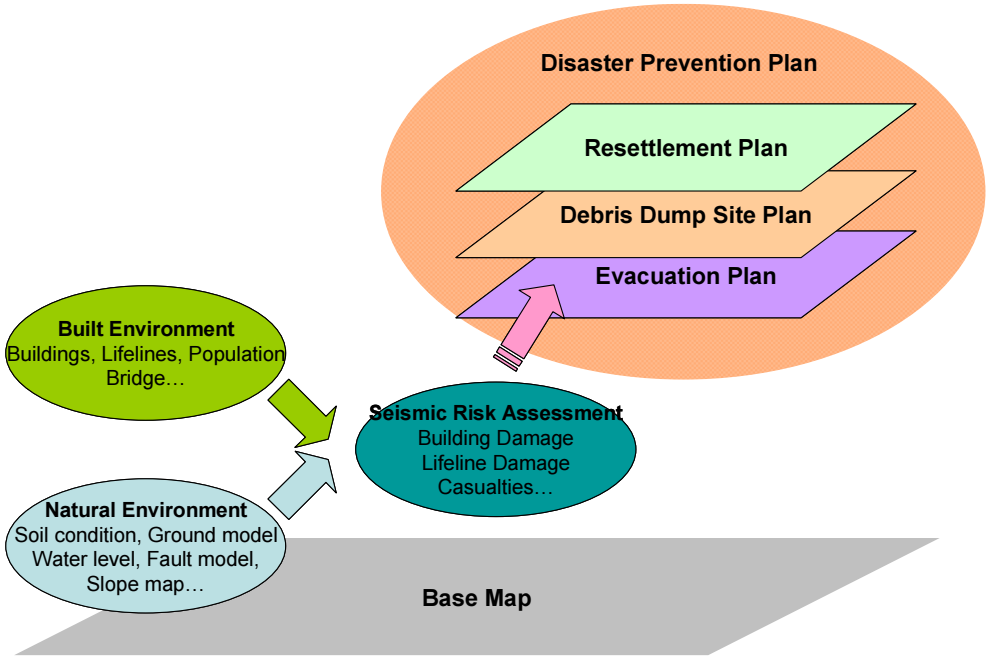


Figure 2.8-1 Structure of each Databases and Perspective of the Project