UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

REPORT ON RECOMMENDED LIST OF STRUCTURES FOR SEISMIC INSTRUMENTATION IN THE SAN FRANCISCO BAY REGION

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PREFACE

The moderate sized Imperial Valley earthquake of October 15, 1979 represents a significant milestone in seismic engineering, in the sense that the shaking-induced failure of a modern engineered structure was accurately documented for the first time. Should a major earthquake recur along the San Andreas fault in either central or southern California, several typical structures could be expected to yield data of similar significance. However, very few non-typical structures are presently instrumented in the United States, and should such an event occur, an opportunity to collect valuable information on many major engineered structures of substantial societal significance would probably not recur for 50-100 years. Considering the significance of this issue for densely urbanized areas such as San Francisco and Los Angeles, an advisory committee was convened under the chairmanship of Dr. Celebi to first develop a set of recommendations regarding the instrumentation of non-typical structures in the San Francisco Bay Region. This report signifies the enthusiastic and dedicated efforts of the committee. The contributions of each of the members, and especially the chairman, at repeated meetings with no motivation other than professional dedication are most certainly appreciated, quite commendable, and no doubt a contribution in the long term to improved earthquake resistant design.

Roger D. Borcherdt

I. INTRODUCTION

Earthquake hazard mitigation programs initiated by various institutions aim at safeguarding life and property. Some of the hazard mitigation programs are quite diversified, ranging from risk analysis, emergency preparedness and response in case of emergencies, to seismic code development. Seismic codes aim at reducing earthquake damage and are based on the understanding of structural behavior under strong ground motion. This understanding has developed over the years from early structural strong-motion instrumentation, post-earthquake studies, laboratory testing and theoretical modeling. Theoretical and experimental research methodologies have developed to a level where static or dynamic analysis methods can be utilized with considerable confidence, to estimate the response of structural systems in the linear elastic range. Although methods do exist for estimating non-linear response of structures, including the response of damaged structures, these methods have not been verified, primarily because of the scarcity of available data. Therefore, it is extremely essential to acquire structural response data to confirm and/or further develop methodologies used for analysis and design of earthquake resistant structural systems. This objective can best be realized by selectively instrumenting structural systems to acquire strong ground motion data and measurement of responses of structural systems (buildings, components, lifeline structures, etc.) to the strong ground motion.

Along with various programs aimed at developing free-field strong motion arrays and networks, other programs pertaining only to the instrumentation of structural systems are being carefully implemented within the resources allocated by federal, state, local, and private agencies. A summary of existing instrumentation programs is provided in Appendix A.

The federal agencies participating in instrumentation of structures are: Army Corps of Engineers (ACOE), U.S. Geological Survey (USGS), U.S. Bureau of Reclamation (USBR), Veterans Administration (VA), and Federal Highway Administration (FHWA). The programs being implemented by federal agencies are coordinated by USGS.

As seen by the statistical tables provided in Appendix A, in the State of California, the most extensive instrumentation program is being conducted by the California Division of Mines and Geology (CDMG). This program is being complemented by the USGS program. However, the CDMG and the USGS programs for instrumentation of structures within the State of California have distinct objectives. The CDMG program is required by law to instrument typical buildings and structural systems. On the other hand, the USGS structural instrumentation program concentrates on research studies of non-typical structures of special engineering interest. Typical structures that are not thoroughly instrumented by other programs are also considered. The USGS structural program is in addition to the large USGS permanent network of ground stations.

It is important to note that instrumentation programs require considerable resources for planning and engineering, purchasing of equipment, electrical installation, periodic maintenance, documentation, and data processing. Therefore, it is doubly important to prevent duplication of efforts by providing exchange of information. Ultimately, both programs are serving to mitigate earthquake hazards.

A. Objectives of Instrumentation Programs

The main objective of any instrumentation program for structural systems is to improve our understanding of the behavior and potential for damage of structures under seismic loading. As a result, one may expect design and construction practices to be modified in the long term to minimize future earthquake damage.

If such a goal is to be attained, an instrumentation program should provide enough information to reconstruct the time dependent response of a structure in enough detail to compare it with the response provided by mathematical models and to correlate it if possible with the damage experienced in the same structure. In addition, the nearby free-field, or at least ground level, time history should also be known to quantify some of the soil-structure interaction characteristics.

To reiterate, it is expected that a well-instrumented structure for which a complete set of recordings has been obtained would provide useful information to:

- check the appropriateness of the dynamic model (both lumped mass and finite element) in the elastic range,

- determine the importance of non-linear behavior on the overall and local response of the structure,
- follow up the spreading non-linear behavior throughout the structure as the response increases and the effect of the non-linear behavior on frequency and damping,
- correlate the damage with inelastic behavior,
- determine ground motion parameters that correlate well with building response damage, and
- make recommendations eventually to improve seismic codes.

Various codes in effect in the United States, whether nationwide or local, recommend different quantities and schemes of instrumentation. For example the Uniform Building Code (1) recommends for Seismic Zones 3 and 4, a minimum of three accelerographs be placed in every building over six stories in height with an aggregate floor area of 60,000 square feet or more. The City of Los Angeles adopted the above recommendation in 1966 but in 1983 revised this requirement to only one accelerograph.

Experiences from past earthquakes show that the instrumentation guidelines given by the UBC code, for example, do not provide sufficient data to perform meaningful model verifications. As an example, three horizontal accelerometers are required to define the horizontal motion of a floor (two translation and torsion). Rojahn and Matthiesen (2) conclude that since the predominant response of a building can be described by the participation of the first four modes of each set of modes (two translation and torsion), a minimum of twelve accelerometers would be necessary to capture these modes for a high-rise. If vertical motion and rocking is expected to be significant and need be recorded, an additional minimum of three vertical accelerometers is required at the basement level. It is also important that high precision record synchronization be available within a structure if the response time histories are to be used together to reconstruct the overall behavior of the structure. Rojahn and Raggett (3) have provided some additional guidelines for instrumentation of bridges, and instrumentation guidelines of earth dams has been addressed by Fedock (4).

B. Objectives of the Advisory Committee

It is somewhat redundant to repeat here that the San Francisco Bay Area is geographically located in proximity to three world famous active faults (San Andreas, Hayward, and Calaveras), and many studies indicate that an earthquake of large magnitude may be expected to occur along one of these faults in the not too distant future. Accordingly, an important opportunity for the acquisition of data is present but as will be apparent from later discussions, there are not many thoroughly instrumented structures within the San Francisco Bay Area. Figure 1 illustrates the current level of instrumentation in the Bay Area. Therefore, the U.S. Geological Survey's San Francisco Bay Area Instrumentation Advisory Committee was slated in April 1983 to:

- look into the status quo of existing instrumentation efforts with the objective of complementing them as needed,
- develop a list of structures in the San Francisco Bay Area within the objectives of the USGS program,
- develop priorities for the list of structures,
- coordinate with other programs and organizations the effort on instrumentation of structures,
- communicate to public and private sectors the importance of programs for instrumentation of buildings,
- extend the scheme to other regions as required,
- enhance the maintenance of instruments in a coordinated way, and
- provide guidance and develop methodologies related to instrumentation of structures.

C. Scope

The scope of this report is to present an initial product of the efforts of the Advisory Committee. The efforts of the committee at this stage has been primarily devoted to development of a prioritized list of structures that have been selected for recommending to the USGS for instrumentation. No additional conclusions will be reported herein.

II. SELECTION PROCESS FOR STRUCTURES

A. Introduction

The primary factor in selecting structures for instrumentation within the USGS program has been identifying the structures that are of engineering interest and that, while not typical, represent systems and materials that are likely to be repeated. Structures that can be labelled as "typical" are not included because the State of California program administered by CDMG is responsible for their instrumentation. CDMG aims to instrument in total 400 buildings, 30 dams, 40 transportation structures, and 25 water and power facilities (5).

The structures in Table 1 constitute the selected structures for instrumentation within the USGS program. A separate process was followed for dams although they are also entered in Table 1.

Two basic specific issues each with different aspects have been used in the final consideration of buildings for selection for instrumentation:

- structural behavior, and
- estimate of the expected value for potential earthquake risk at the site in the next 30 years.

Table 1 has been derived from Tables 2 and 3. Development of Tables 2 and 3 are explained next.

B. Structural Parameters

The following parameters and weighting factors for buildings have been used (the weighting factors are shown in column 1 of Table 2):

Material — Buildings constructed of pre-cast concrete, or using tilt-up concrete construction were deemed of especial interest because of the large number of such buildings and concern about their seismic performance.

Structural System — Buildings using non-ductile frames (typically concrete), eccentric or concentric braced frames, of wide span, or other unusual construction were deemed of special interest. Again, this is based on concern for the structural performance of their systems or their prevalence of use. An example of unusual construction is that of suspended multi-story structures of which a number of examples exist in the Bay Area.

Geometry — Buildings of irregular geometry were deemed of special interest in view of their prevalence and considerable uncertainty as to their performance. Building height, though not explicitly noted was given significance in final rating.

Discontinuity — Buildings may be of regular geometry but suffer from structural discontinuity as a result of detailed architectural and structural configuration. Three classes are singled out as being of special interest: 'soft stories,' perimeter variations (such as open store front buildings), and buildings with large setbacks in elevation.

Age — Buildings constructed before the advent of seismic codes in California - generally taken as about 1935 - are deemed of special interest.

All of these issues were considered in allotting a weighting factor on a scale of 0-3. These weighting factors are entered into column 1 of Table 2. Details of the general approach used in assigning weighting factors for buildings are provided in Tables B-1 and B-2 of Appendix B.

The extent to which specific buildings illustrate the above characteristics was based on knowledge and judgment of particular buildings. The Advisory Committee does not claim the list to be exhaustive - i.e., no claim is made that all appropriate buildings are included - but sufficiently representative to fulfill the mandate of the committee.

The criteria used for bridges, tunnels, and overpasses are different than used for buildings. In Tables B-3 and B-4, the criteria and the descriptions for bridges, tunnels, and overpasses are summarized respectively.

Also, it should be noted that a separate approach was used to place dams on their priority list. This is explained in detail in Section III.

C. Site Related Parameters

In considering the parameters related to site as developed in Table 2, the following steps were taken and associated coding and abbreviations were made:

- An abbreviation for the fault (or faults) with the capacity to cause damaging ground motion at the structure's site within the San Francisco Bay Area. Some structures, because of their location close to more than one such fault, or because of their size spanning the area between two faults, have more than one entry, separated by slashes.

  NH - northern Hayward fault
  SH - southern Hayward fault
  (the demarcation is at Hayward)
  SA - San Andreas fault
  CAL - Calaveras fault

  These abbreviations are used in column 2 of Table 2.

- A code indicating the severity of shaking at the site from USGS Map MF-709 (6)

  A - very violent
  B - violent
  C - very strong
  D - strong
  E - weak
  AB, etc. - very close to, or on, the differentiating contour between A and B regions. Parentheses indicate estimation.

These codes are shown in column 3 of Table 2.

- A numerical value assigned to the coding in column 3 of Table 2. A = 5, B = 4, C = 3, D = 2, E = 1, and AB = 4.5, etc. Multiple values occur corresponding to multiplicity in items in columns 2 and 3 of Table 2. The resulting numerical values are shown in column 4 of Table 1.
- The probability of a large earthquake (M = 6.5 or 7) occurring on the fault(s) in question within the next 30 years:

  Northern Hayward fault - 0.2
  Southern Hayward fault - 0.1
  San Andreas fault - 0.05 (highest 0.08, lowest 0.03)
  Calaveras fault - --

  These probabilities have been entered into column 5 of Table 2. It should be mentioned that these probabilities are derived from one reference only (7). The results may change slightly if these probabilities differ.
- The expected value of strong shaking intensity at the site, given as the product of columns 4 and 5 of Table 2, summing over all contributing earthquakes. Values range up to a maximum of 1.4.

  The calculated expected values are provided in column 6 of Table 2.

- Because it was decided that the value assigned to structural interest and the expected value assigned to strong shaking intensity should have equal weights, column 6 in Table 2 was scaled by a factor of 2.14 to raise the maximum value to 3.0, the same as the maximum prescribed in column 1. The scaled values, now comparable with column 1, are entered in column 7.

- The final priority rating is the sum of the contribution for structural interest (Column 1) and expected value of strong shaking intensity (Column 7) are entered into Column 8 of Table 2. Other approaches to obtaining the final priority rating were attempted; however, the results were similar to the conclusions reached by this approach.

D. Prioritized List of Structures

The numerical values determined in column 8 of Table 2 have been used to sort the structures in the order of decreasing priority. The sorting of the structures brought a dilemma. As a result of the initial sorting, the high-rise buildings in San Francisco would have retained their neglected position. Since only one tall building in San Francisco (Standard Oil Building) has been instrumented by USGS so far (see Table 2), it was decided to subdivide Table 2 into the following categories.

- Category I - structures already instrumented or being instrumented,
- Category II - tall buildings,
- Category III - other buildings and structures, and
- Category IV - dams (listed separately in Table 3).

Thus, it will be possible to choose different structures from the categories depending on resources.

The structures listed in Table 1 have been located on maps provided in Figure 2 (overall Bay Area) and Figure 3 (downtown San Francisco). Table 1 provides coding for both Figures 2 and 3.

III. SELECTION PROCESS FOR EARTH DAMS

The guidelines for the selection of dams are assumed to be similar to those described for buildings and other structures. In particular, the fundamental assumption utilized in these guidelines is that strong-motion data on structural behavior during damaging-level earthquakes are the most desirable types of information. Factors that enter into these guidelines include the proximity to earthquake source regions and expected intensity at the location being considered.

With regard to the type of dam selected for instrumentation, there are several factors that must be considered. These factors include:

Geometry of Structure	Dams that are over 100 ft high or have over 10,000 acre-ft storage are considered most important. Additional considerations include the uniformity of the upstream and downstream slopes and the length/height ratio.
Embankment Material and Method of Construction	Hydraulic fill dams are deemed of special interest because of the concern about their seismic performance (e.g., Lower San Fernando Dam during the 1971 San Fernando Earthquake). Sand-fill dams are also deemed of more interest than clay-fill dams.
Foundation Material	Dams situated on non bedrock foundations are considered more important.
Age	Dams constructed before 1935 are deemed of special interest, especially those that existed prior to the 1906 Earthquake (e.g., Chabot Dam).

Because of the unique nature of sites chosen for dams and other factors in their design, earth dams are generally quite dissimilar. Hence, comparisons of dams based on the listed considerations alone are usually very difficult to perform. Additionally, the information needed to perform an evaluation of a dam's suitability for instrumentation oftentimes is non-existent or sketchy at best.

Based on the above consideration and the goals of the instrumentation program, a list of earth dams is presented in Table 3 ordered according to their priority for instrumentation. A guide for applying weighting factors to earth dams is provided in Table B-5 of Appendix B. It should be noted that these instrumentation plans for earth dams will be coordinated with the program operated by the California Division of Mines and Geology to assure that the respective goals of each program are met.

IV. CONCLUSIONS AND RECOMMENDATIONS:

The Advisory Committee on Instrumentation of Structures in the San Francisco Bay Area has contemplated over a period of one year to develop a list of buildings and other structural systems for recommendation to the United States Geological Survey for instrumenting.

The committee considered a wide range of structural types along with site related parameters and developed a list of approximately fifty structures representative of the total number of such buildings and structures in the Bay Area.

A weighting scheme including type of structures, structural parameters and expected ground motion was applied to prioritize the structures. The results are presented in Table 2. The committee also recommended a selection process for earth dams. The structures presented in Tables 1 through 3 have been screened and sorted by the committee according to criteria developed. The criteria considered the uniqueness of the structures (structural system, geometry, material, etc.) as well as seismic risk factor. The selected structures meet the objectives of the program. Implementation will be commenced to the extent permitted by existing resources.

The Advisory Committee reiterates the following general recommendations for consideration:

- The scientific and engineering benefits to be gained by the program to instrument structures for strong motion are too great to be ignored or postponed. Past experience with processed data acquired from instrumented structures shows that such investigation can contribute to better understand the response and behavior of structures. Ultimately, these programs help to mitigate seismic hazard.
- Since at present very few structures are thoroughly instrumented, there is an urgent need to increase the level of funding and channel ample resources to pursue instrumentation of the structures in the San Francisco Bay Area. This report provides a recommended list of such structures.
- Similar attempts should be extended to other parts of the State of California and/or nationwide.

REFERENCES

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2. Rojahn, Christopher, and Ralph B. Matthiesen, "Earthquake Response and Instrumentation of Buildings," *Journal of the Technical Councils*, ASCE, Vol. 103, No. TCI, Proceedings Paper 13393, December, pp. 1-12, 1977.

3. Rojahn, Christopher, and R. D. Ragget, "Guidelines for Strong-Motion Instrumentation of Highway Bridges," *Federal Highway Administration Report* FHWA/RD-82/016, 1981

4. Fedock, J. J., "Strong-Motion Instrumentation of Earth-Dams": *U.S. Geological Survey Open-File Report* 82-469, 1982.

5. Shakal, A. F., "The California Strong-Motion Instrumentation Program: Status and Goals," *EERI Seminar Proceedings*, Pasadena, California, Feb. 9, 1984.

6. Borcherdt et al., "Maximum Earthquake Intensity Predicted for Large Earthquakes," Southern San Francisco Bay Region, California, *USGS Map MF* 709, 1975.

7. Lindh, A. G., "Preliminary Assessment of Long-Term Probabilities for Large Earthquakes Along Selected Fault Segments of the San Andreas Fault System in California," *U.S. Geological Survey Open-File Report* 83-63.

Table 1
PRELIMINARY STRUCTURES MAP CODE
SAN FRANCISCO BAY REGION INSTRUMENTATION ADVISORY COMMITTEE

Buildings

Berkeley
- *1. Great Western
- 2. Wurster Hall (UCB)
- 3. Underfield Parking (UCB)

Campbell
- 4. Pruneyard Towers

Emeryville
- 5. Pacific Park Plaze

Hayward
- *6. City Hall
- 7. City Hall Parking

Millbrae
- 8. SFO Parking

Mountain View
- 9. Moffett Field Hangar

Oakland
- 10. Arena
- 11. City Hall

Palo Alto
- 12. Hewlett Packard

Richmond
- 13. Bulk Mail Facility

San Jose
- *14. Santa Clara County Office Bldg.
- *15. IBM Facility
- 16. Water Control Plant

San Francisco
- 17. B of A Building
- 18. 45 Fremont (Bechtel Bldg.)
- 19. 1 Metro Plaza (Bechtel Bldg.)
- 20. City Hall
- 21. Embarcadero Center (4)

San Francisco (cont'd)
- 22. Fairmont Hotel
- 23. Hartford
- 24. Levi Plaza
- 25. Moscone Center
- 26. St. Francis Hotel
- 27. Shaklee
- *28. Standard Oil (575 Market)
- 29. Sutter Street Garage
- *30. Transamerica
- *31. 101 California
- 32. Cow Palace
- 33. SFSU Student Union

Santa Clara
- 34. Leavey Center (U of S.C.)

Bridges
- 35. Bay Bridge
- 36. Carquinez
- *37. Dumbarton
- *38. Golden Gate
- 39. Hegenberger OH
- 40. Hayward-San Mateo
- 41. Richmond-San Rafael
- 42. San Joaquin River
- *43. Sierra Point Viaduct
- 44. 101/92
- 45. 280/92
- 46. Crystal Springs Creek

Tunnels
- 47. BART
- *48. Caldecott

Dams
- 49. San Pablo
- 50. Upper San Leandro
- 51. Calaveras
- 52. Leroy Anderson
- 53. Chabot
- 54. Briones

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* Instrumented or in the process of being instrumented.

Table 2

Priority Factors for Structures

Parameters Considered	Structural Weighting Factor	Site Related Parameters and Factors: Proximity to Fault	Shaking Level Index	Shaking Level Factor	Probability	Shaking Level x Probability Col. ④ x Col. ⑤	2.14 x Col. ⑥	Priority Factor Col. ① + Col. ⑦
Column	①	②	③	④	⑤	⑥	⑦	⑧
Category I - Structures already instrumented or being instrumented								
Hayward City Hall	3	NH	AB	4.5	.2	.9	1.93	4.9
Santa Clara County Office Building	2	SH/SA	C/C	3/3	.1/.05	.45	.96	4.0
Great Western Building, Berkeley	2	NH	AB	4.5	.2	.9	1.93	3.9
101 California	3	SA	CD	2.5	.05	.12	.26	3.3
Golden Gate Bridge	3	SA	E	1	.05	.05	0.11	3.1
Caldecott Tunnel	1	NH	BC	3.5	.2	.7	1.5	2.5
Sierra Point Viaduct	2	SA	BD	3	.05	.15	.32	2.3
Transamerica (49,58 fl)	2	SA	D	2	.05	.1	.21	2.2
Dumbarton Bridge	1	SH/SA	C/C	3/3	.1/.05	.45	.96	2.0
Standard Oil, 575 Market		SA	D	2	.05	.1	.21	--
Category II - Tall Buildings								
Pacific Park Plaza, Emeryville (30 fl)	3	NH	BC	3.5	.2	.7	1.5	4.5
Shaklee Building, 444 Market (36 fl)	3	SA	CD	2.5	.05	.12	.26	3.3
Alcoa Building, 1 Maritime Pl.	3	SA	CD	2.5	.05	.12	.26	3.3
Embarcadero 4	2	SA	CD	2.5	.05	.12	.26	2.3
Bank of America Hqtrs, 555 California (52 fl)	2	SA	DE	1.5	.05	.07	.15	2.2
Embarcadero 1	1	SA	CD	2.5	.05	.12	.26	1.3
Embarcadero 2 or 3	1	SA	CD	2.5	.05	.12	.26	1.3
Bechtel: 45 Fremont (34 fl)	0	SA	CD	2.5	.05	.12	.26	.3
425 Market (Met. Bldg.) (38 fl)	0	SA	DE	2.5	.05	.12	.26	.3
Hartford Ins. Building, 650 California (34 fl)	0	SA	D	1.5	.05	.07	.15	.2
St. Francis Hotel, Powell & Geary (32 fl)	0	SA	D	2	.05	.1	.21	.2
Fairmont Hotel, Cal. & Mason (23 fl)	0	SA	DE	1.5	.05	.07	.15	.2

Table 2 (continued)

Priority Factors for Structures

Parameters Considered	Structural Weighting Factor	Site Related Parameters and Factors: Proximity to Fault	Shaking Level Index	Shaking Level Factor	Probability	Shaking Level x Probability Col. ④ x Col. ⑤	2.14 x Col. ⑥	Priority Factor Col. ① + Col. ⑦
Column	①	②	③	④	⑤	⑥	⑦	⑧
Category III - Other Buildings and Structures								
Wurster Hall, UCB	3	NH	A	5	.2	1	2.1	5.1
Bay Bridge	3	NH/SA	B/C	4/3	.2/.05	.95	2.04	5.0
Hayward City Hall Garage	2	NH/SH	AB/AB	4.5/4.5	.2/.1	1.35	2.89	4.9
Oakland Arena	3	NH	AB	4.5	.2	.9	1.93	4.9
BART Tunnel	3	SA/NH	C/C	3/3	.05/.2	.75	1.61	4.6
Underhill Field Park, UCB	2	NH	A	5	.2	1	2.1	4.1
Hayward/San Mateo Bridge	1	NH/SH/SA	B/B/B	4/4/4	.2/.1/.05	1.4	3	4.0
Cow Palace	3	SA	CD	2.5	.05	.12	.26	3.3
Oakland City Hall	2	NH	C	3	.2	.6	1.29	3.3
Moscone Center	3	SA	C	3	.05	.15	.32	3.3
Leavey Activities, USC	2	SH/SA	CD/D	2.5/2	.1/.05	.35	.75	2.8
Richmond Mail Processing	1	NH	(BC)	3.5	.2	.7	1.5	2.5
SFO Airport Parking	2	SA	AB	4.5	.05	.22	.47	2.5
Crystal Springs Br.	2	SA	AB	4.5	.05	.22	.47	2.5
SFSU Student Union	2	SA	C	3	.05	.15	.32	2.3
H/P, Raychem, Syntex	2	SA	CD	2.5	.05	.12	.26	2.3
Levi Plaza Building (7 fl)	2	SA	DE	1.5	.05	.07	.15	2.2
Sutter Street Garage	2	SA	D	2	.05	.1	.21	2.2
San Francisco City Hall	2	SA	D	2	.05	.1	.21	2.2
Moffett Field Hangar	2	SA	D	2	.05	.1	.21	2.2
Hegenberger Road Overpass	0	NH	AB	4.5	.2	.9	1.93	1.9
Pruneyard Towers (18, 10 fl)	1	SH/SA	D/D	2/2	.1/.05	.3	.64	1.6
92/101 and 92/280	0	SA	B	4	.05	.2	.43	.4
Tunnels around Golden Gate	0	SA	DE	1.5	.05	.07	.15	.2
Carquinez Bridge	1	NH/CAL						--
Richmond/San Rafael Bridge	1	NH						--
San Joaquin River Bridge	1	CAL						--

Table 3
Prioritized List of Earth Dams to be Instrumented in San Francisco Bay Region

Name / Location / Comments	County	Height (Ft) / Crest Length (Ft)	Storage (A-ft) / Owner
San Pablo	Contra Costa	170	43190
6 mi SE of El Sobrante		1250	EBMUD
Hydraulic fill, built 1920, dynamic seismic analysis available, foundation = 30-60 ft alluvium, distance to fault = 3 mi Hayward, 10 mi Calaveras			
Upper San Leandro	Alameda	190	41440
		660 (old), 1280 (new)	EBMUD
Hydraulic fill, old dam (hydraulic fill) constructed 1926, new dam (earthfill) completed 1977, dynamic seismic analysis available for both dams			
Calaveras	Alameda	210	100000
Near Milpitas		1200	SFWD
Very non-uniform slopes, earth and gravel fill, built 1924			
Leroy Anderson	Santa Clara	235	91300
Near Morgan Hill		1400	SCVWD
Rolled earth and rockfill structure, constructed 1950, evaluation of stability and performance report available			
Chabot	Alameda	135	12600
Near San Leandro		450	EBMUD
Survived 1906 earthquake, dynamic seismic analysis available			
*Briones	Contra Costa	273	67500
6 mi E of Albany			EBMUD
Large, modern, well-constructed dam			

EBMUD - East Bay Municipal Utility District

SFWD - San Francisco Water Department

SCVWD - Santa Clara Valley Water District

* 4 SMA-1's currently installed.

APPENDIX A

STATUS OF INSTRUMENTATION PROGRAMS

Within the United States, Federal, State, local institutions, as well as academic institutions and private organizations have installed instrumentation in structures for one or both of the following purposes:

a) to evaluate the safety of structural systems (facility evaluation),
b) to study and improve structural response evaluations of structural systems.

In the State of California, the following institutions have been involved with instrumentation of structures:

State of California Agencies:

- CDMG - California Division of Mines and Geology, Sacramento
- CDWR - California Department of Water Resources, Sacramento
- CDOT - California Department of Transportation, Sacramento

Federal Government Agencies:

- ACOE - Army Corps of Engineers, Vicksburg, Mississippi
- USGS - U.S. Geological Survey
- USBR - U.S. Bureau of Reclamation, Denver, Colorado
- VA - Veterans Administration, Washington, D.C.
- FHWA - Federal Highway Administration
- USN - U.S. Navy
- TVA - Tennessee Valley Authority

Educational Institutions:

- CIT - California Institute of Technology, Pasadena
- UCLA - University of California, Los Angeles
- UCB - Universicty of California, Berkeley
- USC - University of Southern California

Local Agencies:

- MWD - Metropolitan Water District, Los Angeles

In addition to the above, private organizations have also been installing instrumentation. For example, IBM facilities in San Jose, California and some privately owned buildings in downtown San Francisco are known to have instrumentation.

A summary of instrumentation programs with the United States are provided by Rojahn and Borcherdt (1983). In this appendix some of the relevant data from the above reference will be repeated.

In Table A-1, status of instrumented structures nationwide to provide data for structural response studies is provided. This table provides information showing distribution of the instrumentation according to states.

In Table A-2, similar statistical data is shown for buildings to provide data for facility-evaluation studies. It is clearly seen in the two tables that while quite a number of structures are instrumented in California, the number of buildings instrumented in the Bay Area has not been extensive to merit the earthquake risk the Bay Area has been associated with.

Table A-3 provides similar data on instrumentation of dams in the United States, and Table A-IV provides data on instrumentation of special structures in the State of California.

Figure 1 depicts the current status of accelerographs located to record strong ground motions in the San Francisco Bay Area.

Table A-1.--Summary of Structures Instrumented to Provide Data for Structural-Response Studies[1]

Location	Agency*	Number of Structures with Extensive Instrumentation	Number of Structures with Minimal Instrumentation
		BUILDINGS	
California	CDMG	51	-
	CIT	-	2
	UCLA	3	11
	USGS	1	2
	VA/USGS	4	2
Alaska	USGS	-	2
		BRIDGES	
Alaska	USGS/FHWA	1	-
California	CDMG	3	-
	CDMG/FHWA/USGS	1	-
	CDOT/USGS	-	3
Missouri	USGS/FHWA	1	-
Nevada	UNV	-	1
New York	FHWA/USGS	1	-
Washington	WHD/USGS	3	-
		DAMS	
California	CDMG	5	14

*CDMG--California Division of Mines and Geology, Sacramento
CDOT--Califiornia Department of Transportation, Sacramento
CIT-- California Institute of Technology, Pasadena
UCLA--University of Californa, Los Angeles
USGS--U.S. Geological Survey, Menlo Park, California
UNV-- University of Nevada, Reno
VA -- Veterans Administration, Washington, D.C.
WHD-- Washington (State) Highway Department
FHWA--Federal Highway Administration

[1] Borcherdt, R. D., 1983, Strong-Motion Networks in the United States; A Review: *Proceedings of Golden Anniversary Workshop on Strong Motion Seismometry*, University of California, Los Angeles.

Table A-2.--Summary of Buildings Instrumented to Provide Data for Facility-Evaluation Studies[1]

Location	Number of Structures		
	Code-Instrumented	VA Hospitals	Other
	BUILDINGS		
California--Los Angeles	200+	0	0
--San Francisco	0	1	6
--Other Cities	100+	4	2
Utah--Salt Lake City	0	1	0
Washington--Seattle	0	0	1

[1] Borcherdt, R. D., 1983, Strong-Motion Networks in the United States; A Review: *Proceedings of Golden Anniversary Workshop on Strong Motion Seismometry*, University of California, Los Angeles.

Table A-3.--Summary of Dams Instrumented to Provide Data for Facility-Evaluation Studies[1]

Location	Number of Structures by Agency*				
	ACOE	CDWR	MWD	USBR	Other
			Western U.S.		
Alaska	2	-	-	-	-
California	17	8	7	6	3
Nevada/Utah	-	-	-	4	-
Northwest	13	-	-	2	1
Southwest	3	-	-	-	-
Rocky Mountain Region	5	-	-	3	-
			Central U.S.		
North Central	16	-	-	-	-
Mississippi Valley	1	-	-	-	-
South Centeral	17	-	-	-	-
			Eastern U.S.		
Northeast	11	-	-	-	-
Mid-Atlantic	6	-	-	-	-
Southeast	7	-	-	-	-

*ACOE--Army Corps of Engineers, Vicksburg, Mississippi
CDWR--California Department of Water Resources, Sacramento, California
MWD-- Metropolitan Water District, Los Angeles, California
USBR--U.S. Bureau of Reclamation, Denver, Colorado

[1] Borcherdt, R. D., 1983, Strong-Motion Networks in the United States; A Review: *Proceedings of Golden Anniversary Workshop on Strong Motion Seismometry*, University of California, Los Angeles.

Table A-4.--Summary of Pumping, Power and Filter Plants Instrumented to Provide Data for Facility-Evaluation Studies[1]

Location	Number of Structures by Agency*		
	CDWR	MWD	Other
California	9	2	1

* CDWR--California Department of Water Resources, Sacramento
MWD --Metropolitan Water District, Los Angeles

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[1] Borcherdt, R. D., 1983, Strong-Motion Networks in the United States; A Review: *Proceedings of Golden Anniversary Workshop on Strong Motion Seismometry*, University of California, Los Angeles.

APPENDIX B

CRITERIA AND WEIGHTING FACTORS

Table B-1
Structural Weighting Factors for Buildings

Parameters		Suggested Weighting Factor
Material	Steel	0
	Concrete: pre-cast	1
	poured	0
	tilt-up	2
	Wood	0
	Masonry	0
	Composite	0
System	Moment Frame	0
	Shear Walls	0
	Non-ductile frame	1
	(Concentric) braced frame	1
	Eccentric bracing (compression control)	1
	Wide span	1-2
	Unusual	1-2
	"Normal" braced frame	0
Geometry	Regular	0
	Irregular	1
	Extremely irregular	2-3
Discontinuity	Soft stories	1-3
	Perimeter variation	1-3
	Set backs	1-2
Age	Pre-1935	1

notes: weighting scale is 1-3

criteria:
- non-typical but likely to be repeated
- innovative, likely to be repeated
- potential problem, need information on behavior
- need information on comparative examples

Table B-2

A Guide to How Weighting Factors Were Applied to Buildings

Structure	Weight Factor	Comments
Hawyard City Hall	3	serious soft first story problem
Great Western Building	2	unusual suspended structure
Transamerica Building	2	unusual: tapered elevation, braced first floor
Standard Oil Co.	-	already instrumented
101 California	3	irregular geometry (1) high first floor (2)
Oakland Arena	3	wide span (2) unusual suspended structure (1)
Moscone Center	3	wide span (2) unusual concrete structure (1)
Cow Palace	3	wide span (2) pre-1935 (1)
Leavey Activities Center	2	unusual, wide span
Embarcadero 1	1	irregular plan (1) (comparison)
Embarcadero 2	1	" " " "
Embarcadero 3	1	" " " "
Embarcadero 4	2	" " " "
Hartford Building	0	steel-ductile, moment resisting
Bechtel Buildings		
45 Fremont	0	steel frame, ductile moment frames
1 Metropolitan Plaza	0	steel frame
Bank of American (HQ)	2	unusual size (1) perimeter variation (1)
Pacific Park Plaza (Emeryville)	3	irregular plan (2) unusually high conc. frame (1)
SFSU Student Union	2	irregular geometry (1) perimeter variation (1)
SF City Hall	2	pre-1935 (1) setback (1)
Shaklee Building (Downtown)	3	irregular plan (2) setbacks (1)

Table B-2 (continued)

A Guide to How Weighting Factors Were Applied to Buildings

Structure	Weight Factor	Comments
Oakland City Hall	2	pre-1935 (1) setbacks (1)
St. Francis Hotel	0	comparison
Fairmont Hotel	0	comparison
Moffett Field Hangar	1	wide span
Santa Clara County Office Building (L-shaped)	2	irregular plan (L-shape)
Pruneyard Towers (Campbell)	1	setbacks
Wurster Hall (UC - Berkeley)	3	pre-cast (1) irregular plan (2)
Alcoa, SF	3	discontinuity, soft story
Levi Plaza Buildings	2	irregular plan geometry
Richmond Mail Processing Building	2	unusual (large size)
IBM Facilities (St. Teresa)	2	irregular, cruciform plan
Raychem building (tilt-up)	2	tilt-up
Syntex buildings (tilt-up)	2	tilt-up
Hewlett Packard (tilt-up)	2	tilt-up
Underfield Parking (Berkeley) (Pre-cast)	2	comparative examples, information needed
Sutter Street Garage (Poured in)	2	" " " "
SF Airport Parking (Poured in)	2	" " " "
Hayward City Hall Parking Garage (Post-tensioned)	2	" " " "

Table B-3

Structural Weighting Factors for Bridges, Tunnels, and Overpassess

BART Tunnel	3
Caldecott Tunnel	1
Golden Gate Tunnels	0
92/101	0
92/280	0
Golden Gate Bridge	3
Bay Bridge	3
Carquinez	1
Richmond-San Rafael	1
San Mateo-Hayward	1
San Joaquin River	1
Dumbarton	1
Hegenberger Rd.	0
Sierra Pt.	2
Crystal Springs	2

Criteria:	Overall Length over 2000'	1
	Unusual type	1
	Importance	1

Table B-4

Bridges With Spans Over 250 Feet

Bridge	Bridge No.	Type	Main Span Length (feet)	Notes
Golden Gate	27-52	Suspension	4200	This structure is owned by the Golden Gate Bridge District and is currently being instrumented by the Golden Gate Bridge Authority.
San Francisco Bay (West)	34-03	Suspension	2310	
San Francisco Bay (East)	33-25	Truss	1400	Cantilever truss and truss spans.
Carquinez Strait	23-15		1175	Cantilever truss spans.
Richmond-San Rafael			1070	Cantilever truss and truss spans.
San Mateo-Hayward	35-54		750	Welded steel box girder spans.
Benicia-Martinez	28-153		528	Deck truss spans.
San Joaquin River	28-153		460	Welded steel girder spans.
San Mateo Creek	35-199		360	Welded steel girder spans.
Dumbarton	35-38		340	Welded steel box girders with precast prestressed concrete approach spans. This bridge is currently planned to be instrumented by CALTRANS and will eventually be maintained by either the USGS or the State Strong Motion Program.
Hegenberger Road Overhead	33C-202		290	Cast-in-place, pre-stressed concrete superstructure. Owned by the City of Oakland.

Table B-5

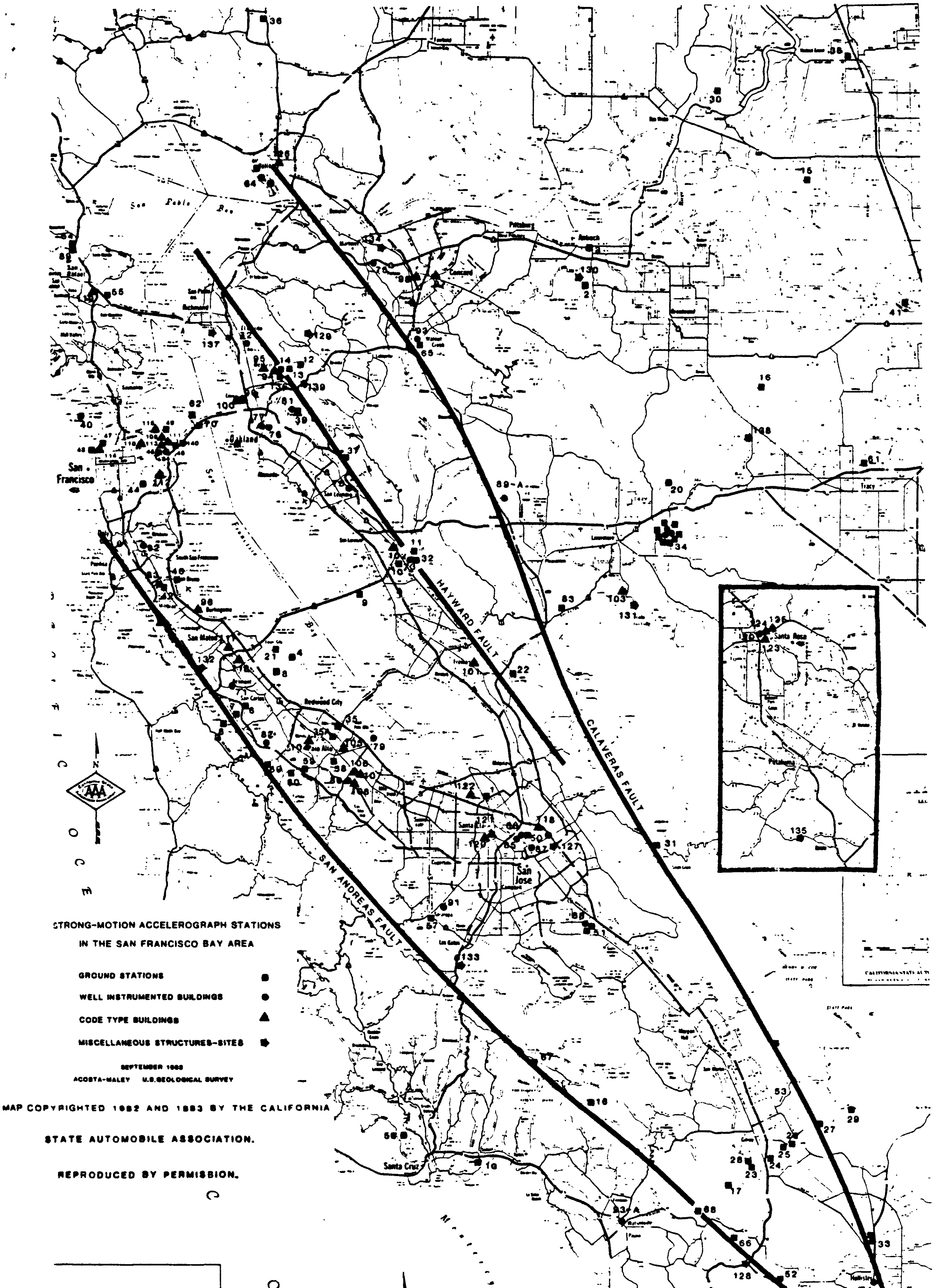
Structural Weighting Factors for Earth Dams*

Issue		Suggested Weighting Factor
Age	Pre-1935	1
Embankment Material	Rockfill	2
	Earthfill	
	Predominately clayey fill	1
	Predominately sandy fill	2
Foundation Material	Bedrock foundation	0
	Non-Bedrock foundation	1-2
Method of Construction	Rolled fill	0
	Hydraulic fill	2
Geometry	Size (Over 100 ft high or over 10,000 acre-ft storage)	1-3
	Non-uniform slopes	1
	Large length/height ratio (Greater than 6)	1

Note: Scale 0-3

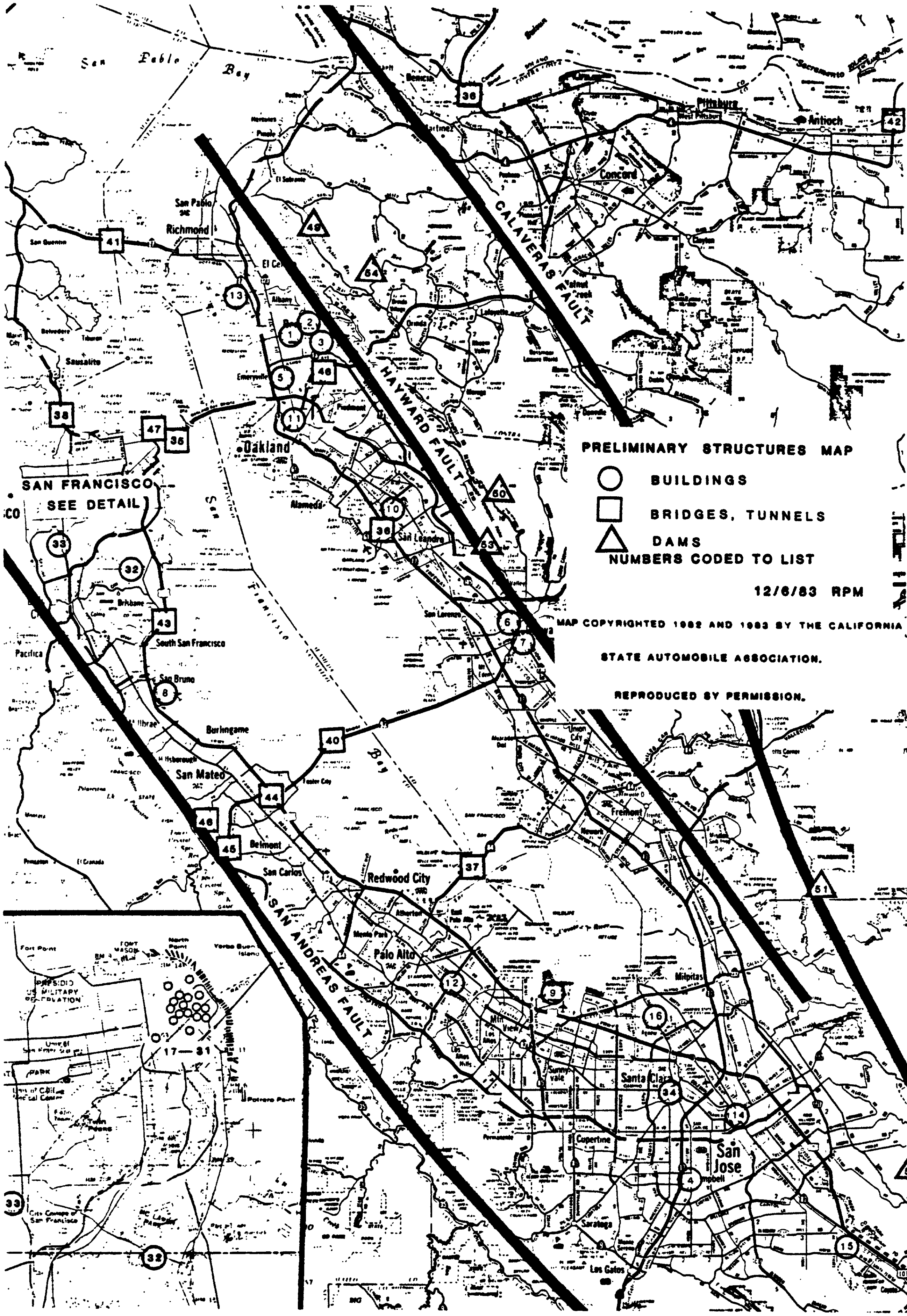
Reference: *"The Performance of Earth Dams During Farthauakes"*, Seed, H.B., *et al.*, UCB/EERC-77/20, August 1983.

* Selected Earth Dams are provided in Table 3.



(The numbers refer to an unpublished list and do not correspond to numbers in the tables of this report).

Figure 1


PRELIMINARY STRUCTURES MAP
BUILDINGS
BRIDGES, TUNNELS
DAMS
NUMBERS CODED TO LIST
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San Mateo
Belmont
San Carlos
Redwood City
Palo Alto
Fremont
Milpitas
Santa Clara
San Jose
Cupertine
Saratoga
Los Gatos
Pacifica
Sausalito
17—31

Figure 2

Location of selected structures in downtown San Francisco (numbers refer to Table 1).

Figure 3