UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

REPORT ON LIST OF STRUCTURES RECOMMENDED FOR SEISMIC INSTRUMENTATION IN THE PUGET SOUND AREA, WASHINGTON

The U.S. Geological Survey Puget Sound Region
Instrumentation Advisory Committee

(Report compiled by B. Olsen, P. Grant, M. Çelebi)

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The U.S. Geological Survey Strong-Motion Instrumentation of Structures
Advisory Committee for the Puget Sound Region

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TABLE OF CONTENTS

Page No.

PREFACE

The Pacific northwest, particularly the Puget Sound lowland area, has historically experienced damaging earthquakes. These occur at a recurrence interval of roughly thirty-five years, with the most recent in 1965 and the largest preceeding one in 1949, but with earthquakes causing damage in 1945 and both damage and loss of life in 1946.

While recurrence in this region is not as frequent as in the more seismic regions of California, the possibility of damage and loss of life is still significant. In spite of this, little has been done in the region to accomplish the instrumentation of buildings.

In California the USGS instrumentation program has been directed towards special classes of buildings, since typical buildings are being instrumented by the California State program. In the Puget Sound region, by contrast, the program will be aimed at a good pattern of structures of varied framing systems, distributed geographically and with respect to variations in soil and geological formations, as well as seeking a spatial distribution to augment understanding of the ground motions and attenuation.

The report which follows represents the efforts of a group of interested individuals. They have been generous in the donation of their time to this project in the interest of improving both our understanding of regional seismicity and structural response. This comprehensive effort could not have been realized without the diligence of Mr. Bruce Olsen, Chairman of the Committee, and of Mr. Paul Grant, who detailed all soil-related recommendations.

1.0 INTRODUCTION

1.1 The Need for Instrumentation

Effective earthquake hazard mitigation is dependent on many different factors. Community and regional recognition of the existing risk, and political acknowledgment of the importance of hazard mitigation are paramount. Application of effective seismic codes in building construction, emergency preparedness for response, and public education concerning the risk are other key factors in hazard mitigation. Technical knowledge both of ground motion and of the response of structures is critical in making structures earthquake resistant. Regional variations in seismicity and in geological formations make regional investigation important.

Seismic codes are aimed primarily at life safety and only secondarily at protection of property. They are dependent on a thorough understanding of structural behavior under strong ground motion. Observation of earthquake damage has provided much initial guidance for conditions to be avoided, and areas to be strengthened. This has been augmented by laboratory testing; however, information obtained from strong-motion instruments is still essential to completing the circle.

Much has been learned from seismic experience with instruments located in California and elsewhere. This has permitted advances in design methods and the confidence with which the methods can be employed, but there is still inadequate information concerning nonlinear action, largely due to unavailability of data. It is therefore desirable to expand the possible sources of new data in order to provide future information of more value in the preparation of seismic codes. A broader geographic distribution of instrumentation in areas of known seismicity improves the probability of obtaining useful information and of increasing the body of data needed to improve seismic design.

1.2 Participants in Instrumentation Programs

Many Federal agencies participate in the instrumentation of structures, including:

Department of the Army, Corps of Engineers

Department of the Navy, Civil Engineer Corps
U.S. Geological Survey
U.S. Bureau of Reclamation
Federal Highway Administration
Veterans Administration

While much of the instrumentation work is coordinated by the U.S. Geological Survey, overall direction of the National Earthquake Hazard Reduction Program is the responsibility of the Federal Emergency Management Administration.

In the state of Washington, bridge instrumentation programs are underway by the Washington State Department of Transportation (WSDOT), while dams are instrumented under a program of the Corps of Engineers, and Veterans Administration Hospitals are instrumented under that agency. Only one city, Tacoma, has developed an instrumentation program and this was developed in collaboration with USGS. In spite of major rapid growth in population and in structural density, none of the other large cities in the region have undertaken such public-safety-conscious action.

1.3 Objectives of the Instrumentation Program

The objective of this instrumentation program is to develop a network of instrumented structures over a broad seismic region to improve the chances of having instrumented structures so located as to secure useful information when a strong earthquake occurs. The total network should incorporate existing or added free-field stations to augment the information needed by the research and design communities. Resulting earthquake records obtained from such a network will be of great value to the interested professions in improving design practice, and furthering the safety of the region through ultimate improvement of design methods and regulations. This system of well-instrumented buildings, combined with a suitable array of existing or augmented ground stations, will serve the research needs of the earth sciences community in establishing a better understanding of regional strong ground motion.

Information obtained from a well-instrumented structure with a complete set of recordings augmented by ground stations can provide useful information to:

- check the appropriateness of the dynamic model which was used in design in the elastic range;
- determine the importance of non-linear behavior on the overall as well as the local response of the structure;
- follow the spreading non-linear behavior throughout the structure as the response increases, and frequency and damping vary;
- correlate damage or damage patterns with inelastic behavior;
- establish ground-motion parameters that correlate well with building response damage;
- provide information which may lead to recommendations to improve seismic codes; and
- assist in identifying source mechanisms, focusing effects or other critical matters.

1.4 Objectives of the Advisory Committee

In the assignment of members of the committee each received a letter containing the following paragraph:

> "The Advisory Committee will be asked to develop a list of potential structures (buildings, bridges, tanks, lifeline structures, etc.) which are deemed important such that if instrumented, the engineering community can benefit from studying data acquired during strong-motion events. After the list is developed, the next step would be to prioritize these structures for recommendations to the USGS for instrumenting."

In order to provide information of broad usefulness, the building instrumentation should be augmented by coordination with existing ground stations or relocated ground stations. This will provide improved seismological information with regard to ground motion of a broad regional area. To this end the members of the committee with earth sciences backgrounds have taken a broader view of their assignment.

1.5 The Scope of the Report

In conformance with the initial charge to the committee, the report is basically limited to providing a list of structures found by the committee to be appropriate for instrumentation. Priorities have, in turn, been established for these structures. These priorities are related to the building type and characteristics. They also take into consideration the geological, geotechnical and seismological aspects of its siting. This will provide not only useful structural information, but simultaneously and with essentially no added cost will furnish better regional seismological data. However, additional recommendations pertaining to ground stations are also included within the report.

2.0 SITE SELECTION PROCESS

2.1 Purpose

A thorough and comprehensive seismic instrumentation program in the Pacific northwest may provide a wealth of data on the behavior of structures following a strong earthquake. This data would be of interest to both earth scientists (geotechnical engineers, geologists, and seismologists) as well as structural engineers. Earth scientists would benefit from the results of such a program by gaining a better understanding of earthquake source mechanisms, travel paths, the effects of local geology on site response, and significant conditions resulting in soil-structure interaction. Similarly, structural engineers would benefit from a better understanding of the earthquake performance of different types of structural systems.

Accordingly, the selection of sites for instrumentation must consider the different needs of earth scientists as well as structural engineers. The following section of the report addresses the needs of practitioners and researchers in the earth science field, and criteria will be developed for instrument deployment to meet the needs of those who will utilize the data acquired. These criteria, when combined with a ranking scheme for addressing the needs of the structural engineering community (Section 3.0), provides a comprehensive basis for selecting instrumentation locations.

From an earth sciences perspective, the following factors must be considered in selecting sites for instrumentation:

- research needs within the seismological and engineering communities;
- seismic activity and risk to the population at large;
- existing accelerographs within the region; and
- funding constraints for instrumentation installation and operation.

Based upon these considerations, a scheme was developed for deploying instruments at specific sites to provide information on soil-structure interaction and other effects. As an extension of this effort, the existing USGS instrumentation program of ground stations within Washington state was reviewed and critiqued for station coverage and potential station relocations. The results of these studies are subsequently discussed.

2.2 Research Needs

Valuable seismological and engineering data may be obtained through the judicious selection of sites for strong ground-motion instrumentation. Appropriate deployment of instruments could provide information on the following:

- source mechanism
- travel path
- focusing (topography/structural discontinuities)
- ground-motion characteristics (peak ground-motion values and response spectra)
  - —variation with magnitude
  - —variation with source distance
  - —variation with soil conditions
- soil/structure interaction effects
  - —resonance
  - —boundary conditions
  - —rocking effects

2.3 Previous Studies

Previous studies have been accomplished by others for siting strong ground-motion accelerograph stations in California (Çelebi *et al.*, 1984; Borcherdt *et al.*, 1984). In both of these studies, instrument deployment was based considering the proximity of active faults and the expected severity of ground shaking at the instrumented site. Instruments were then deployed adjacent to fault systems having the highest probability of earthquake activity.

2.4 Seismicity Considerations

The techniques which were applicable for locating strong ground-motion instruments in California are not entirely appropriate for Washington state, as the local seismicity is not typically related to known surface faults. Thus, any instrumentation program for Washington must consider the unique aspects of the tectonics and seismicity of the region as a basis for instrument deployment.

While the committee was specifically tasked with providing recommendations for instrument deployment in the Puget Sound area, it is useful to review the seismicity of the state of Washington to provide a more complete picture of the tectonics in the Pacific northwest. Thus, for the purposes of this report, the seismicity and tectonics of eastern and western Washington will be reviewed as a basis for establishing guidelines for the instrument deployment scheme.

In many respects, the seismicity of eastern Washington may be similar to that found in California. Specifically, earthquakes in eastern Washington typically occur at shallow depths. While some of these events can be associated with known faults which have established activity or movement rates, most of the events are associated with structural features such as anticlines. Because these features are not associated with surface faults, it is not possible to reasonably estimate earthquake recurrence rates based solely upon geological considerations. While this complicates the assessment of seismicity in eastern Washington, the issue is somewhat mitigated by the fact that faults in eastern Washington do not appear capable of producing major earthquakes. Furthermore, the area has a low population density and inventory of existing significant structures.

The seismicity in western Washington is largely concentrated within the Puget lowland. The Puget lowland is bounded on the east and west by the Cascade range and Olympic mountains, respectively, and the lowland extends from Chehalis north into British Columbia. Earthquakes within the lowland typically tend to occur within two source zones: a shallow zone corresponding to earthquakes with maximum magnitudes of 5 to 6 or less and a deep zone corresponding to moderate earthquakes with maximum magnitudes typically greater than 6 to 7, based on historic data. Historical earthquake activity has not been positively correlated with known or inferred surface faults within the Puget Sound region. Consequently, the earthquake activity appears to be related to plate tectonic activity beneath the Puget lowland without regard to surface structures. Thus, the entire Puget lowland could be assessed as a potential earthquake source zone.

Studies of historical seismicity in the Puget lowland suggest that average recurrence intervals for a magnitude 6 earthquake range from 10 to 70 years (Rasmussen, Millard and Smith, 1974). The longer recurrence interval was extrapolated from a one-year study of microseismicity; whereas, the shorter recurrence interval was based on 133 years of historical data for events occurring within the Puget lowland. A best estimate of regional seismicity would probably be within these upper and lower bounds.

Based upon the above range of recurrence intervals, it is estimated that a magnitude 6 earthquake would have a 2 to 10 per cent annual probability of occurrence. This estimate is based upon a Poisson distribution for earthquake occurrence which does not consider the last occurrence of a major earthquake.

In addition to earthquakes occurring beneath the Puget lowland, various researchers have hypothesized that western Washington could experience a subduction zone earthquake. This earthquake would likely be centered somewhere near the western coast of Washington. Research is currently being undertaken to investigate geologic evidence which may substantiate the occurrence of such a major event prior to written or deduced history in the region. Although the occurrence of a subduction zone earthquake is speculative at this stage, various researchers have estimated that a recurrence interval for such an event would range between several hundred to several thousand years.

As a result of the unique aspects of the seismicity within Washington state, the following conclusions have been derived for formulating an instrument deployment plan:

1. Based upon historical seismicity and population concentrations, the seismic hazard in western Washington, specifically the Puget lowland, is significantly greater than that in eastern Washington. Thus, it is recommended that strong-motion instruments be located exclusively within western Washington.

2. Earthquake activity in the Puget lowland appears to be unrelated to known or inferred faults. Therefore, it is recommended that instruments be deployed within the region based on spatial considerations.

3. There is significant uncertainty in not only the location of a future earthquake within the Puget lowland but also the recurrence intervals of large events. In this regard, it is felt that an extremely costly and extensive instrumentation program would not be economically justifiable. Therefore, to optimize the resources that may be available, the development of a systematic program for instrumentation in which accelerographs are installed on a prioritized basis to meet research needs and funding restrictions is required.

4. Currently, research is being conducted to evaluate evidence of the occurrence of subduction zone earthquakes in western Washington outside recorded time. Since the occurrence of such an event is speculative, it is recommended that instrumentation to record a potential subduction zone earthquake be considered separately from the building instrumentation program.

2.5 Site Selection Scheme

2.5.1 Objectives

The objective of the site selection process is to develop an integrated instrument deployment program that, considering the unique aspects of local seismicity and existing instrumentation, provides a basis for prioritizing instrument deployment to meet research needs in the seismological and engineering communities. To achieve this goal, it is first necessary to review the existing accelerograph stations within the state. This data provides a basis for selecting certain structures for instrumentation. The final step is the development of a site selection plan which meets current research needs. Elements within each of these tasks are discussed subsequently.

2.5.2 Existing Instrumentation

A tabulation of existing accelerograph stations within Washington is presented in Table 1. The locations of these stations are shown in Figure 1. The location of the instruments shown on Table 1 has been developed from both published (Switzer *et al.*, 1981; Hayes and Gori, 1986) and unpublished data. This tabulation includes accelerograph stations owned by the U.S. Geological Survey as well as other agencies. Sites of existing instrumentation within the state include buildings, bridges, dams, marine facilities, downhole arrays, and free-field stations. The coordinates for some of the U.S. Geological Survey accelerograph stations have been modified from published data to reflect a more accurate location. Revised station coordinates were obtained from published literature (Shannon & Wilson and Agbabian Associates, 1980a, 1980b, and 1980c) or from scaling locations on topographic maps for stations in Seattle. Information on the geological conditions at each of the accelerograph stations was determined by reviewing geologic maps and reports for the various regions. The references which are used in this search are cited in the bibliography.

As indicated in Figure 1, the majority of accelerograph stations in Washington are concentrated in the Puget lowland. This deployment of existing instrumentation correlates well with historical seismic activity within the state which is shown on Figure 2.

The data provided in Table 1 was used to prioritize structural categories for future instrumentation. Specifically, existing instrumentation within Washington includes:

Structural Category	Instrumented Locations
Buildings	32
Bridges (overpass structures)	3
Dams	8
Other	4

From the above findings it was concluded that both dams and highway overpasses are relatively well instrumented considering the number of structures of this nature which exist within the state. Thus, it is our opinion that the strong-motion instrumentation program should focus upon instrumenting only buildings.

2.5.3 Selection Scheme

Having inventoried the existing accelerograph stations within the state and concluded that the instrumentation program should be confined to buildings, it is next necessary to establish a framework for deploying the instruments to meet the research needs previously discussed. The following elements, which will be discussed subsequently, provide a frameworking for instrument deployment:

- location
- soil condition
- potential soil/structure interaction effects
  - —resonance
  - —boundary conditions
  - —foundations
- focusing

2.5.3.1 Location

Due to the lack of correlation of seismic activity with known faults within western Washington, a spatial separation of instruments will be required to provide information on the source mechanism, travel path, and attenuation of maximum ground motions and response spectra for the earthquake recording sites. Instruments should be deployed to accomplish three separate goals. First, a select group of sites should be instrumented in the Seattle/Bellevue area to provide a multiplicity of information on frequency content and soil-structure interaction effects. Secondly, sites in outlying areas should be instrumente to provide adequate coverage for recording local earthquakes within the Puget lowla This would necessarily require establishing recording stations in an east–west as w north–south array through the Puget lowland. The third goal for the spatial distr of stations is to provide adequate coverage for the potential occurrence of a subduction zone earthquake. This would necessarily require locating instruments on the Olympic Peninsula, which would be close to the source of such an event.

The above goals may be accomplished by both single and multiple instrumentation at recording sites. Sites with multiple instruments are appropriate for locations in the Seattle/Bellevue area where studies of special subsurface effects such as soil-structure interaction will be accomplished. Sites where single instruments will be appropriate correspond to conditions where only one parameter may be studied, such as ground-motion characteristics from either a local or subduction zone earthquake.

2.5.3.2 Soil Conditions

To evaluate the influence of soil conditions upon the values of recorded peak ground motion and response spectra, it is recommended that ground level instruments be deployed at locations having the following soil types:

- alluvium—more than 150 feet deep
- glacial deposits—glacially consolidated silts, clays, and outwash sands and gravels
- rock

It is recommended that instruments to study the effects of each of the three soil types be located relatively close to one another to minimize differences in ground motion due to different travel paths of the earthquake waves or focusing effects. If possible, it is recommended to provide instrumentation on all three soil types in both Seattle and Olympia. This type of information would be useful in developing microzonation guidelines based upon geologic units.

2.5.3.3 Soil-Structure Interaction Effects

Resonance. It is recommended that instruments be deployed to study potential effects of soil-structure resonance. A condition of resonance exists when the fundamental period of the soil deposit underlying a building matches the fundamental period of the structure. Resonance effects accounted for extensive damage to structures located in

Mexico City during the 1985 earthquake. It was typically observed that 15- to 20-story structures were severely damaged from this earthquake while adjacent 2- to 3-story structures performed relatively well. Similar earthquake damage patterns have also been observed in other cities. Additionally, both the Uniform Building Code and the Applied Technology Council Guidelines for the seismic design of buildings explicitly account for potential conditions of soil-structure resonance in determining equivalent base shear forces for the earthquake design of buildings. Thus it would be extremely beneficial to instrument sites within the Puget Sound area where resonance may occur. Potential study categories include the following:

- low building/stiff soil (glacial deposits)
- low building/soft soil (alluvium)
- high-rise building/stiff soil
- high-rise building/soft soil

It is recommended that buildings selected for this comparison be located within reasonable proximity to one another, preferably in Seattle, to minimize differences in ground motion due to different travel paths of the earthquake waves. It may not be possible to provide complete coverage for this study as high-rise buildings in Seattle are not typically located on soft soils (alluvium). Therefore, this specific study category may require instrumentation of a structure outside of the Seattle–Bellevue area.

Boundary Conditions. It is recommended that instruments be deployed to study various boundary conditions pertinent to the response of the substructure of buildings. Instrumentation should be deployed to study:

- variation of motion below the ground surface
- location of input motion in structural models
- effects of sloping ground conditions on substructure response

Dynamic analyses of structures within Seattle require an evaluation of each of the above parameters in formulating the dynamic model of the structure. Instrumentation of appropriate buildings would provide a basis for assessing the assumptions which are made in the current structural analyses and provide guidance for better modeling procedures. Instrumenting buildings with deep basements should provide confirmation on the variation of ground motion with depth below the ground surface as well as related soil-structure interaction effects. Additionally, locating instruments at both the street level and the lowest basement level would provide ground motions which may be used in a "back analysis" of the structure. This back analysis would indicate if the ground motion is more likely to be transmitted to the building through the floor slabs of the structure at street level or if the controlling motion to the structure is transmitted through the footings at the base of the structure. Finally, instrumenting basements of structures where there is a significant variation in elevation about the site would indicate the appropriate choice for the location of the ground motion for the structural analyses (*i.e.*, uphill or downhill side of structure).

It is anticipated that the above information can be conveniently accomplished through two studies. The first study would instrument buildings with deep basements that are located on sites having sloping ground conditions and the second study would consist of instrumenting buildings with deep basements located at sites where the adjacent ground is level. It is anticipated that the findings from such a study could also be interpolated for buildings with shallow basements on either level or sloping ground.

Foundations. It is recommended to instrument buildings with different foundation types to evaluate the potential effect of rocking on the building response. While the criteria for rocking of structures is based on many factors, it is anticipated that rocking effects would be amplified for those structures having a fundamental period close to the natural frequency on the underlying soil. This effect would be most significant for buildings of intermediate height (5 to 20 stories). While this effect would be less critical for high-rise structures, it is anticipated that high-rise buildings, instrumented for other purposes, could also provide useful information on this phenomena which could be extrapolated for use in the design of intermediate height structures. Therefore, it is recommended that high-rise buildings with the following foundations be instrumented:

- piles
- drilled piers
- mat or footing foundations

Buildings selected for this study do not necessarily need to be constrained to the same geographic area.

2.5.3.4 Focusing

Previous earthquakes in the Puget Sound area have resulted in concentrated damage in local areas. One such area is west Seattle which experienced significantly more structural damage than other areas of the city with similar subsurface soil conditions. It has been theorized that the bedrock geometry beneath west Seattle caused a focusing of earthquake waves which resulted in the local concentration of building damage. Therefore, instrumentation in west Seattle would clarify the issue on the effects of earthquake focusing on recorded ground motions compared to other areas of the city.

Geological and geophysical studies have indicated that Seattle is cut by a major structural discontinuity which quite likely is a fault. This structural discontinuity runs in an east–west direction essentially beneath the center of the city. It has been postulated that the offset in this structural discontinuity may be as great as 1,000 feet. Thus, as a result of this major structural feature, it would be beneficial to have seismic recording instruments located both north and south of this feature to determine if the discontinuity would have any major effects on recorded ground motions.

In our opinion, both of the above studies address specific geological/seismological issues. Accordingly, it is our opinion that single accelerograph stations located in west Seattle and north of the structural discontinuity in Seattle would provide the needed information for these studies and that multiple instrumentation would not be required.

2.6 Deployment Recommendations

2.6.1 Deployment Matrix

A deployment matrix was developed, as presented in Table 2, which addresses the issues in the site selection plan. Since a judicious selection of sites for the deployment of instruments may simultaneously satisfy several study areas, a ranking scheme was developed which would minimize the number of sites which will require instrumentation. This ranking scheme was arranged to include instrumentation at 10 site/building subgroups, where each subgroup would address a specific study category.

The numerical arrangement of the 10 subgroups in Table 2 indicates the general importance of each of the study elements. Therefore, it is recommended that instrumentation be established on a priority basis in sequence with the site subgroup numbers. This sequential instrumentation of the sites is desired as many of the study categories require information from several subgroups to complete a study element. Specifically, information on resonance effects will require instrumentation from building subgroups 1, 2, 4, and 5. Thus, it is important to maintain instrument deployment according to this sequencing to provide the greatest benefit from any recordings of future earthquakes.

The instrument deployment matrix was developed to include sites where both multiple instruments and single instruments would be required. Multiple instrument arrays, subgroups 1, 2, 4, 5, and 6, are applicable to sites where it is desired to obtain information on the effects of soil-structure interaction. Instrumentation is required in only one building of each of the multiple instrumentation sites (subgroups 1, 2, 4, 5, and 6) to provide adequate coverage for studying soil-structure interaction and other effects. Sites of single instruments, subgroups 3, 7, 8, 9, and 10, are appropriate to locations where it is only desired to obtain information of the earthquake motions at the ground surface. These sites may be either free-field locations or ground level installations within existing buildings.

Building subgroup 9 was developed to evaluate the spatial variations of earthquake ground motions as a result of an event occurring locally within the Puget lowland. To provide adequate coverage for such an event it is recommended that, as a minimum, accelerograph stations be located in Issaquah, Bremerton, Anacortes, Stanwood, Everett, Des Moines, Tacoma, Olympia, and Portland. These locations define arrays running both east–west and north–south within the Puget Sound lowland. Except for Bremerton, all locations are presently included in the existing USGS accelerograph station network. Therefore, inclusion of an accelerograph station at Bremerton would be the only instrumentation required to meet this study objective. This study objective would be best accomplished by the Branch of Engineering Seismology and Geology of the U.S. Geological Survey.

Building subgroup 10 was specifically developed to record earthquake ground motions which may occur as a result of a subduction zone earthquake located off the coast of Washington. In our opinion, instrumentation for this study should have the least priority as the occurrence of a subduction zone earthquake is speculative. However, to provide minimal coverage for such an event it is recommended that accelerograph stations be located at Centralia, Snoqualmie Pass, Port Gamble, Port Townsend, La Push, Montesano/Satsop, and Trojan (OR). All of these stations, except Snoqualmie Pass, which is underlain by rock, are located on relatively stable glacial deposits or terrace deposits, which would provide continuity in subsurface conditions for the recording station sites.

The locations of the proposed new ground stations are indicated on Figure 3. These ground stations correspond to sites of new instrumentation from subgroups 9 and 10 where single accelerographs would be required. Again, instrumentation at these sites would be appropriate for installation by the Branch of Engineering Seismology and Geology of the U.S. Geological Survey.

2.6.2 Deployment Subgroups

Information on the requirements for the buildings within each of the 10 site building subgroups is presented in Table 3. The classificational criteria for these subgroups includes information on the building period, location, basement depth, ground surface adjacent to the building, and foundation types. The classificational criteria also require information on the soil conditions at the building sites. To assist in the classification of structures, maps were developed which indicate the general soil conditions within the Metropolitan Puget Sound region. These maps generalized the subsurface conditions into alluvium, glacial deposits, and rock as indicated on Figure 4. Information for this geological classification was derived from the references which are listed in the bibliography.

Thus, classifying structures within one of the 10 site/building subgroupings requires information on the building structure and subsurface soil conditions (Figure 4). Candidate structures for study within each of the subgroups are listed on Table 3. Within each subgroup, the structures have been ranked in descending order of importance for instrumentation, based upon meeting the objectives of the individual study categories. Sites or buildings of existing accelerographs are also noted on Table 3.

2.6.3 Site Selection

Five of the site/building subgroups that are listed in Tables 2 and 3 are appropriate for multiple instrumentation. These correspond to building subgroups 1, 2, 4, 5, and 6. Since these subgroups correspond to specific soil-structure interaction studies, it is recommended that all instrumented sites be located within the Seattle/Bellevue area to minimize variations in recorded ground motion due to differing travel paths of the earthquake waves or other factors. One building from each of these five subgroupings should be instrumented prior to deploying instrumentation in outlying areas. Instrumentation of buildings in outlying areas may be accomplished solely on the basis of structural needs. Section 4.0 of the report presents a master list of buildings recommended for instrumentation, based upon both geotechnical and structural considerations.

Sites recommended for single accelerograph deployment should be accomplished by the USGS as funding becomes available. In our opinion, the existing network of USGS-owned and -operated ground stations within the Puget lowland would provide good coverage for a local earthquake. However, it is recommended to install a few additional stations or relocate existing stations to improve the existing network. The following are our recommendations for new single ground station additions which are independent of any multiple instrumentation programs which may be accomplished by the USGS.

Seattle Rock Station. Current instrumentation in Seattle includes accelerographs located both on alluvial deposits and glacial deposits. To complement these sites, it is recommended to install an accelerograph at a rock site in Seattle. This installation would correspond to site building subgroup 3 in Table 3. The existing accelerograph at the VA Hospital in Seattle does not fully meet the criteria for a rock site, as the site subsurface conditions consist of 20 to 30 feet of glacial deposits overlying bedrock. Consequently, it is recommended that a free-field rock station be established at a location where the rock actually outcrops south of the VA Hospital. Such a site may include a free-field instrument shelter at a city park or along the I-5 freeway cut. Alternatively, it may be possible to instrument a nearby building located on rock such as the Rehabilitation Center for the Blind.

Olympia Glacial Station. Similar to Seattle, it is recommended that ground stations be established in the Olympia/Tumwater area for accelerographs located on alluvium, glacial deposits, and rock. The existing accelerograph station at the highway test lab in Olympia is located on alluvial deposits, and the accelerograph station at Tumwater is located on rock. Thus, to complement these stations, it is recommended that an accelerograph be located on glacial deposits within the Olympia area. This station could either be a free field site or a ground station within an existing building such as the Highway License Building or the Governor's House.

Bremerton Station. To complement the suite of existing ground stations in the Puget Sound area for recording local earthquakes, it is recommended that a ground station be established in the Bremerton area. Such a station should be located upon glacial deposits to correspond to subsurface conditions at similar stations around the Puget Sound. There are existing accelerograph stations owned by the U.S. Department of the Navy at various locations within the Puget Sound Naval Shipyard in Bremerton. It is recommended that one of these sites be included within the USGS accelerograph network. It is recommended that one of the ground stations along the waterfront be included as any events recorded at this station could be used to correlate recorded ground motions with damage to any drydocks or piers during a future earthquake.

Subduction Zone Earthquake Stations. As the lowest priority for station instrumentation, it is recommended that the number of ground stations be increased to include sites for recording ground motions from a subduction zone earthquake. Such an array corresponds to site/building subgroup 10 in Table 3. Sites recommended for instrumentation are located in Centralia, Snoqualmie Pass, Port Gamble, Port Townsend, La Push (Naval Reserve Station), Montesano/Satsop, and the Trojan power plant in Oregon. It is our understanding that accelerographs already exist at Satsop and the Trojan power plant and that this would not require new installation but only maintenance of existing instruments.

New instruments would therefore be required for installation at five sites. Again, these sites would have the lowest priority for installation and should be accomplished only after installation of new instruments at Seattle, Bremerton, and Olympia.

Station Relocations. Based upon our above recommendations and a review of the existing stations within the USGS network, it is recommended that two stations be relocated. The first station recommended for relocation is Nisqually. The Nisqually station is located on alluvial sediments in a relatively undeveloped portion of the Puget Sound. Thus, any recordings of earthquake motions at this station would be of interest only regarding the spatial variations of ground motion in the Puget lowland. Due to the sparse development in the area, recorded motion at this station would not necessarily be correlated to damage of nearby structures. Considering the above and the fact that the Nisqually station is relatively close to the existing highway test lab site in Olympia, which is also located on alluvial soils, it is recommended that the Nisqually station be terminated or relocated.

The other accelerograph station recommended for relocation is Orting. The Orting site is one of the few stations in the Puget Sound region located on rock. The information from this station would be essentially redundant to the existing rock station in Tumwater. In our opinion, it would be preferable to relocate the Orting station to a glacial site in Olympia to complement the existing stations on rock and alluvium. Having recording stations located on all three subsurface conditions in close proximity to one another would minimize differences in ground motions due to different travel paths of the earthquake waves between recording stations and thereby provide useful data on the effects of soil amplification on recorded earthquake ground motions.

It is noted that the rock station in Tumwater is located in a building constructed and previously used by the University of Washington for recording state-wide seismic events. The University-owned seismograph has been removed from the facility, leaving only the USGS accelerographs. The building is not being actively used by the University and the structure may require maintenance in the near future (new roof). It is recommended that the USGS establish agreements with the University to maintain the building or establish a separate instrument shelter at the same location.

2.7 Summary

As a result of seismological and engineering considerations, the following recommendations are provided for locating earthquake recording equipment within Washington:

1. It is recommended that the instrumentation program be concentrated in the immediate Puget Sound area as this region has the greatest likelihood of the occurrence of a moderate or major event and also the highest population and building concentration within the state.

2. It is recommended that instrumentation be deployed only in buildings, as dams and highway structures currently have adequate seismic instrumentation.

3. A deployment matrix has been devised as indicated on Table 2 for locating instruments within western Washington considering sites of both multiple and single instrumentation. Sites of multiple instrumentation apply to the building instrumentation program and address complex factors such as soil-structure interaction. Sites of single instrumentation are appropriate to the USGS for addressing individual issues such as frequency content of earthquake ground motion for local and subduction zone earthquakes.

4. Recommendations for deploying instruments for specific combinations of soil conditions and building configurations have been developed and are presented in Table 3. The individual structures which are shown on Table 3 have been ranked for instrumentation based solely on geotechnical concerns. Final ranking, including structural considerations, is discussed in Section 4.0. It is recommended that multiple instruments be deployed at five building sites (one in each of the subgroups 1, 2, 4, 5, and 6) in the Seattle/Bellevue area prior to accomplishing building instrumentaion in outlying areas.

5. It is recommended that the existing U.S. Geological Survey network of single instrument ground stations be expanded or modified to improve earthquake coverage in the Puget Sound area. Specifically, it is recommended that stations be established in

both Seattle and Olympia which are located on rock and glacial deposits, respectively. Secondly, it is recommended that a station be established in Bremerton, possibly utilizing an existing accelerograph station at the Puget Sound Naval Shipyard, to complement coverage of existing stations for recording a local event. Finally, it is recommended that stations be installed at Centralia, Snoqualmie Pass, Port Gamble, Port Townsend, La Push, Montesano/Satsop, and the Trojan power plant in Oregon to provide minimal coverage for recording a subduction zone earthquake. These stations should have the lowest priority for installation. It is recommended that stations at Nisqually and Orting be relocated as these stations would essentially duplicate information from sites at Olympia.

3.0 THE STRUCTURE SELECTION PROCESS

3.1 Introduction

Fundamentally, instrumentation of any building or structure provides for the possibility of obtaining useful engineering information in the event of an earthquake. In the Puget Sound lowland and Pacific northwest region the existing amount of building instrumentation is very limited. Thus the potential for obtaining important and useful information is essentially lacking. To overcome this lack, a plan has been needed whereby adequate useful information could be secured through a network of instrumentation of regular, typical, average building types. This leaves special conditions and the instrumentation of irregular buildings to future efforts. From this standpoint the guidelines for selection are different than those used elsewhere. The aim of this selection process is to obtain a maximum amount of useful information from the buildings which are chosen. In this report "useful" is interpreted as valuable in reassessing the particular structure instrumented, valuable in making comparisons with similar buildings both locally and elsewhere, and valuable in assisting the understanding of both soil-structure interaction, and potential source mechanisms.

Initial review of existing conditions discloses a limited number of instrumented buildings. These are located in Tacoma and have been instrumented under a City-financed program which was developed with the advice of the USGS in the past. There are a number of ground stations in the region. Some of these are in buildings and some are free field and may be found listed in Table 1. There is also a program for instrumenting the recently constructed VA Hospital addition on Beacon Hill in Seattle.

The program for which this report is made is intended to incorporate existing instrumented structures. In selecting additional buildings, they will be related to the varied types of construction in the area. Recommendations will at the same time be aimed at establishing a systematic relation between the structures selected and the soils and geological conditions encountered and which have been discussed in Section 2.0.

3.2 Structural Parameters

The structural parameters which were considered for establishing a framework for instrument deployment include building geometry, construction material, age of structure, past seismic exposure, and availability of original design drawings. These general categories were used to develop a rating system under which buildings were prioritized for instrumentation. The rating system used a set of weighting values for each of the structural categories to differentiate and prioritize building selection. These weighting values were subjectively selected by the members of the structures subcommitte. The elements of this structural rating system are shown on Table 4. Only buildings have been recommended for instrumentation as existing dams and highway bridges have been adequately instrumented by programs sponsored by the U. S. Army Corps of Engineers and the Washington State Department of Transportation (WSDOT).

All of these measures have been used elsewhere, but are applied in a somewhat different manner for this study. Weighting of the factors was directed toward emphasizing regularity and normal structural conditions, rather than to emphasize unusual types. In this way the priority is directed toward a maximum of information to be obtained from standard types of construction.

It is realized that building types selected may be the same as those found in other areas of high seismicity where instrumentation already exists. In view of the uncertain nature of earthquake recurrence, it was felt that using structural types common to other seismic areas might give even better assurance of securing early instrumental information of general interest. This would be of value to the general engineering community and also to code modification bodies in their efforts to improve the design procedure.

The various parameters which have been utilized have been weighted in an arbitrary manner to give less value to geometrically irregular structures. In materials, utilizations which are generally in common use today have been emphasized.

We have not felt great interest in the age of the buildings since many older buildings have been demolished, and remaining historical buildings have to some extent had seismic strengthening. On the other hand, we have emphasized buildings in the planning stage, or currently under construction, in order to permit instrumentation of new buildings of interest at an appropriate time.

The basic framework established in this manner provided the means for ranking buildings for instrumentation. Structural engineering members of the committee developed a list of candidate structures for instrumentation, selecting those which appeared most representative and of greatest interest. The list was limited to provide geographic distribution as well as characteristic distribution. These buildings are listed in Table 5. The geographic distribution of potential buildings for instrumentation also considered existing instrumentation within the state (Table 1). A master list of buildings recommended for instrumentation was developed by combining the building rankings from Table 4 with the list of potential structures (Table 5). This method was used for all of the buildings in the region, and a listing of global priority over the region was thus established. Since buildings were located in different towns and cities, an added local priority was also prepared to apply to individual areas. These priorities, relating to structural parameters only, and not yet considering soils and geology, are listed in Table 6.

In the list of structures there are also included a number buildings located in the outlying communities away from the heavily populated and built-up areas. From the viewpoint of the earth scientists, ground stations in outlying areas serve adequately, without need of building instrumentation. From the standpoint of the structural engineer, however, instrumentation of a well-chosen building type away from the primary urban centers may be of equal value, and some distribution throughout the region may be desirable.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The Advisory Committee on Instrumentation in the Puget Sound area has over a period of about 16 months given consideration to the need for and significance of instrumentation of a variety of buildings and other stations throughout the area. The result has been the various decisions and actions outlined in the foregoing sections and the recommendations here stated.

A master list of buildings recommended for instrumentation was developed by combining the building rankings determined in the site-selection process (Section 2.0) and the structure selection process (Section 3.0). The recommended buildings for multiple installation are indicated on Table 7 for sites in the Seattle-Bellevue area. It is recommended that one building from each of the 5 subgroups shown on Table 7 be instrumented prior to instrumenting buildings in outlying areas to meet the objectives of the earth sciences subcommittee members in evaluating local geology and soil-structure interaction effects on site response. Upon successful negotiation with building owners for permission to instrument the various structures, it is recommended that the instrumentation committee be contacted for any special requests for locating individual accelerographs within the structures to address special concerns such as soil-structure interaction effects.

The usefulness of information obtained from well-instrumented buildings is recognized from the usefulness of data developed in other regions following earthquakes. The dearth of adequate building instrumentation in this region is acknowledged, as well as the recurrence of damaging earthquakes on a relatively frequent basis. The Advisory Committee therefore urges the early implementation of the instrumentation activities based on the general priorities determined in this report.

It is recommended that the existing USGS network of single instrument ground stations be extended or modified to improve earthquake coverage in western Washington. Specifically, it is recommended that stations be established in both Seattle and Olympia which are located on rock and glacial deposits, respectively. Candidate structures for these sitings include the Rehabilitation Center for the Blind in Seattle and the Highway License Building in Olympia. Secondly, it is recommended that a station be established in Bremerton, possibly utilizing an existing accelerograph station at the Puget Sound Naval Shipyard, to complement coverage of existing stations for recording a local event. Third, it is recommended that stations be installed at Centralia, Snoqualmie Pass, Port Gamble, Port Townsend, La Push, Montesano-Satsop, and the Trojan power plant in Oregan to provide minimal coverage for recording a subduction zone earthquake. These stations should have the lowest priority for installation. Next, it is recommended that stations at Nisqually and Orting be relocated as these stations would essentially duplicate information from sites at Olympia. Finally, it is recommended that the Tumwater rock station site be relocated to an individual instrument shelter or the USGS negotiate with the University of Washington to maintain the existing facility.

The Advisory Committee further recommends that a system be established which will provide for the prompt publication and distribution of instrumental information resulting from any seismic event of significance.

The Advisory Committee finally recommends that major communities in the area be urged to assist and augment the development of this program which has been initiated by USGS. Adoption by major cities of a program similar to that of Tacoma would go far toward establishment of a truly adequate regional instrumental network.

REFERENCES

[1.] Borcherdt, R. D. *et al.*, 1984, National planning considerations for the acquisition of strong ground-motion data, Berkeley, Calif., *Earthquake Engineering Research Institute* **84–08**, 57 pp.

[2.] Celebi, M. (Chairman) *et al.*, 1984, Report on recommended list of structures for seismic instrumentation in the San Francisco bay region, *U.S. Geol. Surv. Open-File Rep.* **84–488**, 36 pp.

[3.] Deeter, J. D., 1979, Quaternary geology and stratigraphy of Kitsap County, Washington, M.Sc. thesis, Western Washington Univ., 175 pp.

[4.] Easterbrook, D. J., 1976, Geologic map of western Whatcom County, Washington, *U.S. Geol. Surv. Misc. Inves. Ser.* **I–854–B**, scale 1:62,500, 1 sheet.

[5.] Eddy, P. A., 1966, Preliminary investigation of the geology and ground-water resources of the lower Chehalis river valley, and adjacent areas, Grays Harbor County, Washington, *Wash. Div. Water Res. Water-Supply Bull.* **30**, 70 p.

[6.] Garling, M. E., Molenaar, D., Bailey, E. G., VanDenberg, A. S., and Fiedler, G. H., 1965, Water resources and geology of the Kitsap peninsula and certain adjacent islands, *Wash. Div. Water Res. Water-Supply Bull.* **18**, 309 p.

[7.] Gayer, M. J., 1976, Geologic map of northeastern Jefferson County, Washington, *Wash. Div. Water Res. Water-Supply Bull.* **76–21**, scale 1:24,000, 1 sheet.

[8.] Hays, W. W. and Gori, P. L., 1986, Proceedings of Conference XXXIII, a workshop on "Earthquake Hazards in the Puget Sound, Washington area," *U.S. Geol. Surv. Open-File Rep.* **86–253**, 237 pp.

[9.] Huntting, M. T., Bennett, W. A. G., Livingstone, V. E., and Moen, W. S., 1961, Geologic map of Washington, *Washing. Div. Mines and Geology*, scale 1:500,000.

[10.] Liesch, B. A., Price, C. E., and Walters, K. L., 1963, Geology and ground-water resources of northwestern King County, Washington, *Wash. Div. Water Res. Water-Supply Bull.* **20**, 241 pp.

[11.] Luzier, J. E., 1969, Geology and ground-water resources of southwestern King County, Washington, *Wash. Dept. Ecology Water-Supply Bull.* **28**, 260 pp.

[12.] Molenaar, D., and Noble, J. B., 1970, Geology and related ground-water occurrence, southeastern Mason County, Washington, *Wash. Dept. Ecology Water-Supply Bull.* **29**, 145 pp.

[13.] Mundorff, M. J., 1960, Geology and ground-water resources of Clark County, Washington, with a description of a major alluvial aquifer along the Columbia river, *Wash. Div. Water Res. Water-Supply Bull.* **9**, 660 pp.

[14.] Newcomb, R. C., 1952, Ground-water resources of Snohomish County, Washington, *U.S. Geol. Surv. Water-Supply Pap.* **1135**, 133 pp.

[15.] Noble, J. B., and Wallace, E. F., 1966, Geology and ground-water resources of Thurston County, Washington, *Wash. Div. Water Res. Water-Supply Bull.* **10**, 141 pp.

[16.] Rasmussen, N. H., Millard, R. C., and Smith, S. W., 1974, Earthquake hazard evaluation of the Puget Sound region, Washington state, *Univ. Wash. Geophysics Proram*, 99 pp.

[17.] Richardson, D., Bingham, J. W., and Madison, R. J., 1968, Water resources of King County, Washington, *U.S. Geol. Surv. Water-Supply Pap.* **1852**, 74 pp.

[18.] Shannon & Wilson and Agbabian Assoc., 1980a, Geotechnical and strong motion earthquake data from U.S. accelerograph stations, Gilroy, CA; Logan, UT; Bozeman, MT; Tacoma, WA; Helena, MT, *U.S. Nuclear Reg. Com. NUREG/CR-0985* **3**.

[19.] ______, 1980b, Geotechnical and strong motion earthquake data from U.S. accelerograph stations, Anchorage, AK; Seattle, WA; Olympia, WA; Portland, OR, *U.S. Nuclear Reg. Com. NUREG/CR-0985*, **4**.

[20.] ______, 1980c, Geotechnical data from accelerograph stations investigated during the period 1975–1979, summary report, *U.S. Nuclear Reg. Com. NUREG/CR-1643*.

[21.] Switzer, J., Johnson, D., Maley, R., and Matthieson, R., 1981, Western hemisphere strong-motion accelerograph station list—1980, *U.S. Geol. Surv. Open-File Rep.* **81–664**.

[22.] Tabor, R. W. and Cady, W. M., 1978, Geologic map of the Olympic peninsula, Washington, *U.S. Geol. Surv. Misc. Inv. Ser. Map* **I–994**, scale 1:125,000, 2 sheets.

[23.] Waldron, H. H., Liesch, B. A., Mullineaux, D. R., and Crandell, D. R., 1962, Preliminary geologic map of Seattle and vicinity, Washington, *U.S. Geol. Surv. Misc. Geol. Inves. Map* **I–354**, 1 sheet.

[24.] Wallace, E. F., and Molenaar, D., 1961, Geology and ground-water resources of Thurston County, Washington, *Wash. Div. Water Res. Water-Supply Bull.* **10**.

[25.] Walters, K. L., and Kimmel, G. E., 1968, Ground-water occurrence and stratigraphy of unconsolidated deposits, central Pierce County, Washington, *Wash. Dept. of Water Res. Water-Supply Bull.* **22**, 428 pp.

[26.] Washington Division of Water Resources Staff, 1960, Water resources of the Nooksack river basin and certain adjacent streams, *Wash. Div. Water Res. Water-Supply Bull.* **12**, 187 pp.

[27.] Weigle, J. M., and Foxworthy, B. L., 1962, Geology and ground-water resources of west-central Lewis County, Washington, *Wash. Div. Water Res. Water-Supply Bull.* **17**, 248 pp.

[28.] Yount, J. C., Dembroff, G. R., and Barats, G. M., 1985, Map showing depth to bedrock in the Seattle 30′ by 60′ quadrangle, Washington, *U.S. Geol. Surv. Misc. Field Studies Map* **MF–1692**, scale 1:100,000, 1 sheet.

TABLE 1

EXISTING ACCELEROGRAPH STATIONS

No.	Station Identification: City	Station Identification: Name	Coord.	Structure Type/Size	Instruments No./Location	Owner	Geology
2178 ANA	Anacortes	Residence 4 Rocky Road	48°28'12"N 122°39'00"W	Instr. Shelter C	1/Gnd.	USGS	Rock
	Bangor	Dry Dock ___ Trident Submarine Base	47°43'N 122°44'W		2/Gnd. & Dock	USN	Glacial
2186 BLO	Bellevue	Fwy. Overpass I-90/136th Ave. S.E.	47°34'46"N 122°09'05"W	5 - 220' (max.) span steel girder	2/Gnd. & Bridge Deck	USGS/ WSDOT	Glacial
2185 BMI	Bellingham	Fwy. Overpass I-5/Bakerview Rd.	48°47'42"N 122°30'40"W	3 - 180' (max.) span conc. box girder	2/Gnd. & Bridge Deck	USGS/ WSDOT	Glacial
2197	Blaine	City Maintenance Yard	48°59'46"N 122°44'31"W	1-story bldg.	1/Gnd.	USGS	Glacial
	Bremerton	Dry Dock ___ Puget Sound Naval Shipyard	47°33'N 122°37'W		3/Gnd. & Dock	USN	Glacial
	Bremerton	Water Pit Facility Puget Sound Naval Shipyard	47°33'38"N 122°37'14"W	3-story, R/C substr. & steel super str.	3/Bsmt, 1st & crane pocket	USN	Glacial
	Bremerton	Hospital Puget Sound Naval Shipyard	47°33'45"N 122°38'37"W	8-story tower 3-story ancillary steel frame	1	USN	Glacial
2161 CJD	Chief Joseph Dam		47°59'42"N 119°38'00"W	Conc. Gravity Dam 918' long; 170' high	3/Crest, L. gallery, Dn. Strm.	ACOE	Rock
2122 EVT	Everett	Courthouse 1810 Wall St.	47°58'48"N 122°12'36"W	5-story bldg.	1/Bsmt.	USGS	Glacial
2173 SBM	Federal Way	Bulk Mail Fac. (Bldg. 3) 34301 9th Ave. So.	47°17'42"N 122°19'27"W	1-story, steel frame	1/Gnd.	USGS	Glacial

No.	Station Identification: City	Station Identification: Name	Coord.	Structure Type/Size	Instruments No./Location	Owner	Geology
2168 GCD	Grand Coulee Dam		47°57'36"N 118°58'48"W	Conc. Dam	2/U&L galleries	WPRS	Rock
2193	Gig Harbor	Fire Station #5	47°19'59"N 122°36'07"W	1-story bldg.	1/Gnd.	USGS	Glacial
2189 HSD	Howard Hanson Dam		47°16'55"N 121°47'28"W	Rolled earth dam w/ rock face, 500' long; 235' high	2/Toe, L. Abut.	ACOE	Rock
2187 ISI	Issaquah	Fwy. Overpass I-90 & Sunset Way	47°31'55"N 122°01'06"W	3 - 160' (max.) span post ten. box girder	2/Gnd. & Bridge Deck	USGS/ WSDOT	Glacial
2184 LGD	Lower Granite Dam		46°39'58"N 117°25'52"W	Conc. Dam w/saddle embankment, 1,650' long; 136' high	5/Crest (R,L,& Ctr.) L. gallery, Dn. strm.	ACOE	Rock
2127 MC3	McChord AFB	Passenger Term.	47°08'15"N 122°28'48"W	1-story bldg.	1/Gnd.	USGS	Glacial
7003	Mt. St. Helens	Castle Creek	46°16'48"N 122°18'00"W	Downhole (Instru. Shelter H&Surf.)	1/DH	USGS	Rock (Volcanic Debris)
7001	Mt. St. Helens	Spirit Lake	46°16'12"N 122°09'36"W	Downhole (Instru. Shelter H&Surf.)	1 DH	USGS	Rock (Volcanic Debris)
7002	Mt. St. Helens	Spirit Lake	46°16'12"N 122°09'36"W	Instr. Shelter H	1/Gnd.	USGS	Rock
2164 MUD	Mud Mountain Dam		47°08'24"N 121°55'48"W	Rockfill w/earth core 1,250' long; 425' high	3/Crest, R. Abut. & Toe	ACOE	Rock
2195	Nisqually	Wildlife Refuge Off.	47°04'59"N 122°43'01"W	1-story bldg.	1/Gnd.	USGS	Alluvium
2101 OLY	Olympia	Hwy. Test Lab 318 State Ave.	47°02'48"N 122°53'51"W	Instr. Shelter A	1/Gnd.	USGS	Alluvium

No.	Station Identification: City	Station Identification: Name	Coord.	Structure Type/Size	Instruments No./Location	Owner	Geology
2179 ORT	Orting	Quarry	47°04'12"N 122°12'36"W	Instr. Shelter C	1/Gnd.	USGS	Rock
2105 RSD	Ross Lake Dam		48°43'48"N 121°04'12"W	Conc. Dam	2/Rt. Abut. & U	SCL	Rock
	Satsop	Nuclear Power Plant #3	47°00'N 123°29'W		1/	WPPSS	Glacial (Wea. Rock)
2102 SEF	Seattle	Federal Office Bldg. 909 1st Ave.	47°36'15"N 122°20'06"W	9-story steel frame & R/C w/bsmts.	1/Bsmt.	USGS	Glacial
2106 SPR	Seattle	Pier 20	47°34'48"N 122°20'42"W	1-story bldg.	1/Gnd.	USGS	Alluvium
2116 SEA	Seattle	Sea-Tac Airport Concourse C	47°26'39"N 122°18'06"W	2-story bldg.	1/Bsmt.	USGS	Glacial
2181 SCB	Seattle	Ship Canal Gnd. 3918 6th N.E.	47°39'19"N 122°19'15"W	2-story bldg.	1/Gnd.	USGS	Glacial
2129 VSE	Seattle	VA Hospital Bldg. 100	47°33'45"N 122°18'24"W	9-story bldg.	3/Bsmt., 5th & 8th	VA	Rock (30' Glacial)
2113 WSH	Seattle	W. Sea. High School 4075 S.W. Stevens	47°34'39"N 122°22'59"W	1-story bldg.	1/Bsmt.	USGS	Glacial
2194	Shelton	Fire Station 100 Franklin St.	47°13'05"N 123°06'29"W	1-story bldg.	1/Gnd.	USGS	Glacial
2123 VSK	Spokane	VA Hospital Bldg. 3	47°42'00"N 117°28'48"W	1-story bldg.	1/Gnd.	VA	Rock
2192	Stanwood	County Lib.	48°14'49"N 122°20'46"W	1-story bldg.	1/Gnd.	USGS	Alluvium

No.	Station Identification: City	Station Identification: Name	Coord.	Structure Type/Size	Instruments No./Location	Owner	Geology
2104 TCB	Tacoma	County-City Bldg. 930 Tacoma Ave. S.	47°15'14"N 122°26'39"W	10-story steel frame bldg. w/bsmt.	1/Bsmt.	USGS	Glacial
	Tacoma	Tacoma Dome 2727 E. D St.	47°14'13"N 122°25'33"W	Wood dome w/conc. walls	1/Gnd.	TDPW	Glacial
	Tacoma	Tacoma Financial Center 1145 Broadway Plaza	47°15'06"N 122°26'17"W	14-story steel frame	1/Bsmt.	TDPW	Glacial
	Tacoma	Fire Station E. 2316 E. 11th St.	47°16'02"N 122°24'26"W	1-story wood frame w/brick	1/Gnd.	TDPW	Alluvium
	Tacoma	Fire Station N. 4701 N. 41st	47°17'11"N 122°29'56"W	1-story wood frame w/brick	1/Bsmt.	TDPW	Glacial
	Tacoma	Fire Station S. 7247 So. Park Ave.	47°11'26"N 122°26'25"W	1-story wood frame w/brick	1/Gnd.	TDPW	Glacial
	Tacoma	Tacoma General Hospital 315 So. K St.	47°15'43"N 122°27'11"W	7-story conc. frame	Bsmt.	TDPW	Glacial
	Tacoma	VA Hospital Bldg. 81	47°07'48"N 122°34'12"W	4-story bldg.	1/Gnd.	VA	Glacial
	Tolt River Dam		47°41'24"N 121°41'24"W	200'high, 960'long Rolled Earth Dam	3/Crest, Abut., & Toe	SWD	Rock
2176 TUM	Tumwater	Seismic Vault 4th & C St.	47°00'54"N 122°54'29"W	1-story wood-frame bldg.	1/Gnd.	USGS	Rock
2131 VVR	Vancouver	VA Hospital Bldg. #3	45°38'24"N 122°39'36"W	1-story bldg w/bsmt.	1/Bsmt.	VA	Alluvium
2124 VWW	Walla Walla	VA Hospital Bldg. #109	46°03'36"N 118°21'36"W	1-story bldg.	1/Gnd.	VA	Alluvium
2158 WYD	Wynoochee Dam		47°23'24"N 123°36'00"W	Conc. Dam with earth dam abut. 1,690' long; 175' high	3/U&L galleries Dn. Strm.	ACOE	Rock

Legend

No. - USGS Station Number and abbreviated station name (Switzer and others, 1981).

Name - Building/Structure name and address or cross streets.

Coordinates - Latitude (N) and Longitude (W) scaled from topographic maps.

Structure - Brief description of building type, number of stories, framing material
Bridge length, span, construction
Dam height, length, construction.

Instr. - Number and locations of accelerographs within the structure.

Owner - ACOE - Army Corps of Engineers
SCL - Seattle City Light
SWD - Seattle Water Department
TDPW - Tacoma Department of Public Works
USGS - U.S. Geological Survey
USN - U.S. Department of Navy
VA - Veterans Administration (owned by VA and maintained by USGS)
WPPSS - Washington Public Power Supply System
WPRS - U.S. Water & Power Research Service (Bureau of Reclamation)
WSDOT - Washington State Department of Transportation

Geology - Alluvium - Quaternary deposits
Glacial - Glacially consolidated Quaternary deposits
Rock - Tertiary metamorphic/volcanic bedrock

Geology inferred from regional maps of surface geology (see list of references).

TABLE 2

INSTRUMENT DEPLOYMENT MATRIX[1]

DEPLOYMENT BASIS	SITE/BUILDING SUBGROUP[2]									
LOCATION (Source Mechanism/Attenuation)										
<u>Special Study Sites</u> (Seattle-Bellevue)										
Multiple Instrument Sites	1	2		4	5	6				
Single Instrument Sites			3				7	8		
<u>Local Earthquake</u> (Single Ground Stations)										
Issaquah (I-90/Sunset)[3]									9	
Bremerton (PSNS)[4]									9	
Anacortes[3]									9	
Stanwood (Co. Library)[3]									9	
Everett (Courthouse)[3]									9	
Des Moines (Sea-Tac)[3]									9	
Tacoma (Co-City Bldg.)[3]									9	
Olympia/Tumwater (Seis. Sta.)[3]									9	
Portland/Vancouver (PSU)[3]									9	
<u>Subduction Earthquake</u> (Single Ground Stations)										
Centralia										10
Snoqualmie Pass										10
Port Gamble										10
Port Townsend										10
La Push										10
Montesano/Satsop										10
Trojan (OR)										10
SOIL CONDITIONS (Frequency Content)										
Soft - Deep Alluvium		2								
Stiff -Glacial Deposits	1					6	7	8	9	10
Rock			3							
SOIL/STRUCTURE INTERACTION										
<u>Resonance</u>										
Low building/Stiff soil	1									
Low building/Soft soil		2								
High-rise/Stiff soil				4						
High-rise/Soft soil					5					
<u>Boundary Conditions</u>										
Sloping Ground/Deep Basement				4						
Level Ground/Deep Basement						6				

FOUNDATION SCHEMES (Rocking Effects)					
Piles		5			
Drilled Piers			6		
Mat/Spread Footings	4				
FOCUSING EFFECTS (Special Research)					
West Seattle (High School)[3]				7	
Structural Discontinuity (Ship Canal Sta.)[3]					8

Notes:

1. The deployment matrix represents the maximum total number of instrumented sites within the state to provide adequate earthquake coverage. Specific objectives of instrumenting various site/building subgroups are as follows:

Study	Subgroup
Source Mechanism/ Attenuation	
Multiple Instrument Locations	1,2,4,5,6
Single Instrument Locations	
Special Studies	3,7,8
Local Deep Event	9
Subduction Event	10
Frequency Content	1,2,3
Soil Structure Interaction	
Resonance	1,2,4,5
Vertical Attenuation of Motion }	4,6
Location of Input Motion }	4,6
Sloping Ground Conditions }	4,6
Rocking Effects	4,5,6
Focusing Effects	1,7,8

2. Definitions of site/building subgroups are presented in Table 3.

3. Existing USGS accelerograph at site.

4. Existing accelerograph, owned by other than USGS, at site.

TABLE 3

SITE/BUILDING SUBGROUPS[1]

	Subgroup 1	Subgroup 2	Subgroup 3	Subgroup 4	Subgroup 5
Classification Criteria:					
Building Period:	0.3-1.0 sec.	0.3-1.0 sec.	0.3-1.0 sec.	>1.5 sec.	1.5-2.5 sec.
Location :	Seattle (downtown)	Seattle	Seattle	Seattle	Seattle - Bellevue
Soil Conditions:	Glacial Deposits	Alluvium	Rock	Glacial Deposits	Alluvium
Basement :				Deep	N/A
Ground Surface :	N/A	N/A	N/A	Sloping	N/A
Foundations :				Mat/Footings	Piles
Instruments :	Multiple	Multiple	Single	Multiple	Multiple
Candidate Structures:	Airborne Bldg. Denny Bldg. Newport Lane Federal Office Bldg.[2] Red Lion Arlington North/South	Sears Rainier Cold Storage Boeing Engr. Bldg. King Street Station COE Bldg. Kistler Morse Eldeck Mercer Canal Bldg. Boeing Field Power Plant	Rehab. Ctr. for Blind V.A. Hosp.[3] (30' to Rock)	Columbia Seafirst Center Rainier Tower Gateway Tower Block 5 First Interstate Center Seafirst Fifth Avenue Plaza Seattle Trust Tower Bay Vista Tower Watermark Tower Westin Bldg. Hoge Bldg. 84 Union	World Trade Center (Tacoma) Capitol Ctr. Bldg. (Olympia)

	Subgroup 6	Subgroup 7	Subgroup 8	Subgroup 9	Subgroup 10
Classification Criteria:					
Building Period:	>1.5 sec	0.3-1.0 sec.	0.3-1.0 sec.	N/A	N/A
Location :	Seattle - Bellevue	West Seattle	North Seattle	See below	See below
Soil Conditions:	Glacial Deposits	Glacial Deposits	Glacial Deposits	Glacial Deposits	Glacial Deposits
Basement :	Deep				
Ground Surface :	Level	N/A	N/A	N/A	N/A
Foundations :	Drilled Piers				
Instruments :	Multiple	Single	Single	Single	Single
Candidate Structures:	Two Union Square Westlake Project Crowne Plaza Hotel 4th & Blanchard Bldg. Bellevue Place One-Bellevue Center Rainier Bank Place H.M. Jackson Bldg. Vance Bldg.	West Seattle High School[2]	Ship Canal Ground Sta.[2]	Issaquah - I-90/Overpass[2] Bremerton - Hospital[3] Des Moines - Airport[2] Tacoma - Co.-County Bldg.[2] Tumwater - Seis. Sta.[2] Portland - PSU Cramer Hall[2]	Centralia Snoqualmie Pass (Rock) Port Gamble Port Townsend LaPush (Naval Res. Sta.) Montesano/Satsop[3] Trojan Power Plant[3]

Notes:

1. Buildings within each subgroup have been ranked in descending order of importance in satisfying the classificational criteria.
2. Contains (ground level only) USGS Accelerograph.
3. Contains Accelerograph owned by USGS and VA (Veterans Administration).

Table 4. Priority Ranking.

1 Category	2 Category Value	3 Subdivision	4 Subdivision Value	5 Product (2)x(4)
Vertical Geometry	2	Low-Rise	1	2
		Mid-rise 6-10	4	8
		High-rise	2	4
Lateral	3	Regular	3	9
		Plan Irregular	2	6
		Elevation Irreg.	2	6
		Both Irregular	1	3
Material	3	Steel - BR Frame	1	3
		DMRF	2	6
		EBF	3	9
		Concrete - SW & CIP	2	6
		SW & PC	3	9
		DMRF	3	9
Foundations	3	Spread Footings	1	3
		Piles - all types	2	6
		Caissons, piers	2	6
		Mat	4	12
Age of Building	2	Pre-1937	2	4
		Pre-1967	1	2
		Pre-1987	3	6
		Planning or Const.	5	10
Seismic Experience for building type	1	Frequent prior exper.	1	1
		Some prior record for type	2	2
		Little prior record	5	5
Design Info. & Dwgs. Available	2	Sophisticated	3	6
		Special Conditions	2	4
		Equiv. Lat. Force	1	2

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Table 5. Structure and Characteristics.

Nr.	Name Address	(N.Lat.) W. Long.	Built (Remod)	Nr. Stories	Structural System	K	T Sec.	Foundations Type	Depth	Topog.
01	Arlington N-S. 1023 First Ave.	(47.3619) 122.2007	1901 (1982)	7	Conc.SW+ URM	1.33	0.35	Piles	Shallow	Slope
02	Watermark Tower 1011 First Ave.	(47.3621) 122.2009	1983	23	Dual,RCSW+ RCMRF	0.80	2.3	Piers	Shallow	Slope
03	84 Union Bldg. 84 Union Street	(47.3630) 122.2019	1985	15	Dual, RCSW+ RCMRF	1.00	0.75	Piers	Shallow	Slope
04	Bayvista Tower 2815 Second Ave.	(47.302) 122.2101	1982	20	RCMRF	0.67	2.00	Spread	Shallow	Level.
05	Seafst 5th Ave Plaza 800 Fifth Ave.	(47.3621) 122.1944	1980	42	SBRF+ 25%Ext MF	0.80	4.20	Piers	Deep	Slope
06	4th & Blanchard Bldg 2101 Fourth Avenue	(47.3652) 122.2025	1978	27	Dual 1 wy SMRF 1 wy	0.80 1.00				Level
07	Westlake Project 400 Pine Street	(47.3643) 122.2010	1987	25	SMRF 1 wy EBF 1 wy	0.67 1.00	2.50			Level
08	Two Union Square 600 University St.	(47.3637) 122.1953	1987-8	58	SBF Int 25% Ext FR	1.00	2.90	Piers	Deep	Level
09	King Street Station 303 So. Jackson	(47.3600) 122.1946	1904	3+Tow.	URM,Steel		0.30		Shallow	Level
10	Crowne Plaza Hotel 1113 Sixth Avenue	(47.3629) 122.1951	1980	33	RCDMRF	0.67	3.30	Mat	Shallow	Level
11	Seattle Trust Tower 1000 Second Ave.	(47.3622) 122.2000	1986	44	SMRF Con.Enc.Cols	0.67	4.40	Piers	Shallow	Slope
12	Boeing Engrg Bldg. 7755 E. Marginay Way	(47.3202) 122.1846	1940 (1987)	5	RC SW * added		0.50	Piles	Shallow	Level
13	Denny Building 2200 Sixth Avenue	(47.3703)	1968	11	SMRF	1.00	0.55	Spread	Shallow	Level
14	Newport Lane 3650 131st SE	(47.3445) 122.1020	1987	7	RCMRF	0.67	0.70			
15	Block Five 1201 Third Ave.	(47.3627) 122.2006	1987-8	55	SMRF+	0.67	5.50			Slope

Table 5 (continued)

Nr.	Name Address	(N.Lat.) W. Long.	Built (Remod)	Nr. Stories	Structural System	K	T Sec.	Foundations Type	Depth	Topog.
16	Bellevue Place 104th & 8th NE	(47.3705) 122.1212	1987	24	RCSW+ RCMRF	0.67	2.40			
17	Red Lion 300 112th S.E. Blvu.	(47,3452) 122.1124	1980	10	RCSW	1.33	0.60	Spread	Shallow	Level
18	One Bellevue Center 411 NE 108th. Blvu.	(47.3652)	1981	21	SBF	0.80	2.10	Mat/Spread		Level
19	Rainier Bank Place 108th NE & NE 8th	(47.3701) 122.1145	1986	24	SMRF Space Frm	0.67	2.40	Mat/Spread		Level
20	Kistler Morse 10201 Redmond Willows Road. Redmond	(47.4226)	1983	3	SMRF	1.00	0.15	Spread		Level
21	Eldeck, 1 & 2 22000 Bothell Wy S.E.	(47.4833) 122.1330	1980 (1986)	2	Mas SW SMRF	1.33 0.67	0.10			
22	Rainier Cold Storage Terminal 25 E,Marginal Wy & Spokane.	(47.3419) 122.2002	1914	7	Flat Slab	1.00	0.70	Piles	Shallow	Level
23	Westin Building 2101 Sixth Ave.	(47.3655) 122.2013	1977	34	SMRF	0.67	3.40	Spread	Shallow	Level
24	Sears Roebuck 2465 Utah Ave.	(47.3451) 122.2003	1912 (1974)	8	RC FlatSl		0.80	Piles	Shallow	Level
25	Mercer Canal Bldg 1300 114th S.E.Blvu.	(47.3557) 122.1120	1982	3	SMRF&BF	1.00	0.15	Piles (40')	Shallow	Level
26	Gateway Tower 5th Ave Columbia	(47.3619) 122.1941	Future	50	SBF	0.80	3.6 NS	Mat		Sloping
27	Airborne Express 3101 Western Ave.	(47.3703) 122.2120	1984	8	SEBF	1.00	0.40	Spread		Sloping
28	Henry M Jackson Bldg 915 Second Ave.	(47.3618) 122.2004	1973	30	SDMRF	0.67	3.00	Piers	Deep	Sloping
29	Vance Building 1402 Third Ave.	(47.3635) 122.2008	1929	14	RCMRF		1.40	Spread	Shallow	Level
30	Veterans Admin. Hosp. 1660 S. Columbian Way	(47.3347) 122.1830	1948 (1987)	7? 7?	RC Box SMRF	1.33 0.67		Spread Spread	Shallow Shallow	Sloping Sloping

Table 5 (continued)

Nr.	Name Address	(N.Lat.) W. Long.	Built (Remod)	Nr. Stories	Structural System	K	T Sec.	Foundations Type	 Depth	Topog.
31	Hoge Building 705 Second Ave.	(47.3612) 122.1937	1910	17	Stl Frame		1.70	Spread	?	Sloping
32	1st Interstate Tower 999 Third Ave,	(47.3622) 122.1955	1978	34	SBF	1.00	?	Spread	?	Sloping
33	Power Plant (Museum) Boeing Field - North.	(47.3233) 122.1900	1906	4	RCBox	1.33	0.40	?		Level
34	Rehab Ctr for the Blind 35th So. & So. Alaska	(47.3308) 122.1716	1963	2	SMRF	1.00	0.10	Rock	Shallow	Sloping
35	West Seattle H.S. California Ave & Stevens	(47.3438) 122.2302	1920's?	2	RCMRF	1.00	0.20	Spread	Shallow	Level

Tacoma Group

Nr.	Name Address	(N.Lat.) W. Long.	Built (Remod)	Nr. Stories	Structural System	K	T Sec.	Foundations Type	 Depth	Topog.
101	Zarelli Condominium 9 N. E Street, Tac.	(47.1556) 122.2645	1972	16	CMUSW	1.33	1.00	Mat/Auger	Shallow	Ridge
102	St. Joseph Hospital 1718 S. I Street Tac.	(47.1415) 122.2640	1972	13	RCMRF	1.33	1.00	Mat/spread	Shallow	Ridge
103	Frank Russell Bldg. 909 A St. Tac.	(47.1519) 122.2609	1987	14	SDMRF	0.67	0.75	Caissons	Shallow	Ridge
104	Pierce Cty-City Bldg 930 Tacoma Ave So.	(47.1514) 122.2639	1954	11	SMRF	1.00	1.10	Spread	Deep	Slope
105	1st Interstate Plaza 1201 Pacific Ave,	(47.1509) 122.2610	1968	22	RCDMRF	0.67Tower 1.00Base		Mat	Deep	Ridge
106	Tacoma Municipal Bldg. 747 Market St.	(47.1522) 122.2626	1930	17	RCMRF	1.00		Spread	Shallow	Slope
107	Russell Garage 110 So. 10th Tac.	(47.1515) 122.2611	1987	14	RCSW/BW	1.00	?	Spread	Shallow	Level
108	Sealand CFS Bldg. Port of Tacoma	(47.1534) 122.2457	1985	1	TILT-UP	1.33	0.08	Spread	Shallow	Level

Table 5 (continued)

Nr.	Name Address	(N.Lat.) W. Long.	Built (Remod)	Nr. Stories	Structural System	K	T Sec.	Foundations Type	Depth	Topog.
109	Marshall Ave. Whse. Port of Tacoma	(47.1510) 122,2317	1982	1	RCSW	1.33	0.08	Spread	Shallow	Level
110	W.R. Rust Building 950 Pacific Ave.	(47.1515) 122.2617	1920	12	SMRF	1.00	0.70	Spread	Deep	Level
111	World Trade Center Port of Tacoma Road	(47.1542) 122.2314	1984	5	RCMRF	0.67	0.90	Piles (battered)	58'Ave	Level
112	Madigan Army Hospital Fort Lewis, Pierce Cty.		1991	9	RCDMRF	0.67	?	Spread	Deep	Level
113	Transpacific Bldg. Fife, WA.	(47.1432) 122.2227	1985	4	SMRF	0.67	0.17	Piles/conc.		Level
114	Transpacific Whse Fife, WA.	(47.1420) 122.2230	1985	- 1	RCSW	1.33	0.06	Spread	Shallow	Level
Olympia Group										
201	Capitol Center Buildg. 410 W. 5th Ave. Olympia	(47.2140) 122.5414	1972	16	SBF RCSW	1.33	0.45 0.70	Piles	?	Slope
202	Capitol Lake Tower 1910 Evergreen Pk, Oly.	(47.1053) 122.5452	1967	10	RCSW Lift-slab	0.67	0.60 0.75	Spread		Slope
203	St. Peters' Hospital Lilly Road, Olympia	(47.0255) 122.5003	1972	11	RCSW RCMRF	0.67	0.45 0.80	Spread	?	Level
204	Governor House 602 Capitol Blvd.	(47.0229) 122.5401	1964	8	CMUSW	1.33	0.45	Piles	Shallow	Slope
205	Highway License Bldg. Olympia.	(47.0223)	1960	8	RCSW	1.00	0.40	Piles	Shallow	Level
Whidbey Island										
301	Maintenance Hangar Whidbey Is. NAS	(	1988	3	SBF	1.00	0.15	Piles Auger-cast	Shallow	Level

Table 5 (continued)

Nr.	Name Address	(N.Lat.) W. Long.	Built (Remod)	Nr. Stories	Structural System	K	T Sec.	Foundations Type	Depth	Topog.
Everett Group										
401	General Tel. Bldg 4th & Colby, Ev.	(47.2119) 122.2022	1986	5	SBF	1.00	0.25	Spread	?	Slope
402	Snohomish Cty Cths. Wetmore & Wall Ev.	(	1965	5	SMRF RCSW	1.33	0.25	Spread	Shallow	Level
Port Angeles Group										
501	Olympic Mem. Hosp. 939 Caroline, Pt.A.		1951	3	RCSW/ CMU Infill	1.33	0.15	Spread	Shallow	Level
502	Elks Building 1st & Front, Pt.A.		1928	5	RCSW/ Masonry	1.33	0.25	Spread	?	Slope
503	Clallam Cty. Cthse. 223 E. 4th, Pt. A.		1915	3	RCSW Masonry	1.33	0.15	Spread	?	Level
504	ITT Rayonier Ennis Creek, Pt.A.		1975	11	SBF		1.10	Piles/ steel	?	Level
505	Pt. Townsend Paper Water St. Pt. Towns,		1975	16	SBF/		1.60	Piling	?	Level

Bremerton

601	USN Hospital Bremerton	No Ranking	- Some existing instruments.
602	Water Pit Facility PS Naval Shipyard	No Ranking	- Some existing instruments.

Table 5 (continued)

Nr.	Name Address	(N.Lat.) W. Long.	Built (Remod)	Nr. Stories	Structural System	K	T Sec.	Foundations Type	Depth	Topog.
Bellingham Group										
701	Whatcom Cty Cthse Bellingham			5	RCMRF/ RCSW	1.33	0.5	?		Level
702	Lincoln Square 409 York		1970	10	RCBox/ BrgWall	1.33		Piles	Shallow	Bluff edge.
703	Leopold Hotel 1224 Cornwall		1920's	11	SFRM/ Mas.Infill		0.50 0.75	Spread (rock)	Shallow	Level
704	Bond Hall Western Wa Univ		1960's	4	RCBox/ Mas.Infill	1.00	0.17 0.28	Piles (peat)	?	?

MRF = Moment Resisting Frame
DMRF = Ductile Moment-resisting Frame
RC = Reinforced Concrete
S = Steel
BF = Braced Frame
RCSW = Reinforced Conc. Shear Walls
BW = Bearing Wall

Unlisted structures of earth sciences interest:

Federal Office Building 909-1st Ave. Seattle.
COE Building - 4725 E. Marginal Way, Seattle.
Columbia Seafirst Center, Seattle.
Rainier Tower.

<u>Table 6. Structural Group Priority Evaluation and Ranking</u>

Nr	Name Address	Geometry Vert	 Lat	Mat	Fdn	Age	Seis Exp	Des Dwgs	SUM	Comm. Subject.	Geology A,G,R	Revised Sum	Priority Global	 Local
01	Arlington N-S 1023 First Ave.	8	9	6	6	4	5	4	42	-13	A	29	44	23S
02	Watermark Tower 1011 First Ave.	4	6	6	6	6	1	2	31	--	A	31	40	20S
03	84 Union Building 84 Union St.	4	9	6	3	6	1	2	31	--	G	31	40	21S
04	Bay Vista Tower 2815 Second Ave.	4	6	9	3	6	1	2	31	--	G	31	40	22S
05	Seafst 5th Ave. Plaza 800 Fifth Ave.	4	9	3	6	6	1	6	35	--	G	35	23	15S
06	4th & Blanchard Bldg 2101 Fourth Ave.	4	6	3	3	6	1	2	25	--	G	25	49	32S
07	Westlake Project 400 Pine St.	4	6	9	3	10	5	2	39	--	G	39	17	11S
08	Two Union Square 600 University Street	4	9	9	6	10	5	6	49	--	G	49	10	7S
09	King Street Station 303 So. Jackson St.	2	6	6	6	4	1	2	27	-13	A	14	60	33S
10	Crowne Plaza Hotel 1113 Sixth Ave.	4	9	9	12	6	1	2	43	+13	G	56	1	1S
11	Seattle Trust Tower 1000 Second Avenue	4	3	6	3	6	1	2	25	--	G	25	53	29S
12	Boeing Engrg Bldg 7755 E. Marginal Wy S.	2	6	6	6	2	1	2	25	--	A	25	53	30S
13	Denny Building 2200 Sixth Ave.	8	9	3	3	6	1	2	32	--	G	32	32	20S
14	Newport Lane 3650 131st S.E.	8	9	9	3	6	1	2	38	--	G	38	18	12S
15	Block 5 1201 Third Ave.	4	9	6	3	10	1	6	39	+13	G	52	7	4S

Table 6. (continued)

Nr	Name Address	Geometry Vert	Geometry Lat	Mat	Fdn	Age	Seis Exp	Des Dwgs	SUM	Comm. Subjctv	Geology A,G,R	Revised Sum.	Priority Global	Priority Local.
16	Bellevue Place 104th NE & 8th. Blvu.	4	9	9	3	10	1	2	38	--	G	38	18	13S
17	Red Lion 300 112th S.E. Blvu.	8	9	6	3	6	1	2	35	--	G	35	23	16S
18	One Bellevue Ctr. 411 NE 108th Blvu	4	6	3	3	6	1	2	25	--		25	53	31S
19	Rainier Bank Place 108th NE & NE 8th Blvu.	4	6	6	3	6	1	2	28	--		28	47	24S
20	Kistler Morse 10201 Redmond-Willows Rd. Redmond.	2	9	3	3	6	1	2	26	--		26	48	27S
21	Eldeck 1,2 22000 Bothell Wy SE Bothell	2	9	9	3	6	1	2	32	--		32	32	18S
22	Rainier Cold Storage Terminal 25. E. Marginal Wy & Spokane	8	9	9	6	4	2	2	40	+13	A	53	4	20S
23	Westin Building 2101 Sixth Ave.	4	9	3	3	6	1	2	28	+13	G	41	15	9S
24	Sears, Roebuck 2465 Utah Ave.	2	6	6	6	4	1	2	27	+13	A	40	16	17S
25	Mercer Canal Bldg. 1300 114th Ave.SE Blvu	2	9	6	6	6	1	2	32	--	A	32	32	19S
26	Gateway Tower 5th Ave.& Columbia	4	9	6	6	10	1	6	42	--	G	42	14	8S
27	Airborne Express 3101 Western Ave.	8	6	9	3	6	2	6	40	+13	G	53	4	3S
28	Henry M. Jackson Bldg 915 Second Ave.	4	9	6	6	6	2	6	39	+13	G	52	7	5S
29	Vance Building 1402 Third Ave.	4	6	6	3	4	1	2	26	--	G	26	48	26S
30	Veterans Admin. Hosp. 1660 S. Columbian Wy.	8	6	6	3	6	2	6	37	+13	G	50	9	6S

Table 6. (continued)

Nr	Name Address	Geometry Vert	 Lat	Mat	Fdn	Age	Seis Exp	Des Dwgs	SUM	Comm. Subjctv	Geology A,G,R	Revised Sum.	Priority Global	 Local.
31	Hoge Building 705 Second Ave.	4	9	3	3	4	1	2	26	--	G	26	48	28S
32	First Interstate Tower 999 Third Ave.	4	6	3	6	6	5	2	32	--	G	32	32	17S
33	Power Plant (Museum) Boeing Field.	2	9	6	6	4	1	0	28	--	A	28	47	25S
34	Rehab. Ctr. for Blind 35 So & So Alaska	2	6	6	3	2	2	2	25	+13	R	38	18	14S
35	West Seattle High Sch.* California & Stevens.	2	9	6	3	4	2	0	26	--	G	26	48	29S
Tacoma Group														
101	Zarelli Condominium 9 No. E St. Tacoma	4	9	9	12	6	2	2	44	--	G	44	12	4TAC
102	St. Joseph's Hospital 1718 S. I St. Tacoma	4	3	6	12	6	5	6	42	-13	G	29	44	11T
103	Frank Russell Bldg. 909 So. A St. Tacoma	4	6	6	6	10	5	6	43	--		43	13	5T
104	Pierce Cty-City Bldg 930 Tacoma Ave. S.	4	9	3	3	2	1	2	24	--		24	55	13T
105	1st Interstate Plaza So. 12th & Pacific, Tac.	4	9	8	12	6	1	0	40	+13	A	53	4	3T
106	Tacoma Municipal Bldg. 747 Market St. Tacoma	4	3	6	3	4	1	2	23	--	G	23	56	14T
107	Russell Garage 110 S. 10th Tacoma.	8	9	6	3	8	1	2	37	--		37	22	6T

Table 6. (continued)

Nr	Name Address	Geometry Vert	 Lat	Mat	Fdn	Age	Seis Exp	Des Dwgs	SUM	Comm. Subjctv	Geology A,G,R	Revised Sum.	Priority Global	 Local.
108	SeaLand CPS Bldg. Port of Tacoma	2	9	9	3	6	1	2	32	--	A	32	33	7T
109	Marshall Ave. Warehouse Port of Tacoma	2	9	9	3	6	1	2	32	--	A	32	33	8T
110	W. E. Rust Building 950 Pacific Ave. Tacoma.	4	9	3	3	4	1	2	26	--	G	26	48	12T
111	World Trade Center Port of Tacoma	8	9	9	6	6	1	2	41	+13	A	54	3	2T
112	Madigan Army Hospital Ft. Lewis, Pierce Cty.	4	9	6	3	10	5	6	43	+13	G	56	1	1T
113	Transpacific Building Fife, WA	2	6	6	6	6	1	2	29	--	A	29	44	10T
114	Transpacific Warehse. Fife, WA.	2	9	9	3	6	1	2	32	--	A	32	33	9T
Olympia Group														
201	Capitol Center Buildg. 410 W. 5th Ave, Olympia	8	9	6	6	2	1	2	34	+13	A	47	11	1-0
202	Capitol Lake Tower 1910 Evergreen Pk. Oly.	8	9	6	3	6	1	2	35	--	G	35	23	3-0
203	St. Peters Hospital Lilly Road, Olympia	4	9	9	3	6	1	2	34	--		34	29	4-0
204	Governor House 602 Capitol Blvd.Oly.	8	6	9	6	6	1	2	38	--		38	18	2-0
205	Highway License Bldg. Olympia.	8	9	6	6	2	1	2	34	--	G	34	29	5-0

Table 6. (continued)

Nr	Name Address	Geometry Vert	Geometry Lat	Mat	Fdn	Age	Seis Exp	Des Dwgs	SUM	Comm. Subjctv	Geology A,G,R	Revised Sum.	Priority Global	Priority Local.
301	Maintenance Hangar Whidbey Is. NAS	2	6	3	6	10	1	6	34	--		34	29	--
Everett Group														
401	General Tel. Bldg. 4th & Colby, Everett.	2	9	3	3	6	1	6	30	--	G	30	43	--
402	Snohomish Cty Courths.* Wetmore & Wall, Everett.	8	9	3	3	6	2	2	33	--	G	33	37	
Port Angeles Group														
501	Olympic Mem. Hospital 939 Caroline, Pt. Ang.	2	6	6	2	3	1	2	22	--	G	22	58	3PA
502	Elks Building 1st & Front, Pt. Angls.	2	6	6	3	2	1	2	22	--	G	22	58	4PA
503	Clallam Cty Courthse. 223 E 4th Pt. Angeles.	2	9	3	3	4	1	0	22	--	G	22	58	5PA
504	ITT Rayonier - Indust. Ennis Creek Pt. Angeles	4	9	6	6	6	5	2	35	--	A	35	23	1PA
505	Pt. Townsend Paper Co Water St. Pt.Townsend.	4	9	3	6	6	5	2	35	--	A	35	23	2PA
Bremerton														
601	USN Hospital * Bremerton												No Ranking.	
602	Water Pit Facility * P.S. Naval Shipyard												No Ranking.	

Table 6. (continued)

Nr	Name Address	Geometry Vert	Lat	Mat	Fdn	Age	Seis Exp	Des Dwgs	SUM	Comm. Subjctv	Geology A,G,R	Revised Sum.	Priority Global	Local.
Bellingham Group														
701	Whatcom Cty.Courthse. Bellingham.	8	9	6	3	2	1	2	31	--		31	39	2BEL
702	Lincoln Square 409 York Bellingham	8	6	6	6	6	1	2	35	--		35	23	1B
703	Leopold Hotel 1224 Cornwall, Bellhm.	8	9	3	3	4	2	2	31	--	R	31	39	3B
704	Bond Hall Western Wa. Univ.	2	6	6	6	2	1	2	25	--	G	25	53	4B

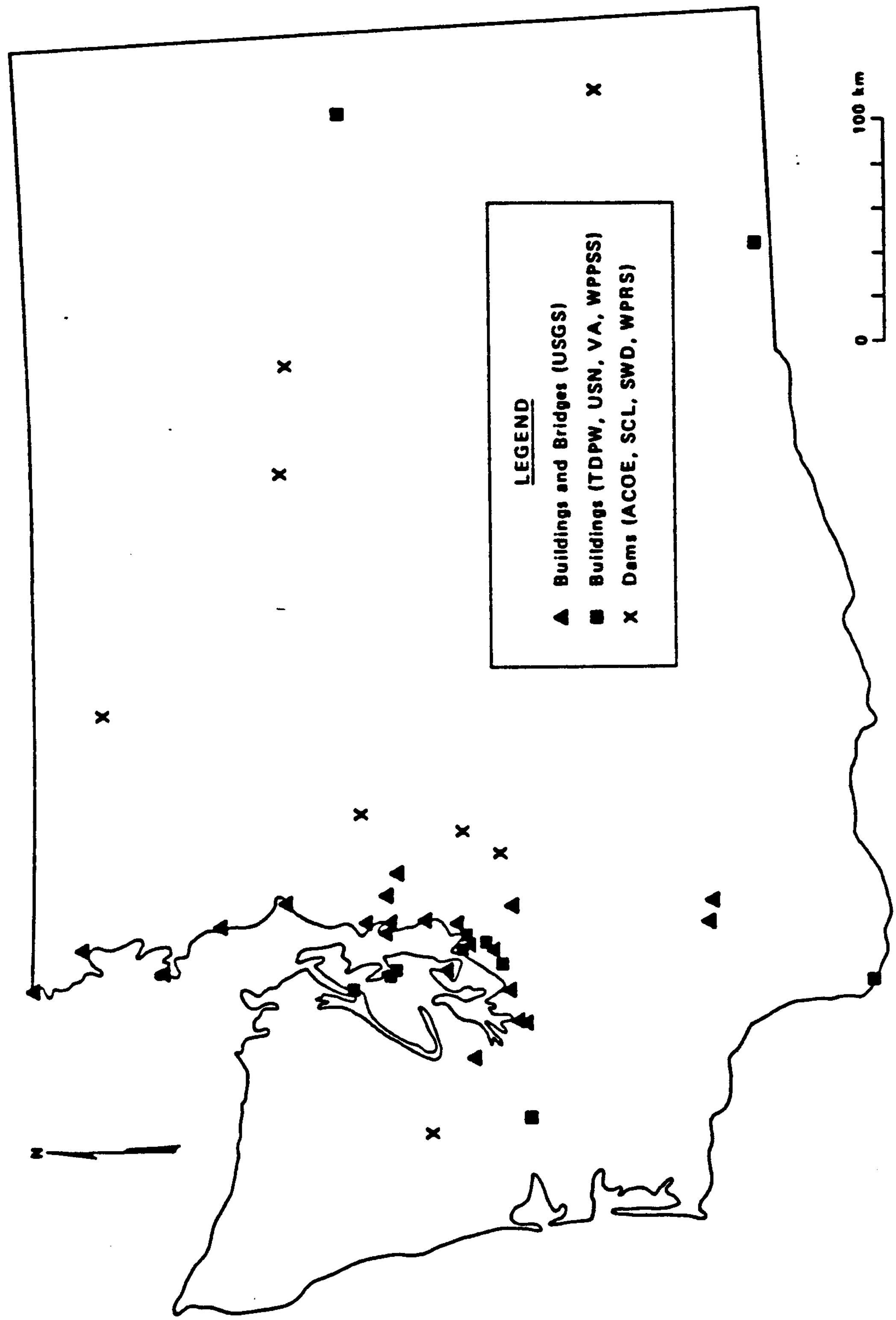
* Some Instrumentation exists.

Table 7. Recommended Instrumentation Sites in Seattle/Bellevue[1,2].

Sugroup 1	*Subgroup 2*	*Subgroup 4*
Airborne Bldg.	Rainer Cold Storage	Block 5
Newport Lane	Sears	Gateway Tower
- - -	- - -	- - -
Red Lion	Eldeck	Westin Bldg.
Denny Bldg.	Mercer Canal Bldg.	Seafirst 5th Ave. Plaza
Old Federal Office Bldg.	Boeing Field Pwr. Plant	First Interstate Center
Arlington North/South	Kirstler Morse	Bay Vista Tower
	Boeing Engr. Bldg.	Watermark Tower
	King St. Station	84 Union
		Seattle Trust Tower

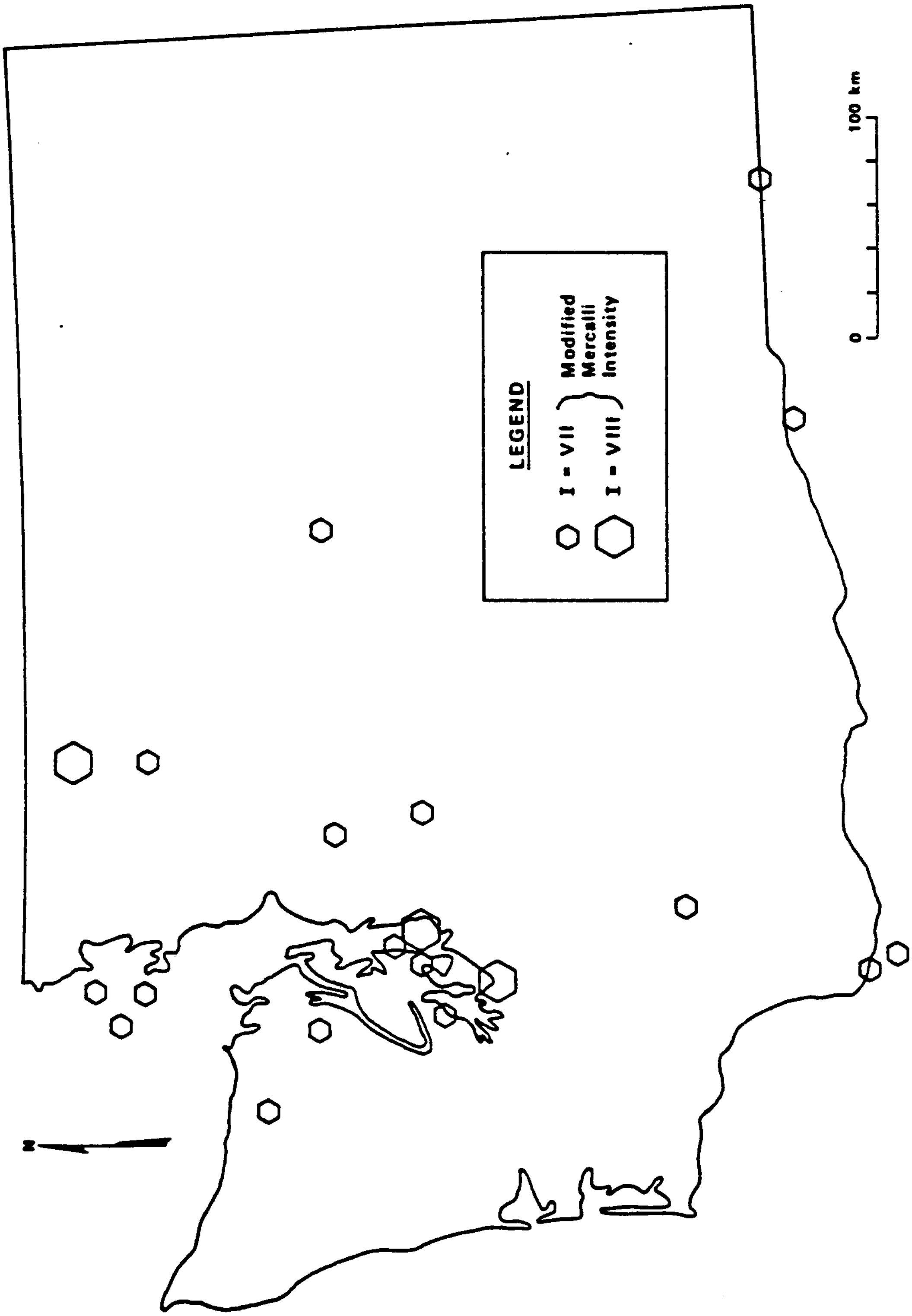
Subgroup 5	*Subgroup 6*
World Trade Center (Tacoma)	Crowne Plaza Hotel
Capitol Center Bldg. (Olympic)	H.M. Jackson Bldg.
	- - -
	2 Union Square
	Westlake Project
	Bellevue Place
	Rainier Bank Place
	Vance Bldg.
	4th & Blanchard Bldg.

1. Buildings have been arranged within each subgroup in descending order of importance for instrumentation based upon both geotechnical and structural criteria.
2. It is recommended to instrument one building from each subgroup with multiple instruments. Instrumentation should be installed sequentially, according to subgroup number.
3. Building subgroups correspond to those on Tables 2 and 3.
4. Subgroup 3, 7, and 8 are for single instruments and not included in this table.



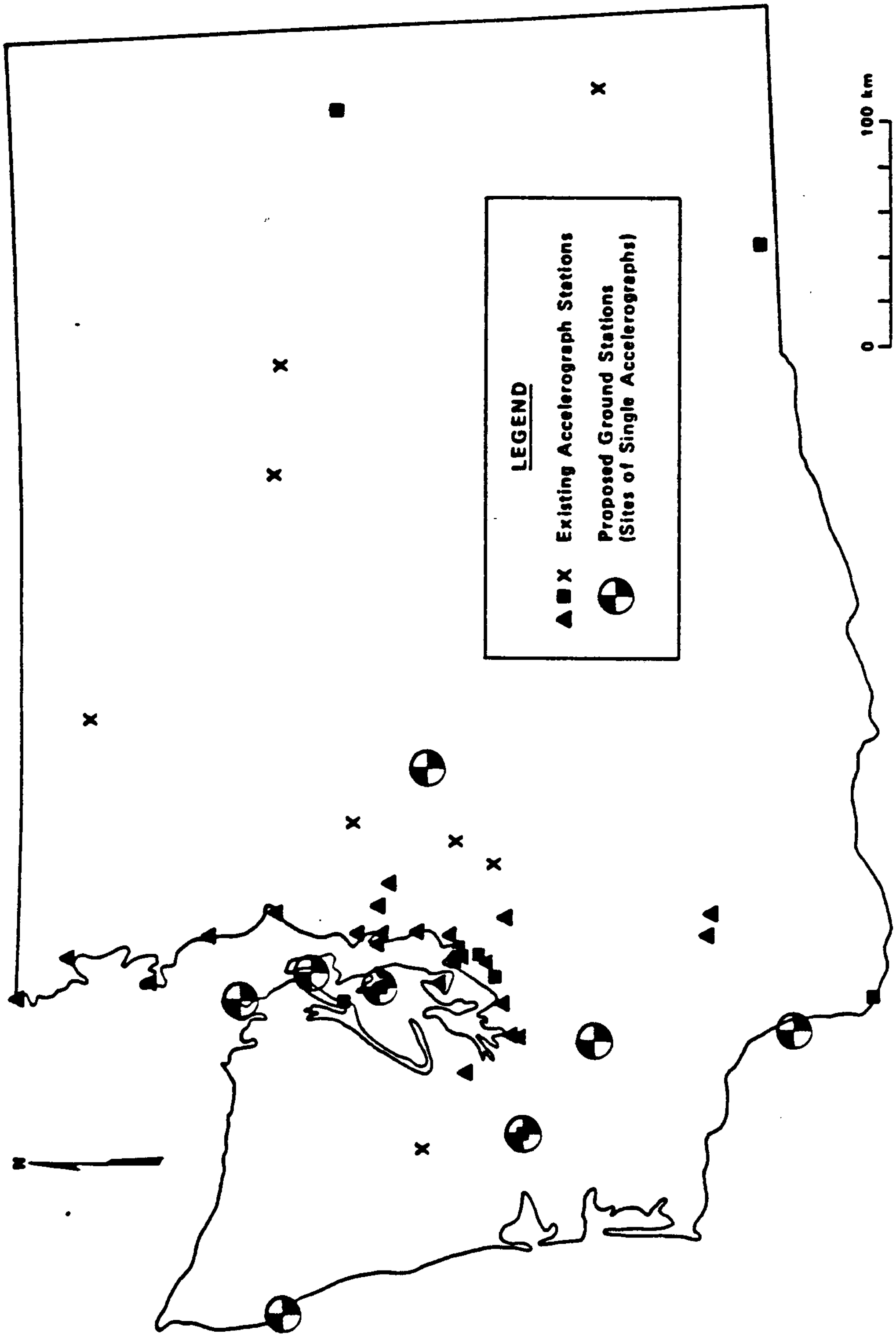
EXISTING ACCELEROGRAPH
STATIONS

FIG. 1



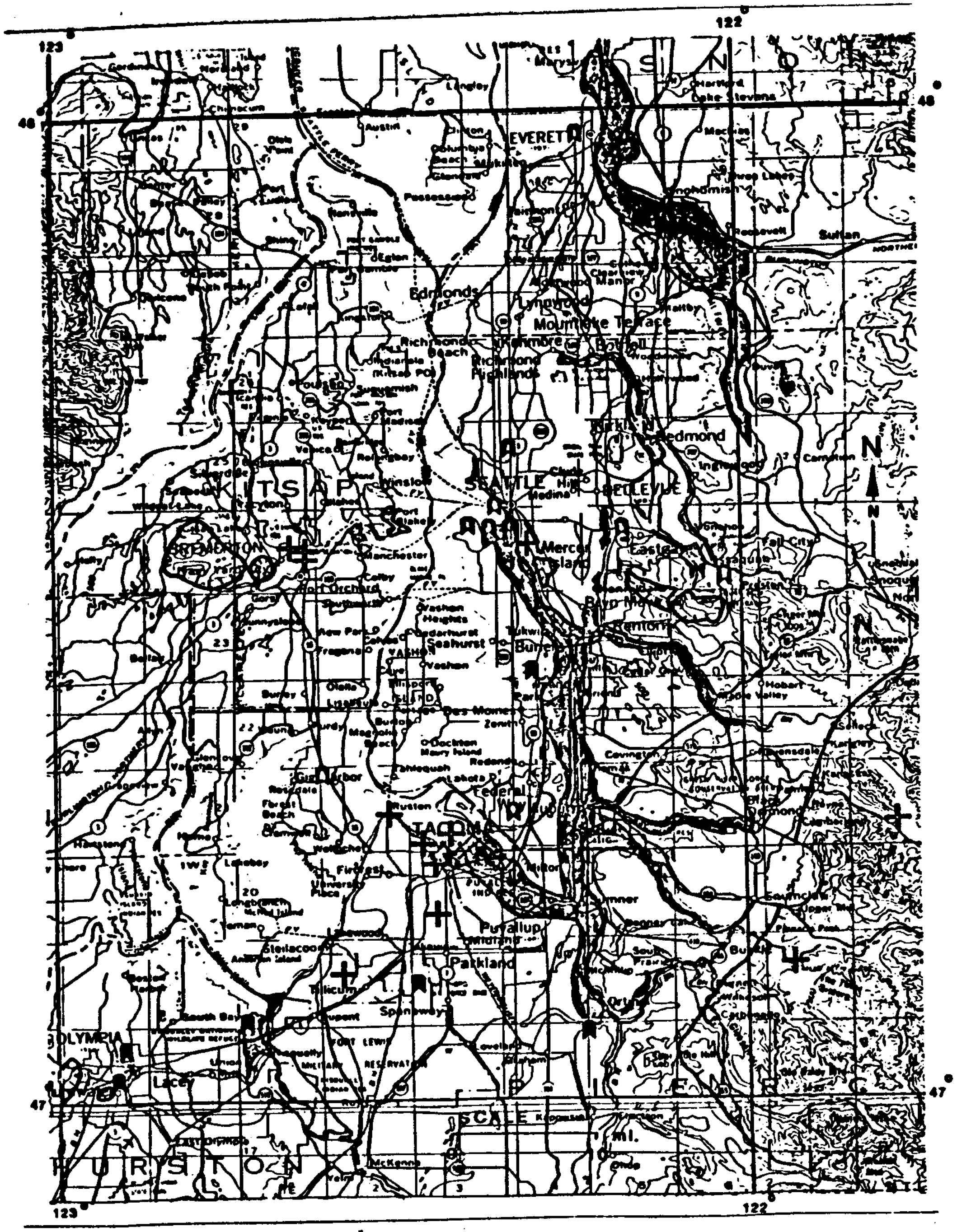
HISTORICAL SEISMICITY
1872 - 1988

FIG. 2



PROPOSED GROUND
STATIONS

FIG. 3



SCALE: 1 : 500,000

LEGEND

(solid shading)	ALLUVIUM
(blank)	GLACIAL DEPOSITS
(patterned)	ROCK

EXISTING ACCELEROGRAPH STATIONS

- ⬤ Buildings and bridges (U.S.G.S.)
- + Buildings (others)

NOTES:
1. Map indicates generalized surface geology.
2. Base map from State of Washington topographic map scale 1 : 500,000, 500 foot contour interval: U.S. Geological Survey.
3. See text for reference on geology.

GENERALIZED SOIL CONDITIONS

FIG. 4

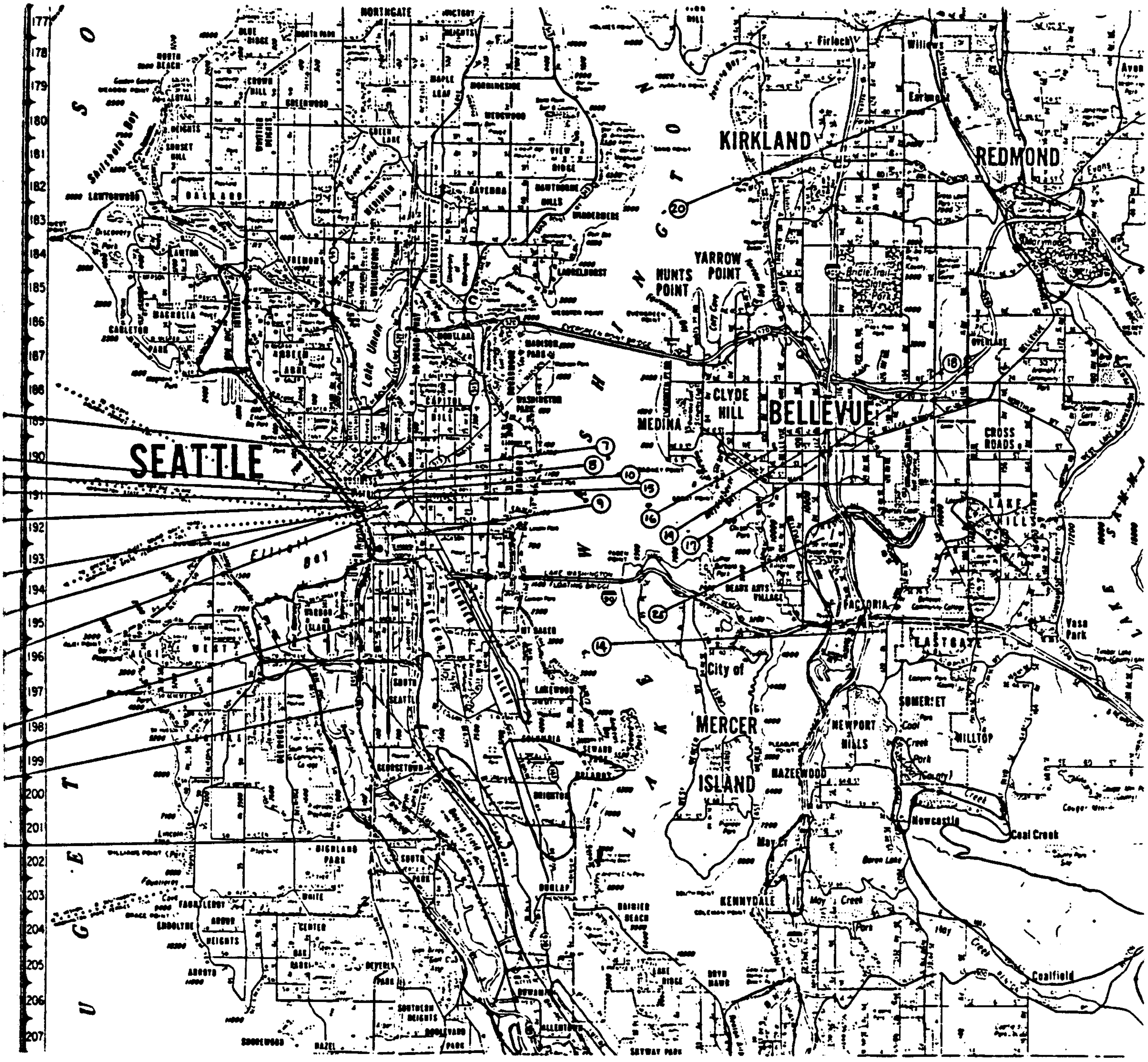


Fig. 5 Prospective Sites in Seattle & Bellevue