U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Liquefaction Hazard and Shaking Amplification Maps of Alameda, Berkeley, Emeryville, Oakland, and Piedmont, California: A Digital Database

by

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Open-File Report 02-296
Version 1.1

2002, revised 2005

INTRODUCTION

This Open-File Report is a digital database for hazard maps of liquefaction effects and shaking amplification in the Oakland, California, area. This accompanying pamphlet serves to introduce and describe the digital data. Paper maps are not included in the Open-File Report; instead PDF plot files are included that can be used to plot images of the hazard maps.

This digital database is based on a previously published map of surficial geology by Helley and Graymer (1997) as modified by R. Witter (digital communication, 2003) together with 210 newly acquired seismic cone penetration test (SCPT) soundings supplemented by unpublished commercial borings. The database identifies areas that have potential (1) to produce surface manifestations of liquefaction, for example, sand boils, ground cracks, and lateral spreading, and (2) to amplify ground shaking from earthquakes. The scale of the source map limits the spatial resolution (scale) of the database to 1:24,000 and smaller for the liquefaction map and 1:50,000 and smaller for the shaking amplification map; plotting at larger scales will not yield greater real detail. These maps depict the hazard at a regional scale and should not be used for site-specific design. Subsurface conditions can vary abruptly and borings are required to address the hazard at a given location. The liquefaction hazard map also does not account for local ground improvements that have been made to mitigate against the occurrence of liquefaction.

LIQUEFACTION HAZARD

The liquefaction hazard map predicts the approximate percentage of each designated area that will have surface manifestations of liquefaction during an M7.1 earthquake on the Hayward fault. An earthquake of this magnitude is expected if the whole Hayward fault ruptures in a single event (Working Group on California Earthquake Probabilities, 1999). This event dominates the deaggregated hazard near the eastern shore of San Francisco Bay (http://earthquake.usgs.gov/hazmaps/interactive/). The estimated annual probability for this earthquake is 0.00191 per year, and no such event has occurred since 1740 (Working Group on California Earthquake Probabilities, 1999). However, other smaller events may occur. For example, an M6.6 associated with a rupture of the northern segment of the Hayward fault has an estimated annual probability of 0.00258 per year. For these smaller events, liquefaction will be less extensive than for the M7.1 earthquake considered in this report.

The prediction of liquefaction is based on the liquefaction potential index (LPI) (Toprak and Holzer, 2003). LPI is a weighted integration of one minus the factor of safety against liquefaction within the uppermost 20 m of sediment at a specific location. The previous study by Toprak and Holzer (2003) investigated the correlation of LPI with surface manifestations of liquefaction during the 1989 Loma Prieta, California, earthquake and found that surface manifestations typically occurred where LPI values exceed 5. LPI values were computed at the 210 locations where CPT soundings were conducted in the communities of Alameda, Berkeley, Emeryville, and Oakland. Distributions of LPI values were calculated for each of the major surficial geologic units mapped by Helley and Graymer (1997) as modified by R. Witter. For each geologic unit in the study area, the percentage of the LPI values that exceed 5 for a M7.1 Hayward fault earthquake indicates the approximate percentage of the area in which liquefaction effects can be expected (See Holzer and others, in press).

Because of the major difference in liquefaction susceptibility between Holocene and Pleistocene alluvial fan deposits, areas where unsaturated Holocene alluvial fan deposits overlie Pleistocene alluvial fan deposits were identified by comparing the depth to the water table with the thickness of the Holocene alluvial fan deposits. In areas where the Holocene alluvial fan deposits are completely above the water table, the liquefaction hazard is derived from the underlying Pleistocene alluvial fan deposits. Thus, the boundary between the saturated and unsaturated Holocene alluvial fan deposits distinguishes between areas with different degrees of hazard. Areas shown on the map as "not studied" are narrow valleys where Helley and Graymer (1997) as modified by R. Witter mapped Holocene deposits, but in which it was not feasible to conduct sufficient soundings to document sediment thickness and liquefaction susceptibility.

SHAKING AMPLIFICATION

The shaking amplification map is based only on shear-wave velocity measurements conducted during the SCPT soundings. It uses the 2000 National Earthquake Hazards Reduction Program (NEHRP) V_{S30} site classification scheme to categorize the potential for shallow soils to amplify ground shaking (Building Seismic Safety Council, 2001). Although the scheme relies primarily on a time-averaged shear-wave velocity to a depth of 30 m (V_{S30}) to classify the soils at a site (Table 1), site classes E and F can be determined by other soil properties, such as thickness. This classification is used to determine appropriate amplification factors for use in engineering design, with type E soils having the largest amplification factor (Building Seismic Safety Council, 2001).

For the shaking amplification map presented here, only V_{S30} was considered when classifying a site. The regional distribution of V_{S30} was estimated by dividing the study area into three approximately northwest-southeast regions. The western region is west of the predevelopment shoreline of San Francisco Bay where the upper 30 m typically consists of artificial fill placed over younger bay mud, which in turn overlies either fine-grained Pleistocene sediment or Merritt sand. The central region lies immediately northeast of the predevelopment shoreline where the upper 30 m typically consists of Holocene alluvial fan deposits overlying Pleistocene alluvial fan deposits. The eastern region is underlain by bedrock. To map the NEHRP V_{S30} site classification in the western and central regions, maps showing the thickness of Holocene sediment and artificial fill were prepared and then the V_{S30} at points on a regular grid with 50-m spacing was computed based on average velocities of each geologic unit. With the exception of the younger bay mud, a constant average shear-wave velocity of each geologic unit was computed from the velocities measured during the cone penetration testing. The velocity of the younger bay mud increases linearly with depth, so a depth-dependent equation was used to compute the travel time through this layer in the estimation of V_{S30}.

The map in the southwestern region may underestimate values of V_{S30} in some areas because it was assumed that the Holocene sediment beneath the artificial fill at each control point was younger bay mud. This unit has the lowest shear-wave velocity of all of the geologic units. Special studies are required in these areas to determine if V_{S30} values are indeed lower than 180 m/s, the prerequisite for a type E classification. Because points where V_{S30} was estimated were 50 m apart, modern stream valleys with Holocene fluvial deposits less than approximately 50-m wide were not mapped and classified.

Table 1. Ground-amplification V_{S30} site classes (adapted from Building Seismic Safety Council (2000)).

Site Class	Description	V_{S30} (m/s) Minimum	Maximum
A	Hard Rock (Eastern US only)	1500	
B	Rock	760	1500
C	Very Dense Soil and Soft Rock	360	760
D	Stiff Soils	180	360
E	Soft Soils		180

Locations of and data from the CPT soundings, including the shear-wave travel times, are available on the World Wide Web at the following URL: http://quake.usgs.gov/prepare/cpt/. For more information on the mapping procedure, the reader is referred to Holzer and others (2005a). For an analysis of the shear wave velocities of the geologic units including velocity gradients, the reader is referred to Holzer and others (2005b).

ACKNOWLEDGMENTS

The field investigations with the CPT soundings that provided the subsurface data used in this report were facilitated by the cooperation of Coleen Bell and David Skinner of the City of Oakland; Capt Larry Picinic and Flavio Barrantes of the City of Alameda; Maurice Kaufman, John Flores, and Hank Van Dyke of the City of Emeryville, Arrieta Chakos, Diana Aikenhead, Roger Miller, Jay Wilson, Rene Cardineaux of the City of Berkeley, and Gerald Serventi and Karl Kuhlmann of the Port of Oakland. Selcuk Toprak, Suzanna Brooks, and Eric Hand of the USGS provided help with data reduction and analysis. We also are grateful to the

California Geological Survey and the Port of Oakland for providing subsurface data. Carl Wentworth of the USGS provided valuable guidance with GIS and the preparation of this report. Carl Wentworth and Manuel Bonilla provided thorough and thoughtful reviews of the report.

DATABASE CONTENTS AND PRESENTATION

The report consists of digital files representing the 8 parts of the database, some of which are presented in more than one format. The names of the files are unique designators based on the report identifier, of02-296, followed by part numbers and an extension indicating file type. Some of the files have been have been bundled and compressed with WinZip for convenience. The report file (of02-296_1.1.pdf) is provided as a Portable Document Format (.pdf) file and is also packaged with the database files in WinZip compressed form. The revision history file (version_history.pdf) is presented as a Portable Document Format (.pdf) file bundled in the database .zip files, as well as an individual download. The six .pdf map images may be downloaded individually or as a complete set in a single .zip file (of02-296_all_maps.zip). The liquefaction and shaking amplification databases are also packaged separately in compressed form with WinZip (.zip). The files and their identities are as follows:

1. Open-File Pamphlet: The text of the open-file pamphlet (this text, in Portable Document Format), which describes the database.

a. of02-296_1.1.pdf   PDF file, 104 KB.

2. Liquefaction Map Images: The image files representing the liquefaction hazard map as a Portable Document Format file (.pdf). Files with an (-sg) extension contain the major streets and highways displayed on the map.

a. of02-296_2liq.pdf   Portable Document Format, 528 KB

b. of02-296_2liq-sg.pdf Portable Document Format, 727 KB

3. Shaking Amplification Map Images: The image files representing the shaking amplification map as a Portable Document Format file (.pdf). Files with an (-sg) extension contain the major streets and highways displayed on the map.

a. of02-296_3sa.pdf   Portable Document Format, 305 KB

b. of02-296_3sa-sg.pdf Portable Document Format, 303 KB

4. CPT Location Map Images: The image files representing the location of 210 SCPT soundings on the liquefaction map (scptliq) and the shaking amplification map (scptsa) Portable Document Format files (.pdf).

a. of02-296_4scptliq.pdf Portable Document Format, 532 KB

b. of02-296_4scptsa.pdf Portable Document Format, 309 KB

5. Liquefaction Map Database Package: The zipped file containing the open file pamphlet, revision list, and the data component files of the liquefaction hazard map, in ArcGIS format. The ArcGIS format files consist of shapefiles for the Hayward fault, the study area boundary, the liquefaction hazard, the latitude and longitude lines, the CPT locations, the streets and the major freeways. Additionally there are 3 .mxd files, named according to the unique identifier discussed above that were created using ArcMap 9.1, and the projection file.

a. of02-296_5liq.zip WinZip file, 1.3 MB

6. Shaking Amplification Map Database Package: The zipped files containing the open file pamphlet, revision list, and the data component files of the shaking amplification map, in ArcGIS format. The ArcGIS format files consist of shapefiles for the Hayward fault, the study area boundary, the latitude and longitude lines, the water boundary, the grid of shaking amplification values, the CPT locations, the streets and the major freeways. Additionally there are 3 .mxd files, named according to the unique identifier discussed above that were created using ArcMap 9.1, and the projection file.

a. of02-296_6sa.zip WinZip file, 3.9 MB

7. All map Images: The liquefaction map images, the shaking amplification map images, and the SCPT location map images (6 in total), in .pdf format, compressed into one .zip file.

a. of02-296_all_maps.zip WinZip file 2.8 MB

8. Revision List: A list of the parts of the report (including bundled packages of parts), indication of the current version number for the report and in which version each part was last revised, followed by a chronologic list describing any revisions (see REVISIONS, below).

a. Version_history.pdf Portable Document Format, 15 KB

OBTAINING THE DIGITAL FILES

The database and image files can be downloaded from the Western Region Geologic Information Web Server.

1. The files for this report are stored on the publication server of the U.S. Geological Survey. The Internet address of this open file report is:

http://pubs.usgs.gov/of/2002/of02-296/

PROCESSING THE FILES

The database files require initial processing before they are usable if they are bundled compressed files. These files were intended for PC platforms. For other formats contact the senior author at tholzer@usgs.gov.

OPENING THE WINZIP FILES

Some of the files are packaged as WinZip (.zip files). Thus, WinZip or another similar utility is required to uncompress the files. Once extracted from the compressed files, the data files can be imported into ArcGIS. Several ArcMap .mxd files, created using ArcMap 9.1, are provided. It is important that the embedded file structure in each .zip file be maintained upon extraction for the .mxd files to work properly. The necessary utility for uncompressing and extracting from zipped format (WinZip) is available on-line. This commercial package runs on PCs. An evaluation copy of WinZip can be downloaded from: http://www.winzip.com/downwzeval.htm

REVISIONS

Changes to any part of this report (parts are the numbered items described above in 'Database Contents' and listed in the revision list (Version_history.txt) may be made in the future if needed. This could involve, for example, fixing files that don't work properly, revising details, adding new file formats, or adding other components to the report.

The report began at version 1.0. This report is version 1.1. Previous versions are archived and available for download. Any revisions will be specified in the revision list and will result in the recording of a new version number for the report. Small changes will be indicated by decimal increments and larger changes by integer increments in the version number. Revisions will be announced and maintained on the Web page for this report on the Western Region Geologic Publications Web Server. Consult the revision list there to determine if a revision is significant for your purposes.

SPATIAL RESOLUTION

The digital database should not be used in ways that violate the spatial resolution of the data. Although the digital form of the data removes the physical constraint imposed by the scale of a paper map, the detail and accuracy inherent in map scale are also present in the digital data. Use of the liquefaction and shaking amplification databases, respectively, at scales larger than 1:24,000 and 1:50,000, will not yield greater real detail although it may reveal fine-scale irregularities below the intended resolution of the database. Similarly, where this database is used in combination with other data of higher resolution, the resolution of the combined output will be limited by the lower resolution of these data. The quadrangle boundaries in the images are accurate at 1:24,000.

DESCRIPTION OF THE SPATIAL DATABASE

The spatial database consists of ArcGIS formatted files. A description of the projection is listed below in table 2. The GIS files are in decimal degrees of longitude and latitude, prepared by projecting and converting the primary UTM coverages.

Table 2. Map Projection

Projection	GEOGRAPHIC
Units	DECIMAL DEGREES
Datum	NAD27
Spheroid	CLARKE1866
Parameters	NONE

REFERENCES CITED

Building Seismic Safety Council, 2001. 2000 edition, NEHRP recommended provision for seismic regulation for new buildings and other structures, FEMA-368, Part 1(Provisions) and Part 2 (Commentary). Washington, D.C., Federal Emergency Management Agency.

Helley, E.J., and Graymer, R.W., 1997, Quaternary geology of Alameda County, and parts of Contra Costa, Santa Clara, San Mateo, Stanislaus, and San Joaquin Counties, California: A digital database: U.S. Geological Survey Open-File Report 97-97, http://geopubs.wr.usgs.gov/open-file/of97-97/ .

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