Evaluation of Non-Residential and Multi-Family Residential Buildings for Seismic Risk

Portland Metropolitan Area

Natural Hazard Program
Growth Management Services Department

METRO

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Metro Disclaimer

Metro, Portland State University and the sponsoring agency, Federal Emergency Management Agency, assume no responsibility for the accuracy of the building information presented in this report. The information on structural integrity of buildings presented in this report may not be used or relied upon for any application on specific buildings. Information on buildings presented in this report has been used for regional vulnerability assessment purposes only. Users of the structural integrity of building data assume all liability arising from such use.

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A. INTRODUCTION

This project is based on the principle of the four Rs of Mitigation: Recognize, Rate, Retrofit, and Remove. First, it is fundamental for a community to recognize the potential hazards that will cause buildings to fail or be damaged. Second, buildings should be evaluated to determine their structural integrity and then rated based on their expected performance in the event of an earthquake. Third, the rate information should be used to prioritize the dangerous buildings for retrofitting based on the level of risk the community is willing to tolerate at any point in time. Fourth and finally, the community may decide to remove those buildings, for which retrofitting is not economically feasible. Rating building performances requires knowledge of the building inventory, the local geology, regional seismicity, and loss estimation methodologies.

In the Portland metropolitan region, some actions are already being implemented in the four steps above. For example, the effects of natural hazards and the potential damage to buildings has been recognized through the Regional Relative Earthquake Hazard Map produced by the Oregon Department of Geology and Mineral Industries (DOGAMI). Likewise, the U.S. Army Corps of Engineers mapped the February 1996 flood inundation level and Metro and Portland State University developed the landslide hazard zones map based on the storm of February 1996.

The purpose of this report is to shed some light on the knowledge of the building stock by describing how the building evaluation was conducted and how the buildings' spatial distribution relates to earthquake hazards. The report also provides some information on how local governments and businesses can rate and prioritize their buildings in order to enhance current seismic retrofit activities in this region.

Approximately 50,000 non-residential and multi-family buildings have been evaluated for seismic risk. Single-family dwellings within the Metro urban growth boundary (approximately 325,000) were not evaluated because of high degree of similarity of their structural composition.

With regards to retrofit activities, several buildings have been retrofitted for seismic risk, including the Multnomah County Central Library, Portland City Hall, U.S. Bank headquarters, and The Benson Hotel.

As the reader will observe later in this document, the information in this report can be used by a variety of disciplines for a variety of purposes including non-rigorous vulnerability analysis and prioritization of key facilities for seismic retrofit, and estimation of damage and loss for scenario earthquakes.

B. BACKGROUND

B.1 Earthquakes and Related Damages

Earthquakes and the related damages have continued as front-page news in recent decades. In the western region of the U.S., we recall the recent notable quakes of ’71 San Fernando, ’89 Loma Prieta, ’94 Northridge, and the lesser magnitude quakes of ’81 Elk Lake, ’93 Scotts Mills, and ’93 Klamath Falls. Outside this region, the 1995 Kobe quake attracted world attention by causing surprisingly large damage in terms of human loss, with casualties in the thousands, and property damage of over $200 billion. What these recent events bring to the foreground are the real impacts of earthquakes to buildings, bridges, utilities, and the ensuing damages to people, the society and the economy.

The fact that the Pacific Northwest can expect moderate to large size earthquakes has been confirmed by seismologists. Large Metropolitan areas such as Portland/Vancouver, Eugene, Salem, and others, are at a great risk when these earthquakes occur. Government agencies such as the Federal Emergency Management Agency, United States Geological Survey, DOGAMI, Metro, and local governments in the region continue to expend efforts in forecasting sources, magnitudes and intensities of potential earthquakes, and assessing potential damage and loss. Both the State of Oregon and Metro are also developing policies and strategies for the mitigation of hazard and risk, coordination of response to emergency and recovery from disaster. The engineering community (structural, geotechnical, and civil) continues to put forth stronger efforts in designing structures that are more earthquake resistant.

B.2 An Historic Perspective on Improving the Quality of Buildings

The structural, geotechnical, and construction knowledge base upon which the building codes rest is continually expanding. Over the years, the building codes have become more precise, with design and construction regulations that are more stringent. Building performance quality relates to the adequacy of building codes, quality of design, inspection, construction, as well as other factors such as maintenance, use, and age.

In the Portland Metropolitan Area the quality of construction has generally improved in the past half century, predominantly because of higher design capacities required by the building code.

The City of Portland has had a building code in effect since 1892, but there were no requirements for seismic design until the mid-fifties. In 1955 the city adopted the Uniform Building Code (UBC) but did not adopt the designated seismic zone. The minimum required design forces were one-half of those required by the UBC, and

generally wind forces governed the lateral force design for buildings. In 1972 the city adopted the 1970 version of the UBC, with the designated seismic zone.

In 1974, the state adopted the 1973 UBC and has adopted each subsequent edition of the UBC. In 1990 the State adopted the 1988 edition which had changed the seismic zone for Western Oregon from 2 to 2B, thus increasing the lateral resistance demand by one-third over the previous code.

In 1991, the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) was formed and given responsibility for addressing earthquake hazards in Oregon and promoting mitigation activities. One area of concern was a need to improve seismic design requirements within the Oregon Building Code. The OSSPAC, working in collaboration with the Oregon State Building Code Division and other engineers and geologists, helped to amend the Building Code, placing western Oregon in seismic zone 3. This revision, effective January 1, 1993, increased the minimum design seismic loads by 50 percent over the 1990 version.

At the local level, in August 1993 the City of Portland established the Task Force on Seismic Strengthening of Existing Buildings to "determine how to apply the state code to buildings in a way that saves lives in an earthquake and protects the economic viability of Portland's buildings." Following the Task Force recommendations and introduction and passage of SB 1057 in the Oregon 1995 legislature, a state task force on seismic rehabilitation of existing buildings was created to address a variety of issues such as standards, incentives, liability, etc.

In September 1996, the state Seismic Rehabilitation Task Force submitted its recommendations to the Oregon 1996 Legislature. Based on these recommendations, DOGAMI introduced House Bill 2139 on behalf of the Task Force. The bill was not approved by the legislature. However, one of the recommendations in the bill includes requirement of the State Department of Consumer and Business Services to conduct an inventory of existing buildings, similar to this project, and, where appropriate, provide notice of seismic hazard to building owners.

C. BUILDING INFORMATION COLLECTED

C. 1 Rapid Visual Screening

The objective of the study is to employ a procedure to rapidly and easily identify those buildings that might pose a risk of loss of life or injury, or severe curtailment of community services in the event of a damaging earthquake. The procedure needed to be implemented quickly and relatively inexpensively, so that a list of potentially hazardous buildings could be developed without the high cost of a detailed analysis of every building.

For the foregoing reasons, the FEMA 154 (ATC 21) Rapid Visual Screening (RVS) method was employed:(ATC-21, 1988,Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, Applied Technology Council, FEMA-155, Redwood City, California.)

The RVS procedure is designed so that structural analysis calculations are not performed. The user of the RVS data will make decisions based on an attribute assessment or scoring system. In this project, the inspection, data collection and decision-making process typically occurred at the building site, taking an average of 30 person-minutes per building. In most cases the structures were reviewed from the sidewalk without entering the building or structural drawings and calculations were inspected. In most cases, supplemental data, such as square footage and year built, were available from the county tax assessor. Such information was reviewed, collated and preprocessed before beginning the field survey.

Rapid visual screening is meant to be the first phase of a multi-phase of building evaluation procedure in which visual survey data are obtained to estimate the potential hazard of the building. If a building receives a low score and is thus determined to be potentially hazardous on the basis of this initial screening procedure, that building would be targeted for a subsequent phase of study by a professional engineer with experience/training in seismic design. On the basis of a review of structural drawings, a more detailed inspection, and engineering analysis, the degree of life-safety hazard can be determined. These latter phases were not included in this project.

The RVS method could be applied to all buildings, but due to budget constraints it was decided to restrict the survey to non-residential and multi-family residential buildings.

A field survey form is shown in Exhibit D. This form is based on ATC-21 (FEMA 154) form, with the following modifications:

1. The upper right-hand side label was designed based on the available assessor's data, and preprocessed labels were attached to the forms;

2. The "No. of Persons" section under "occupancy" (lower left side of the form) was modified to gain a more accurate estimate of occupancy load. Since a significant portion of the commercial buildings house less than 30 people, the ATC-21 range of 10-100 was divided into two ranges: 10-30 and 30-100;
3. The state occupancy categories were added to the form. These are shown also in Exhibit D.

Additional information on the RVS procedure is provided in the Appendix.

C. 2 Data Structure

The use of the tax assessor information to prepare evaluation materials for the fieldwork increased the amount of information that resulted from the whole project. As indicated below, there was important information available in the tax assessor database that was easily combined with the field data, resulting in a rich building database.

Tax Assessor information included in the building database:

1. Address
2. Year built
3. Area or square foot
4. Usecode (property classification code)
5. Number of stories

Field and other information included in the database:

1. Structure type
2. Non-structural falling hazard
3. Mixed construction
4. Modifiers
5. Name
6. Building Use
7. Occupancy type (was modified with the state of Oregon occupancy structure)
8. Number of Persons

Classification of building structural systems used in this evaluation was based on the 12-class system of ATC 21.

The following structure types were used in the study:

Table 1: Building Classification

LABEL	DESCRIPTION
W	Wood frame
S1	Steel moment resisting frame
S2	Braced steel frame
S3	Light metal
S4	Steel frame with concrete shear walls
C1	Reinforced concrete moment resisting frame
C2	Reinforced concrete shear walls, no MRF
C3/S5	Concrete or steel frame buildings with URM infill walls
PC1	Tilt-up concrete buildings
PC2	Precast concrete frame
RM	Reinforced masonry
URM	Unreinforced masonry

Other Structural Information collected:

- Non-structural falling hazard
- Mixed construction
- Modifiers - defined as follows:
    - High Rise
    - Poor Condition
    - Vertical Irregularity
    - Soft Story
    - Torsion
    - Plan Irregularity
    - Pounding
    - Large Heavy Cladding
    - Short Columns
    - Post Benchmark Year

C.3 Spatial Distribution of the Building Data

The spatial distribution of the non-residential and multi-family residential buildings for which RVS was conducted is given in Figures 1 and 2. The non-residential buildings are denoted by black squares, and multi-family residential buildings by gray squares. As shown, a major concentration of these buildings occurs in the City of Portland downtown vicinity, as well as along major freeways and streets.

D. ANALYSIS AND UTILIZATION OF BUILDING INFORMATION

D.1 ANALYSIS OF BUILDING INFORMATION

1.1 Statistical Analysis of Results

There is predominance of wood frame (W) construction (67 percent) in the region and respectively in the three counties as shown in Table 2. This structure class encompasses approximately 42% of the studied building stock in Washington County and approximately 37% in Multnomah County. Reinforced masonry buildings (RM), including those with bearing walls with wood or metal and precast concrete diaphragms, is the next largest stock – nine percent.

Unreinforced masonry (URM), which are considered poor performers during earthquake events, represent three percent of the stock of non-residential buildings and multi-family construction in the region.

Table 2: Building Structure Type by County

COUNTY	STRUCTURE TYPE												
	C1	C2	C3	PC1	PC2	RM	S1	S2	S3	S4	URM	W	Grand Total
Clackamas County	46	259	3	357	5	819	354	3	450	30	44	7,151	9,521
Multnomah County	398	2,474	78	1,111	64	2,442	330	45	1,107	140	1,361	12,329	21,879
Washington County	104	195	2	736	26	1,312	1427	8	468	38	81	13,844	18,241
Grand Total	548	2,928	83	2,204	95	4,573	2,111	56	2,025	208	1,486	33,324	49,641

Table 3 shows the building structure type by city and unincorporated areas of the counties. Again, wood structures predominate.

Table 3: Building Structure Type by City And Unincorporated Areas of the Counties

JURISDICTION	STRUCTURE TYPE												
	C1	C2	C3	PC1	PC2	RM	S1	S2	S3	S4	URM	W	Grand Total
Beaverton	23	24	1	226	0	375	657	2	35	2	10	3324	4,679
Clackamas Co. (unincorp)	9	58	0	142	2	299	68	1	262	11	9	2418	3,279
Cornelius	0	0	0	4	0	40	18	0	17	0	5	217	301
Durham	0	0	0	5	0	0	0	0	4	0	0	74	83
Fairview	0	2	0	4	0	18	2	0	17	0	3	142	188
Forest Grove	7	28	0	29	0	90	16	0	51	0	13	578	812
Gladstone	1	1	0	7	0	56	2	0	18	0	2	472	559
Gresham	19	53	1	100	2	307	163	1	101	3	5	2519	3,274
Happy Valley	0	0	0	0	0	5	0	0	1	0	0	6	12
Hillsboro	9	64	1	92	0	258	146	0	120	13	44	1448	2,195
Johnson City	0	0	0	0	0	0	0	0	0	0	0	2	2
King City	0	3	0	0	0	6	4	0	0	0	0	275	288
Lake Oswego	16	47	0	42	2	120	42	0	28	4	9	1977	2,287
Maywood Park	0	1	0	0	0	1	0	0	0	0	0	0	2
Milwaukie	11	47	2	92	1	105	35	1	39	7	3	805	1,148
Multnomah Co. (uninc)	0	16	1	4	1	44	0	1	45	0	7	126	245
Oregon City	5	89	1	22	0	133	99	1	64	2	17	981	1,414
Portland	377	2393	76	997	61	2038	147	43	879	137	1344	8829	17,321
Sherwood	0	3	0	2	0	25	24	1	26	0	5	185	271
Rivergrove													
Tigard	34	25	0	150	11	175	224	0	67	4	1	1713	2,404
Troutdale	1	6	0	3	0	33	11	0	53	0	1	104	212
Tualatin	7	4	0	119	0	82	21	1	89	5	2	1040	1,370
Washington Co. (uninc)	29	38	0	80	13	258	318	4	55	14	1	4953	5,763
West Linn	1	10	0	1	0	41	9	0	7	0	4	497	570
Wilsonville	3	10	0	79	2	56	101	0	33	6	0	606	896
Wood Village	1	1	0	4	0	8	4	0	14	0	1	33	66
Grand Total	553	2,923	83	2,204	95	4,573	2,111	56	2,025	208	1,486	33,324	49,641

Table 4 shows structure types by square footage in each of the three counties. As evident in this table, about one-third of the building are wood structures.

Table 4: Structure Types by Square Footage by County

	COUNTY			
STRUCTURE TYPE	Clackamas County	Multnomah County	Washington County	Grand Total
C1	2,126,205	16,547,393	5,675,770	24,349,368
C2	7,044,589	46,659,398	4,134,988	57,838,975
C3	204,850	1,849,765	17,400	2,072,015
PC1	21,921,248	37,407,986	29,935,133	89,264,367
PC2	420,750	4,821,691	945,840	6,188,281
RM	11,955,415	23,725,068	17,059,681	52,740,164
S1	2,246,452	14,616,042	7,287,853	24,150,347
S2	16,400	1,660,668	104,375	1,781,443
S3	5,009,386	13,078,690	5,119,391	23,207,467
S4	1,200,330	12,943,483	1,542,615	15,686,428
URM	329,600	19,187,915	711,375	20,228,890
W	37,286,677	62,986,693	60,076,042	160,349,412
Grand Total	89,761,902	255,484,792	132,610,463	477,857,157

Table 5 shows structure types by occupancy in each of the three counties. As evident in this table, about one-half of the total occupancies is in residential (Multi-family Residential). As noted, the data were collected over a three-year period by Portland State University and the City of Portland Bureau of Buildings. In 1993, the City of Portland did not include a normalized field for occupancy which accounts for the occupancies designated as “other.”

Table 5: Occupancy Type by County

OCCUPANCY	**COUNTY**			**Grand Total**
	Clackamas	Multnomah	Washington	
Commercial	1,282	3,957	2,103	7,342
Emergency Services	33	70	27	130
Government Buildings	415	406	73	894
Historical Buildings	5	23	2	30
Industrial	1,027	3,230	1,299	5,556
Office	686	1,969	1,008	3,663
Public Assembly	286	660	276	1,222
Residential	5,490	6,106	13,099	24,695
School	297	583	354	1,234
Other	--	--	--	4,875
Grand Total	9,521	21,879	18,241	49,641

Table 6 shows structure types by value and area in each of the three counties. As evident in this table, two-thirds of the buildings are wood structures but account for only one-third of the total value. Tilt-up concrete (PCI) buildings account for four percent of all structures but represent approximately 19 percent of the total value. Other structures accounting for relatively high proportion of the total value include reinforced concrete moment resisting frame (C1), reinforced concrete sheer walls (C2) and steel frame with concrete sheer walls (S4).

Table 6: Value and Area of Buildings by Structure Type

TYPE	NUMBER	AREA	VALUE
C1	553	24,349,368	$ 2,593,012,330
C2	2,923	57,838,975	$ 7,833,889,095
C3	83	2,072,015	$ 109,014,330
PC1	2,204	89,264,367	$ 5,079,489,380
PC2	95	6,188,281	$ 418,926,050
RM	4,573	52,740,164	$ 5,354,092,270
S1	2,111	24,150,347	$12,564,285,490
S2	56	1,781,443	$ 496,530,730
S3	2,025	23,207,467	$ 4,030,645,610
S4	208	15,686,428	$ 1,462,343,560
URM	1,486	20,228,890	$ 740,970,845
W	33,324	160,349,412	$58,638,917,878
Total	49,641	477,857,157	$99,322,117,568

D.2 UTILIZATION OF BUILDING INFORMATION

2.1 Community Damage and Loss Estimation:

One of the most important uses of the data for buildings assessed for seismic risk is for estimation of damage and loss that could result from an earthquake. Some of the regional building data were used by the National Institute of Building Sciences and Federal Emergency Management Agency and their consultants in extrapolating data used to model earthquake damage and loss estimates for the Portland metropolitan region published in March 1997.

Local governments and institutions that own a large number of buildings can use the building data to conduct damage and loss estimation for their buildings.

2.2 Community Hazard Mitigation Actions

In the absence of resources necessary to conduct damage and loss estimation, the building data and geologic hazard information can be used to prepare schematic plans for rebuilding/recovery after an earthquake. Local governments can use the building information to develop programs to encourage owners of especially dangerous buildings (such as unreinforced masonry) in high earthquake hazard zones to engage in retrofit activities.

2.3 Community Emergency Response Actions

Building type can be combined with hazard information such as the relative earthquake zones or floodplain and used to develop emergency response exercises.

Knowledge of building types as well as their structural integrity can help local emergency management personnel and social service agencies to develop projections of the population that is likely to need shelter during earthquakes and to identify buildings that could be used for shelter.

2.4 Community Emergency Recovery Actions

Knowledge of the structural integrity of buildings can be used to develop a community redevelopment plan that takes into consideration areas that may likely sustain greater damage and may determine how to rebuild such areas after a major disaster.

E. UNCERTAINTIES

The purpose of a building inventory is to use these data in conjunction with a model to estimate earthquake damage and losses for a large community of buildings. The estimating techniques and the building inventory data are not intended for the determination of the seismic safety nor potential damage and losses for individual buildings.

Earthquake loss estimation is only an estimate, and includes uncertainties from many sources, including: intensity of ground shaking, local geology, structural response, and time of event. The purpose of RVS is to gather data on buildings, within a budgeted resource of about thirty person-minutes per building, to include a visual assessment of important features that may influence earthquake-induced damages.

In the RVS procedure, varying degrees of uncertainty relate to nearly all elements of the assessment: building type, age, occupancy, floor area, building irregularities, soft story, torsion, post benchmark year, and geologic site condition. For example, in many cases the inspector may not be able to identify the structure type for a particular building. This may be due to a variety of reasons, including: the structural material and/or the configuration is obscured by finish material, the building may display atypical characteristics, the structural type cannot be determined by looking at the exterior, or the building may be of mixed construction or has gone through major renovations.

When the inspector could not identify the structure type with confidence, the steps outlined in ATC-21 were followed to eliminate unlikely possibilities and assign the lowest possible score.

From the exterior, the inspector was generally able to determine the approximate era or age of the building, original occupancy, and the height of the building. This information and ATC-21 guidelines were used to determine the most likely type, based on original occupancy and number of stories. The inspector also used the information gathered from visual inspection of the building to further reduce the list of probable types. If it could be determined that the building was a frame structure, bearing wall structures were then eliminated. For example, for a residential 6-story pre-1930 building, the likely building types are a URM building, or a concrete or steel frame building with URM infill. Consulting the values for the Basic Structural Hazard scores provided on the form, the score is 1.5 for URM infill and 1.0 for URM. Both building types should be employed in the process of using PMFs to modify the Basic Structural Hazard score and arrive at a final Structural Score. After determining the final Structural Score for both types, the lower value was used.

A general indication of the inspector's confidence regarding identifying the basic structural material and system and other building data was provided on the form. An asterisk was used on the form to indicate when data were estimated or unreliable. Data

fields that could fall in this category are year built, total floor area, number of persons, building type, or the existence of any of the modifiers. The comment section was used to explain further the sources of uncertainty.

When the inspector was uncertain of the building type, he/she attempted to eliminate all unlikely building types. If the inspector were then left with several choices, computation of the Structural Score would be treated several ways:

1. The inspector or supervisor calculated the score for all the remaining options and chose the lowest score. This is a conservative approach and in some cases it may be too conservative and the assigned score may indicate that the building presents a greater hazard than it actually does;
2. When the inspector had little or no confidence at all about the structural system, the “Do Not Know” item was circled, indicating an automatic default of the building for detailed review by the supervisor;
3. A more detailed field inspection could include entering the building and examining basements, roofs, and other structural elements.

F. AVAILABILITY OF THE DATA

The building data are being integrated into the Metro Area Disaster Geographic Information System (MAD GIS) CD ROM-based application. The MAD GIS consists of a compiled VB/MapObjects application supporting several functions such as map navigation consisting of familiar places, menu and zoom in, zoom out and pan tools, scale dependent display various hazard datasets, infrastructures and environmental data, geosearch query capability. The deployment of the MAD GIS onto target computer equipment with minimal user interaction is facilitated with an installation routine.

G. SUMMARY

The purpose of conducting the building inventory is to create a model to estimate earthquake damage and losses for a large community of buildings. Earthquake loss estimation includes uncertainties from many sources, including: intensity of ground shaking, local geology, structural response, and time of event. The estimating techniques, as well as the building inventory data are not intended for the determination of the seismic safety nor potential damage and losses for individual buildings.

The premise of the project described in this report was based on the principle of the four R's of Mitigation: Recognize, Rate, Retrofit, Remove. First, it is fundamental to recognize the potential seismic hazard in a community. Next, the buildings should be evaluated and rated based on their expected performance, followed by prioritization of buildings for retrofit; and finally, the community may decide to remove those buildings that are not economically feasible to be retrofitted.

The objective of this project was to enhance the knowledge of the building stock acquired through the RVS procedure and to determine the spatial distribution of buildings and relationship to earthquake hazards. Approximately 50,000 non-residential and multi-family buildings were evaluated for seismic risk within the Metro urban growth boundary.

The implementation of a RVS on buildings, within a budgeted resource of about thirty person-minutes per building, includes a visual assessment of important features that influence earthquake-induced damages.

The training sessions for the inspectors comprised of several days of instruction, fieldwork, and supervised workshops. Training materials included the ATC-21 handbook and supporting documentation, rapid assessment forms, and slide presentation based on figures in ATC-21. At the outset, all survey personnel studied and became familiar with the ATC-21 handbook, followed by training sessions. Supervisors provided additional slides to illustrate the discussion further. Extensive pre-planning made the field experience productive with a minimum amount of difficulties. Each surveyor (inspector) was issued an identification card including his/her name, photo and a general description of the purpose of survey.

In RVS, varying degrees of uncertainty relate to nearly all elements of the assessment: building type, age, occupancy, floor area, attributes such as irregularities, soft story, torsion, post benchmark year, and geologic site condition. For example, in many cases the inspector may not be able to identify the structure type of a particular building for a variety of reasons, including: the structural material and/or the configuration is obscured by finish material, the building may display atypical characteristics, the structural type cannot be determined by looking at the exterior, or the building may be of mixed construction or has gone through major renovations.

From the exterior, the inspector was generally able to determine the approximate era or age of the building, original occupancy, and the height of the building. These information and ATC-21 guidelines were used to determine the most likely type, based on original occupancy and number of stories. A general indication of the inspector's confidence regarding identifying the basic structural material and system and other building data was provided on the form. An asterisk was used on the form to indicate that data were estimated or unreliable. Data that could fall in this category are year built, total floor area, number of persons, building type, or the existence of any of the modifiers. The comment section was used to explain further the sources of uncertainty.

When the inspector was uncertain of the building type, he/she attempted to eliminate all unlikely building types. If the inspector were then left with several choices, computation of the Structural Score would be treated several ways as outlined in ATC-21.

Overall, the experience of the project team with the RVS procedure was very satisfactory. Occasionally, the owner/manager would refuse to cooperate and would deny access to building grounds. Inconsistencies between the preprocessed information and the field data, when noted, were recorded on the form and discussed with the supervisors.

H. APPENDIX: FIELD WORK PROCEDURE

H.1 Preparation of Survey Tools and Staff

Three major steps were undertaken in preparation for the field work: 1) preprocessing of maps for field work; 2) field survey form and data entry; 3) training field surveyors. These tasks are detailed below.

H.2 Preprocessing of Maps for Field Staff

The objective was to create detailed section maps that would aid the surveyors in their field work. Metro and PSU chose to use one-mile square sections as the geography for organizing the field work. This scale of map (1"=200') provides the surveyor enough detail for organizing survey routes.

Before creating the section maps, a database of all non-residential tax account records based on the tax assessor's building use code was created. Information on the year built, square footage of the structure, and address were attached to the database using the tax account number as the related field. One-mile section maps (36"x44") depicting the relationship of the information in the new database to the tax lot data coverage were created for every section in the study region. Other information on the section maps

included the tax lot lines, street names, condominium buildings to be screened, and the tax account number of the building (see Exhibit A).

Other maps created for the field work included a county scale map (scale about 1:25,000; 36"x44") and a 7 ½ minute quadrangle map (36"x44") for each quadrangle in the study region. These two groups of maps were useful to the field surveyors in planning the RVS routes.

H.3 The Issue of Tax Account and Number of Structures

The use of tax assessor information to process section maps for the field work created a 'tax account and number of structures' problem. This problem occurred in two areas: i) in one case there were several tax account numbers that represented condominiums in one structure (see Exhibit B - map of condos) because there are four separate property owners; and ii) in another case there were many structures (like the Metro Zoo) that were represented in one tax account (Refer to Exhibit C).

Correcting the 'tax account and number of structures' problem is crucial for the accuracy of the modeling project. In the condominium case, the dollar value for the units (or tax accounts) were added together to capture the value of building. In the case of one tax account (e.g., Metro Zoo) and many buildings, the processor assigned sequence numbers 90.01, 90.02, etc. to the structures. The assessed dollar value for the structures was determined by dividing the total value by the total square footage of all buildings and then calculating the values for individual structures based on respective areas.

H.4 Notifying Citizens

Metro prepared a letter for field staff stating the purpose of the survey and requesting the cooperation of building owners during the evaluation of their buildings. This letter was used occasionally when the building owner/manager requested additional documents from the field survey team.

H.5 Field Survey Form and Data Entry

The goal was to employ a procedure to rapidly and easily identify those buildings that might pose a risk of loss of life or injury, or severe curtailment of community services in the event of a damaging earthquake. The method needed to be implemented quickly and relatively inexpensively, so that a list of potentially hazardous buildings could be developed without the high cost of a detailed analysis of every building.

For the foregoing reasons, the FEMA 154 (ATC 21) Rapid Visual Screening (RVS) method was chosen. Non-building structures such as bridges and large utility towers were excluded in this survey. The RVS Procedure is designed such that no structural analysis calculations are performed. The user will be making decisions based on an

attribute assessment or scoring system. In this project, the inspection, data collection and decision-making process typically occurred at the building site, taking an average of 30 person-minutes per building. In most cases the buildings were reviewed from the sidewalk without entering the building, or inspecting structural drawings and calculations. In most cases supplemental data were available from the assessor. Such information was reviewed, collated and preprocessed before beginning the field survey.

Generally speaking, visual screening is meant to be the first phase of a multi-phase procedure in which visual survey data are obtained to estimate the potential hazard of the building. If a building receives a low score and is thus determined to be potentially hazardous on the basis of this initial rapid visual screening procedure, that building would be targeted for a subsequent phase of study by a professional engineer having experience/training in seismic design. On the basis of a review of structural drawings, and a more detailed inspection and engineering analysis, the life-safety hazard can be determined. These latter phases were not included in the study.

The rapid visual screening method could be applied to all buildings, but due to budget constraints we decided to restrict the survey to non-residential and multi-family residential buildings.

A field survey form is shown in Exhibit D. This form is based on ATC-21 (FEMA 154) form, with the following modifications:

1. The upper right-hand side label was designed based on the available assessor's data, and preprocessed labels were attached to the forms;
2. The "No. of Persons" was modified to gain a more accurate estimate of occupancy load. Since a significant portion of the commercial buildings house less than 30 people, the ATC-21 range of 10-100 was divided into two ranges: 10-30 and 30-100;
3. The state occupancy categories were added to the form. These are shown in Exhibit E.

Sample field survey forms completed by inspectors are presented in Exhibit E through G. The names and addresses of the buildings have been crossed off to protect the identity of these buildings. The first 12 samples are for the following 12 different structure types:

W	Wood frame
S1	Steel moment resisting frame
S2	Braced steel frame
S3	Light metal
S4	Steel frame with concrete shear walls
C1	Reinforced concrete moment resisting frame
C2	Reinforced concrete shear walls, no MRF
C3/S5	Concrete or steel frame buildings with URM infill walls
PC1	Tilt-up concrete buildings

PC2	Precast concrete frame
RM	Reinforced masonry
URM	Unreinforced masonry

The next eight figures, Exhibit F through H, show examples of mixed construction and where building type was considered for more than one possibility, and the lowest score selected. All 12 examples of field survey forms presented in this report are actual forms with field notes taken by inspectors, and include comments and notes by the supervisor.

After the buildings have been surveyed, the ATC-21 RVS data was entered into a spreadsheet. The surveyor kept the original data for finding the buildings in a database and then added the new surveyed data to the original data. The more reentering of the data, the greater the likelihood that the data will be reformatted. It is imperative that the data be both consistent and normalized. During data entry, the data entry personnel had the same spelling codes for each field type. For example, the occupancy field on the ATC-21 form has ten possibilities. It is imperative that all entries are, for example, Emerg. Serv. or Emergency Management, and not emer. Serv. The data needs to be consistent in order to be captured correctly. One more problem experienced was the extra spaces in the data. If a particular data has extra spaces, it will either not be captured, or it will be displayed in a form that represents something else.

H.6 Training Field Surveyors

As originally conceived, the RVS procedure was developed for a target inspection team consisting of local building officials, professional engineers, registered architects, building owners, emergency managers, and interested citizens.

Any or all of these people could potentially be involved in the efforts to identify seismically hazardous buildings. Senior and graduate engineering and architecture students were chosen to conduct the field surveys. Due to the varied backgrounds of the members of our survey teams, different types of training sessions were provided, and whenever possible, guidelines were provided to assist the surveyors in making judgments.

The training sessions comprised of several days of instruction, fieldwork, and supervised workshops. Training materials included the ATC-21 handbook and supporting documentation, rapid assessment forms, and a slide presentation based on figures in ATC-21. At the outset, all survey personnel studied and became familiar with the ATC-21 handbook, followed by training sessions. Supervisors provided additional slides to illustrate the discussion further. Student surveyors were supplied with pencils, clipboards, and cameras. The cameras were a Polaroid-type that produced instant photos. The training sessions included the following:

- Review of ATC-21 document and its purpose;

- Review of global and regional seismicity, and potential shaking intensities;
- Description of 12 types of structural systems in ATC-21;
- Effects of structural configuration, soil types, falling hazards, and other attributes on building damage;
- Description of the pre-survey maps and documents;
- Review of the basic parts of the form, including basis identifier information, photograph, plan sketch, occupancy, structural score, comments and conclusion;
- Guidelines on drawing a plan and taking a photo. The plan sketch would include scale and orientation, and should clearly depict the building layout. The photograph area should be as wide as possible, with as little obstruction by trees, etc. as possible;
- General guidelines on how to estimate age and floor area. Clues to building vintage may be found in the architectural style and the construction material. Floor area can be estimated using the plan sketch and basic geometry;
- Detailed description of the 12 structural types employed by ATC-21 and how to recognize them;
- Guidelines on how to handle non-cooperative building owners/managers.

Using slides the supervisor led the participants through the evaluation of several examples. This was followed by a classroom review of basic principles. The supervisor guided participants through sidewalk evaluations of a number of nearby buildings, demonstrating proper plan sketching and photography, and pointing out structural features, configuration, and clues to age, structural type, and modifiers. Participants then performed rapid assessments without guidance from the supervisor. Each evaluation was followed by on-site group discussion.

Teams consisting of two members were formed, and the member with more experience (academic or practical) was appointed as the leader. Sometimes one experienced surveyor would lead two or more surveyors on different days. Every morning the team members would gather to present their data from the previous day, discuss any questions with the supervisor, and receive (or confirm) assignments for that day. The team members would be frequently switched, in order to cross-cultivate different experiences and to avoid potential systematic errors.

On a daily basis all results were inspected by the supervisor, corrections made, and questions raised to be discussed with the surveyors. Generally, it was our observation that one supervisor was needed for every five teams.

H.7 PSU Field Experiences

Extensive pre-planning made the field experience productive with a minimum amount of difficulties. Each surveyor (inspector) was issued an identification card including his/her name, photo, and general description of the purpose of survey. Most of the time the

building owners/managers were cooperative and did not object to the survey. From time to time, there were owners/managers/occupants who requested an explanation as to the purpose of the survey and the agencies/personnel involved in the survey.

Occasionally, the owner/managers would call the supervisors to confirm the validity of the survey, or would refuse to cooperate and would deny access to building grounds. The surveyors were trained on how to handle such cases, i.e., not to argue with the owner, mark the form "Access Denied", and refer the matter to the supervisors. The supervisors would, in such cases, handle these individually and personally. On a few rare occasions, letters had to be written to the building owners to seek permission to survey.

Inconsistencies between the preprocessed information and the field data, when noted, were recorded on the form and discussed with the supervisors.

I. EXHIBITS

A.	Non-residential and multi-family buildings in One-Mile Section Map #1n2e18
B.	Many tax accounts under one condominium building
C.	Many buildings under one tax account
D.	Sample of field survey form
E.	State of Oregon occupancy categories
F.1-F.12	Twelve completed sample of field survey forms
F.13-F.20	Eight examples of mixed construction

Exhibit A

Non-residential and multi-family buildings in One-Mile Section Map# 1n2e18

Exhibit B

Many tax accounts under one condominium building

Exhibit C

Many buildings under one tax account

Exhibit D

Sample of field survey form

Exhibit E

State of Oregon occupancy categories

Exhibit F.1 – F.12

Twelve completed sample of field survey forms

Exhibit F.13 – F. 20

Eight examples of mixed construction

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