Award 05HQGR0017

PROBABILISITIC LIQUEFACTION POTENTIAL AND LIQUEFACTION-INDUCED GROUND FAILURE MAPS FOR THE URBAN WASATCH FRONT:

PHASE II
FY2005

by

Steven F. Bartlett, Ph.D., P.E.
Associate Professor
Department of Civil and Environmental Engineering
University of Utah
122 S. Central Campus Dr.
Salt Lake City, Utah 84112
801-587-7726 (voice)
801-585-5477 (fax)
bartlett@civil.utah.edu

Term of Award 12/01/04 to 11/01/05

September 22, 2010

Abstract

Probabilistic-based hazard calculations and assessments are important components in managing risk and reducing potential losses from seismic hazards. The development of probabilistic national seismic hazard maps and the implementation of these maps into current building codes allow for the use of probabilistic techniques to assess liquefaction and liquefaction-induced ground failure.

This report summarizes ongoing work by the Utah Liquefaction Advisory Group (ULAG) to update the liquefaction hazard maps along the Wasatch Front. ULAG was formed in 2004 and has the overall goal of producing probabilistic-based liquefaction hazard and ground displacement and settlement maps that can be implemented in planning, hazard assessment and risk reduction. The methods and tasks put forth herein are a consensus of ULAG, which met in March 2004 to prioritize FY 2005 activities.

The funded FY 2005 tasks are: Task 1- Creation of an ArcGIS subsurface database of relevant geotechnical and geological factors for southern Salt Lake County to be used in liquefaction and ground failure mapping (University of Utah) and Task 2 - Correlation of Subsurface Geologic and Geotechnical ArcGIS™ Database with Surficial Geologic Mapping (Utah Geological Survey).

In subsequent years, ULAG plans to develop probabilistic and scenario liquefaction and ground failure hazard maps for other urban Wasatch Front counties. The produced maps will be used by city and county planners to identify which areas require site-specific liquefaction evaluations and by risk assessors to quantify the seismic hazard at site or area. Also, the methods developed during this project will be generalized so that they can be applied at other U.S. locales where probabilistic maps are desired. In addition, the Utah subsurface GIS database will be made available to the public for other uses. Periodic stakeholder meetings will also be held by ULAG to obtain end user input and comments regarding map and GIS database development and their implementation.

Contents

Abstract 2
List of Figures 4
Acknowledgements 5
1 Introduction........ 6
2 Project Status 7
3 Creation of an ArcGIS Subsurface Database........ 7
4 Correlation of Geologic and Geotechnical Database with Surficial Geologic Mapping 10
5 References........ 13
6 Appendix A – Data Base Structure........ 14

List of Figures

Figure 1. Surficial geologic map and SPT borehole locations... 9
Figure 2. Surficial geologic map of Salt Lake Valley (modified from Personius and Scott, 1992; Biek et al., 2004; and Biek, 2005). Quartenary faults are shown by heavy lines; symbols for geological units are explained in Table 1. 11

Acknowledgements

This study is part of an ongoing United States Geological Survey (USGS) National Earthquake Hazards Reduction Program (NEHRP) mapping project for Utah (Award 05HQGR0017). The authors thank the USGS for the funding of this research and the Utah Liquefaction Advisory Group for its participation in guiding and reviewing this work. The Utah Department of Transportation, local governmental agencies and private consulting companies should also be acknowledged for their donation of the borehole data used in this mapping project.

1 Introduction

Liquefaction induced ground failure causes considerable damage to the built environment. Types of ground failure include: flow failure, lateral spread, ground oscillation, differential settlement, loss of bearing capacity and ground fissures. Some locales along Utah's Wasatch Front have a considerable liquefaction hazard due the presence of loose, saturated granular soils and the proximity to sources of significant seismic ground shaking such as the Wasatch and West Valley fault zones.

The Utah Liquefaction Advisory Group (ULAG) was formed in 2003 under the auspices of the Utah Geological Survey to oversee the liquefaction mapping effort in Utah. ULAG includes representatives of government, academia, and industry with expertise in liquefaction mapping. The group establishes a consensus on societal needs and technical capabilities, identifies data needs and mapping techniques, and forms a partnership to propose programs to accomplish the goals of the group. The guiding objectives presented in this section were developed ULAG in meetings held in Salt Lake City, Utah during March and April of 2003 and are reviewed and updated on an annual basis.

The program objectives established by ULAG in 2003 and updated annually are:

- Create a liquefaction database of relevant geotechnical factors and develop Geographic Information System (GIS) methods for probabilistic liquefaction hazard assessment using the database, strong motion estimates from the USGS National Seismic Hazard Map Program and appropriate site amplification factors to modify the strong motion estimates for soil effects.
- Develop methods to perform uncertainty analyses and/or quantify the uncertainties associated with the liquefaction-hazard mapping project.
- Correlate the GIS geotechnical database and surficial geological mapping to estimate geotechnical and properties for similar geological units in areas with limited or no subsurface data. These correlations will be used to better understand the liquefaction susceptibility of a given geological unit or facies and improve the quality of the liquefaction assessment in areas that are under sampled. Initial correlations will be developed during the pilot project and will continue in future mapped areas, as the data from additional geologic units and geographic areas are compiled.
- Compile the GIS database for other areas along the Wasatch Front using the pilot-project methods and complete the liquefaction triggering maps for these areas. The preliminary priority of data compilation and mapping is: Salt Lake County, Utah County, Weber-Davis Counties, Cache County and Box Elder County.
- Develop probabilistic methods to map the amount of liquefaction-induced horizontal ground displacement and liquefaction-induced settlement. These methods will use existing correlations that relate thickness of liquefiable layers and other soil factors to the potential for lateral spread displacement and settlement. This mapping will be done for the same areas as the probabilistic liquefaction-hazard maps.

- Study documented occurrences of deformed Quaternary soils to: 1) determine if deformation is liquefaction-induced or related to other mechanisms (for example, failure of underlying clay), which will help implement criteria similar to those of California for establishing liquefaction hazard zones based on the presence of historical liquefaction; and 2) determine the age of failed soils to establish the liquefaction hazard posed by latest Pleistocene Lake Bonneville deposits.

2 Project Status

During FY 2004, ULAG was funded to gather subsurface data in northern Salt Lake County and to develop a probabilistic liquefaction-triggering map for that area. In conjunction with this effort, geotechnical and geological data were obtained and entered into a geographic information system (GIS) database by the University of Utah. The types of subsurface data gathered included: 1) standard penetration tests (SPT), 2) cone penetrometer tests (CPT), 3) shear wave velocity (V_s) measurements, 4) soil type, laboratory classification tests and Atterberg limits, 5) grain-size analysis and 6) correlations with geological surficial units. The GIS database for Salt Lake County has been completed and can be found at: www.civil.utah.edu\~bartlett\ulag.html

In addition during FY2004, the University of Utah developed ARC GIS code for lateral spread analysis (Bartlett et al. 2005). From the code, a draft lateral spread map for a M7.0 scenario earthquake northern Salt Lake Valley was developed (Figure 1) (Bartlett et al. 2005).

In FY2005, the University of Utah was funded to gather geotechnical data in the southern part of Salt Lake Valley and to correlated these boreholes with the geological mapping.

3 Creation of an ArcGIS Subsurface Database

The geotechnical data needed to calculate the liquefaction hazard were obtained from several different sources and screened using quality indicators developed by Bartlett et al. (2005). The database structure is given in Appendix A of this report and is further described in Bartlett et al. (2005). The subsurface database contains SPT, CPT, V_s, groundwater levels, soil descriptions, and other classification properties such as fines content and Atterberg limits. Overall there were approximately 930 SPT boreholes and 400 CPT soundings collected in Salt Lake County. The SPT borehole locations are shown in Figure 1. The GIS database for Salt Lake County for data collection activies during FY2004 and FY2005 can be found at: www.civil.utah.edu\~bartlett\ulag.html.

A primary source of the geotechnical borehole data was the Utah Department of Transportation, which provided a significant electronic subsurface database from the recently finished I-15 Reconstruction project. Other geotechnical data used for the mapping project were obtained from several sources. Data from previous site-specific liquefaction studies were obtained from the Salt Lake County Government. Data from the I-15 Reconstruction Project and other highway investigations were provided by the Utah Department of Transportation (UDOT). These data include borehole logs for the older Interstate 80 (I-80) and Interstate 215 (I-215) construction projects. The I-15 Reconstruction Project subsurface data is a very extensive portion of the database. It was available in electronic format (GINT® database), allowing for a more rapid transfer of data to the ArcGIS® database. In addition, the boring data used by Anderson et al. (1986) from their previous mappings were obtained from the Utah Geological Survey and were used to fill in gaps where more recent data was unavailable. Some geotechnical consultants also provided data for the mapping effort. These data, in combination, allow a reasonable sampling of most geologic units and had sufficient spatial distribution to perform the various analyses.

Because the quality of the subsurface data varied, due to its numerous sources, some properties were estimated to fill in data gaps. To keep track of estimated properties, a system of data qualifiers was implemented. The data tables include data qualifier fields for important information, ranking the data quality from 1 to 3. A "1" was given to data and supporting information that was recorded in the originating report. A "2" was given to the data that could be reasonably estimated from nearby borehole logs from the originating report. A "3" denoted data that was estimated from another source beyond the originating report.

Some of the boreholes did not have recorded depths to groundwater. However, because the groundwater table recorded in the borehole data was found to be reasonably consistent in the northern Salt Lake Valley, an inverse distance square method was used to interpolate groundwater depths for missing data. This method was also compared to results from Kriging and Spline interpolation methods and produced reasonable results; thus it was used to produce the groundwater map (Bartlett et al. 2005).

The amount and spatial distribution of the collected data provided a reasonable characterization of most of the geologic units in the mapped area; however, some judgment was applied, as discussed in the map production section of this paper. In addition, some required information was missing in some of the SPT boreholes (e.g., soil unit weight, fines content, etc.). For these boreholes, Microsoft Visual Basic for Applications (VBA) routines were used to fill in data gaps by averaging according to soil type and geologic unit (Bartlett et al., 2005). However, in no case was SPT blowcount values estimated; if this information was not available, the corresponding borehole information was not used.

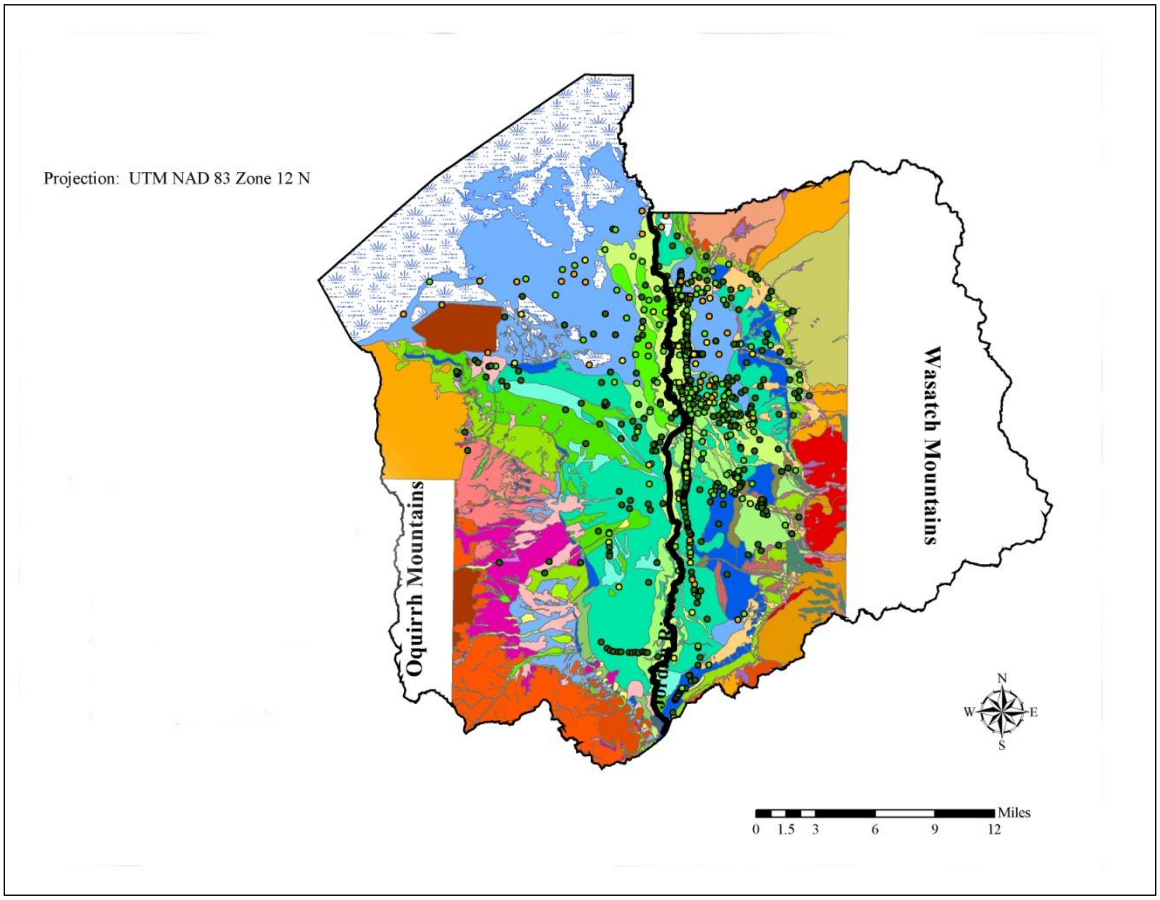

Figure 1. Surficial geologic map and SPT borehole locations.

4 Correlation of Geologic and Geotechnical Database with Surficial Geologic Mapping

The geologic data for Salt Lake Valley was acquired from two main sources: a surficial geologic map of the Salt Lake City segment of the Wasatch fault zone (Personius and Scott, 1992) for the eastern side of the valley and several quadrangle maps (Biek et al., 2004 and Biek, 2005) that cover the remainder of the valley. These maps were combined to produce the geologic map of the entire valley that was later used in conjunction with the hazard calculations to define the extent of each hazard zone. Table 1 summarizes the geologic map units shown on Figure 2.

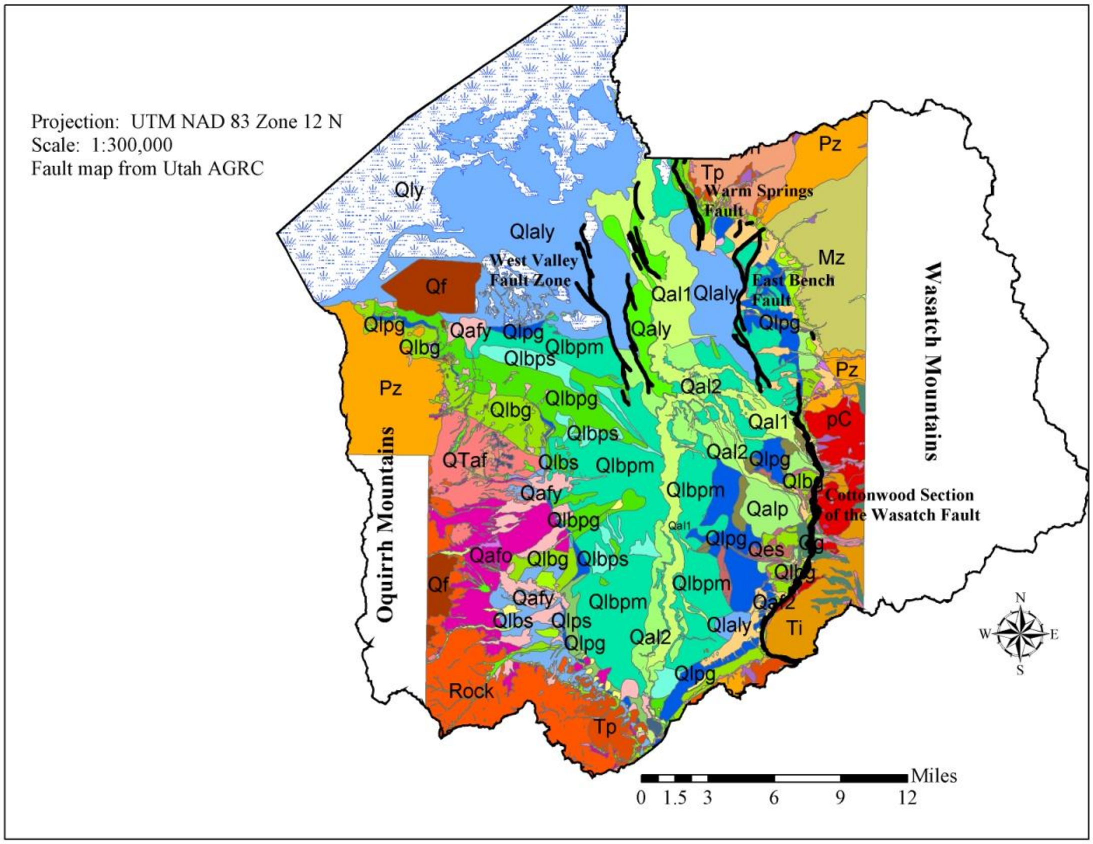

Figure 2. Surficial geologic map of Salt Lake Valley (modified from Personius and Scott, 1992; Biek et al., 2004; and Biek, 2005). Quartenary faults are shown by heavy lines; symbols for geological units are explained in Table 1.

Table 1. Geological units and descriptions

Name	Description	Age
Qaf1	Fan alluvium 1	Upper Holocene
Qaf2	Fan alluvium 2	Middle Holocene - Upper Pleistocene
Qafo	Older fan alluvium, undivided	Middle Pleistocene
Qafy	Younger fan alluvium, undivided	Holocene - Uppermost Pleistocene
Qal1	Stream alluvium 1	Upper Holocene
Qal2	Stream alluvium 2	Middle Holocene - Uppermost Pleistocene
Qaly	Younger stream alluvium, undivided	Holocene - Uppermost Pleistocene
Qalp	Stream alluvium related to Lake Bonneville regressive phase	Uppermost Pleistocene
Qes	Eolian sand	Holocene - Upper Pleistocene
Qf	Artificial fill	Historical
Qg	Glacial deposits	Middle - Upper Pleistocene
Qlaly	Lacustrine, marsh, and alluvial deposits, undivided	Holocene - Upper Pleistocene
Qlao	Lacustrine and alluvial deposits, undivided	Holocene - Upper Pleistocene
Qlbg	Lacustrine sand and gravel related to Lake Bonneville transgressive phase	Upper Pleistocene
Qlbm	Lacustrine clay and silt related to Lake Bonneville transgressive phase	Upper Pleistocene
Qlbpg	Lacustrine sand and gravel, undivided by Lake Bonneville phase	Upper Pleistocene
Qlbps	Lacustrine sand and silt, undivided by Lake Bonneville phase	Upper Pleistocene
Qlpg	Lacustrine sand and gravel related to Lake Bonneville regressive phase	Upper Pleistocene
Qlps	Lacustrine sand and silt related to Lake Bonneville regressive phase	Upper Pleistocene
Qly	Marsh and lacustrine deposits, undivided	Holocene - Uppermost Pleistocene
QTaf	Oldest alluvial-fan deposits	Middle Pleistocene
Rock	Bedrock	Various

5 References

Anderson, L. R., Keaton, J. R., Spitzley, J. E., and Allen, A. C., 1986, "Liquefaction potential map for Salt Lake County, Utah:" Utah State University Department of Civil and Environmental Engineering and Dames and Moore, unpublished final technical report prepared for the U.S. Geological Survey, National Earthquake Hazards Reduction Program Award No. 14-08-0001-19910, 48 p.; published as Utah Geological Survey Contract Report 94-9, 1994.

Bartlett S. F., Olsen, M. J., and Solomon, B. J., 2005, "Lateral Spread Hazard Mapping of Northern Salt Lake County for a Magnitude 7.0 Scenario Earthquake," United States Geological Survey, USGS Award No. 04HQGR0026, 218 p.

Biek, R. F., Solomon, B. J., Keith, J. D., and Smith T. W., 2004, "Interim geologic maps of the Copperton, Magna, and Tickville Spring Quadrangles, Salt Lake and Utah Counties, Utah:" Utah Geological Survey Open-File Report 434, scale 1:24,000.

Biek, R. F., 2005, "Geologic map of the Jordan Narrows Quadrangle, Salt Lake and Utah Counties, Utah:" Utah Geological Survey Map 208, scale 1:24,000.

Personius, S. F., and Scott, W. E., 1992, "Surficial geologic map of the Salt Lake City segment and parts of adjacent segments of the Wasatch fault zone, Davis, Salt Lake, and Utah Counties, Utah:" U.S. Geological Survey Miscellaneous Investigations Map I-2106, scale 1:50,000.

Robertson, P.K., 1990, "Soil Classification Using CPT," Canadian Geotechnical Journal, Vol. 27 No. 1, p. 151-158.

6 Appendix A – Data Base Structure

Database structure for the SITE table

Field Name	Type	Description
OBJECTIDNO	AutoNumber	This is a field for ArcGIS- DO NOT EDIT THIS FIELD.
SITEIDNO	Integer	Site identification number
RENUMBERED	Yes/No	Used for renumbering site id
REPORT	Text	Name of Report for Borehole Data
REFERENCE	Text	Name and Date of Authors
SITENAME	Text	Name of Site
BORING	Text	Boring Name
PAGENO	Text	Pg. No. in report of Boring log
BOREELEV	Double	Surface Elevation of Borehole (m)
ELEVEST	Single	Quality of Elevation Estimate: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
BORINGDEPTH	Double	The total depth of the borehole
DATE_	Date/Time	Date of Boring
LOCATION	Text	Street Address
NORTHING	Double	Northing Coordinate (UTM NAD83 Z12N)
EASTING	Double	Easting Coordinate (UTM NAD83 Z12N)
LATITUDE	Double	Latitude of Boring
LONGITUDE	Double	Longitude of Boring
LATITEST	Text	Quality of Lat & Long Est: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
GWDATE	Date/Time	Date of Groundwater
GWEST	Long Integer	Quality of Depth to Groundwater
DEPTHGW	Double	Depth to Groundwater (ft)
DRILLCONT	Text	The Contractor doing the drilling
LOGGER	Text	The name of the person logging the boring
RIGTYPE	Text	Name or Type of Drill Rig
DRILLMETH	Text	Method used for drilling
BoreDiam	Double	Diameter of the Borehole (in) for calculating corrected Blow Counts (CB)
BoreDiamEst	Integer	Quality of the Estimate 1= documented, 2= reasonably estimated, 3= guess from other source
BIT_	Text	Type of Bit used
DRILLER	Text	Name of Driller
HAMMER_TYPE	Text	Type of SPT Hammer
HAMMER_MASS	Double	The hammer mass used to drive the split-spoon sampler. The standard mass is 140 lb (63.5 kg)
HAMMER_ RELEASE	Text	The mechanism used to lift and drop the hammer.
HAMMER_DROP _HEIGHT	Long Integer	The hammer drop height for SPT Penetration.
ENERGY	Integer	[HAM_ER] Hammer Energy Ratio (%)

HAMEST	Text	Quality of Hammer Est: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
ROD_TYPE	Text	Type of Drilling Rod
ROD_ EXTERNAL	Long Integer	The external diameter of the sampling rods.
ROD_WEIGHT	Long Integer	The drive rod weight per unit length.
CATHEAD_DIAMETER	Long Integer	The diameter of the cathead used to pull the rope attached to the hammer. Typical diameters range from 6 to 10 inches (150 to 250 mm)
ROPE_TURNS	Long Integer	The number of rope turns on the cathead for performing the SPT. Max allowed Number of turns is 2 1/4.
RODTYPEEST	Text	Quality of Rod Doc: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
Local Slope	Double	The local slope at the site (Calculated using ArcGIS Spatial Analyst). Filled in by the Slopefinder Routine.
SLOPE	Double	The slope according to the Bartlett/Youd Lateral Spread Regression Definition. Filled in by the Slopefinder Routine.
GEOLUNIT	Text	The Surficial Geological Unit that the SITE is located in
VS12	Double	The 12 m (40ft) Shear Wave Velocity Measurement (filled in by VSFinder). Used to calculate rd.
VS30	Double	The 30m Shear Wave Velocity Measurement (filled in by VSFinder). Used to classify the SITE according to IBC
VSEST	Integer	The quality of the VS measurement 1= test done in the borehole, 2= test done nearby in the same geological unit, 3= guess from other source
WFreeFace	Double	The Free Face Ratio (H/L*100%). Filled in by the Wfinder Routine.
R	Double	The horizontal distance to the fault (R, km). Filled in by the RFinder Routine.
EARTHQUAKE	Text	Earthquake Used in Analysis
MAGNITUDE	Double	Magnitude of Earthquake
acc	Double	The estimated peak ground acceleration at the site (g). Filled in by the Acceleration Reader Routine
accEst	Integer	The quality of the Estimate of the acceleration
DH	Double	The maximum predicted lateral spreading in the borehole. Filled in by the Lateral Spread Calculator Routine.
NOTES	Memo	This is a memo field for any additional notes that need to be attached to the record.
PDF	Memo	This is a hyperlink to the pdf file where a scanned image of the log can be found
Shape	OLE Object	This is a field for ArcGIS- DO NOT EDIT THIS FIELD.

Database structure for the BLOW and BLOWFILL tables

Name	Type	Description
OBJECTID	AutoNumber	This field is used by ArcGIS as a unique identifier for each record
SITEIDNO	Integer	Site identification number
BOREIDNO	Text	Same as BORING in site.dbf
RENUMBERED	Yes/No	Used for renumbering site ID
DEPTH	Double	Depth of Sample (ft)
DEPTHM	Double	Depth of Sample (m)
BOUNDARY	Yes/No	If recorded layer is boundary. T=layer boundary
ELEV	Double	Elevation of sample (ft) do not fill in this field
ELEVM	Double	Elevation of sample (m) do not need to fill in this field
NVALUE	Double	[NM] SPT N value (blow/ft)
BLOWS1	Long Integer	Blow Count for first 6"
BLOWS2	Long Integer	Blow Count for second 6"
BLOWS3	Long Integer	Blow Count for third 6"
BLOWS4	Long Integer	Blow Count for fourth 6"
ESTNM	Text	Quality of SPT Estimate: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
SAMPLER	Text	Type of Sampler ("Standard Split-Spoon Sampler";"Dames and Moore Sampler";"Modified California Sampler")
SAMPLEREST	Integer	Qualtiy of Sampler Doc: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
SAMPLER_INSIDE_DIAMETER	Double	[SAMPLERID] Inside dia. of sampler (mm)
SAMPLER_OUTSIDE_DIAMETER	Double	[SAMPLEROD] Outside dia. of sampler (mm)
SAMPLERLENGTH	Double	The length of the split spoon sampler
LINER	Yes/No	The use of a liner in the sampling
BASKET	Yes/No	The use of a basket retainer
NMCPT	Double	SPT N Estimated from CPT
CPTQUAL	Long Integer	Quality of CPT Data: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
SOILTYPE	Text	Soil Type Description
UCSC	Text	Unified Soil Classification System Label
ESTUCSC	Text	Quality of UCSC: 1=laboratory 2=field 3= guess from other source
AASHTO	Text	Aashto Classification w/ Group Index
ESTAASHTO	Integer	Quality of AASHTO Classification: 1=laboratory 2=field 3= guess from other source
GEOLUNIT	Text	Name of Geologic Unit
ESTGEOL	Text	Quality of Geological Estimate: 1 = mapped, 2 = guess when it is deeper, 3 = geotechnical report w/o geologist

DEPENV	Text	Depositional Environment
SITERESUN	Text	Site Response Unit
ESTSITERES	Integer	Site Response Data Qualifier: 1 = mapped, 2 = guess when it is deeper, 3 = geotechnical report without geologist
CLASS	Double	Do not need to fill in this field
DRYUNIT	Double	Dry Unit Weight (kN/m^3)
ESTDRY	Text	Quality of DUW: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
WETUNIT	Double	Moist Unit Weight (kN/m^3)
ESTWET	Text	Quality of MUW: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
DRYUNITPCF	Double	Dry unit weight (pcf)
WETUNITPCF	Double	Wet Unit Weight (pcf)
MOISTURE_ CONTENT	Double	The moisture content (%) of the soil
ESTMOIST	Text	Quality of WC: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
DENSITY	Double	Relative Soil Density- Do not fill out this field
RELDENSITY	Double	Relative Soil Density: Do not fill out this field
SPGRAVITY	Double	Specific Gravity: 2.65 sand, 2.70 silt, and 2.75 clay
ESTSPGR	Text	Quality of Specific Gravity: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
PERGRAVEL	Double	Gravel Content (%)
PERSAND	Double	Sand Content (%)
FINES	Double	Fines Content (%)
CLAY	Integer	Clay Content (%)
ESTFINES	Text	Quality of Fines Estimate: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
ESTCLAY	Text	Quality of Clay Estimate: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
NONLIQ	Yes/No	T= Nonliquefiable
ESTNONLIQ	Text	Quality of Nonliquefiable Estimate:
D50	Double	Mean Grain size (mm)
D50EST	Text	Quality of D50 Estimate: 1 = documented, 2 = reasonably estimated, 3 = guess from other source
LIQUIDLIMIT	Double	Liquid Limit
LIQUIDLIMIT_ METHOD	Text	Method used for determining liquid limit
LIQUIDLIMIT_PREP	Text	Method used for preparing sample for liquid limit
PLASTICLIMIT	Double	Plastic Limit
PLASTICINDEX	Double	Plastic Index = Liquid Limit - Plastic Limit
SHRINKAGELIMIT	Double	Shrinkage Limit
LIQUIDINDEX	Double	The Liquid Index

NATURALWATERCONTENT	Double	Natural Water Content
ESTATT	Integer	Data Qualifier for Atterberg Limits: 1 = documented on report, 2 = reasonably estimated from another layer on same report, 3 = guess from other source
BOTTOM	Double	The depth to the bottom of the current layer
VS	Double	Shear Wave Velocity
CPT	Yes/No	If the record is CPT data
QC	Double	For CPT Data
QCUNC	Double	For CPT Data
SLEEVE	Double	For CPT Data
FRATIO	Double	For CPT Data
PPRESSURE	Double	For CPT Data
EXCIT	Double	For CPT Data
QCEST	Text	For CPT Data
EXCITATION	Double	For CPT Data
INTERP	Text	For CPT Data
MoistUnitWeight	Double	The calculated moist unit weight. From the Stress Calculator Routine.
SatUnitWeight	Double	The calculated saturated unit weight. From the Stress Calculator Routine.
TotalStress	Double	The total stress at the depth of the record. From the Stress Calculator Routine.
EffectiveStress	Double	The effective Stress at the depth of the record. From the Stress Calculator Routine.
CB	Double	The correction for the borehole diameter. From the N160 Calculator Routine.
CE	Double	The correction for the energy ratio. From the N160 Calculator Routine.
CN	Double	The overburden correction factor. From the N160 Calculator Routine.
CR	Double	The correction for the rod length. From the N160 Calculator Routine.
CS	Double	The correction for the sampler. From the N160 Calculator Routine.
N160	Double	The corrected blow count for an energy of 60% and corrected for overburden. From the N160 Calculator Routine.
rd	Double	The reduction factor for depth. From the Atrigger Calculator Routine.
CRR	Double	Cyclic Resistance Ratio. From the Atrigger Calculator Routine.
N160CS	Double	The blow count corrected for clean sands. From the Atrigger Calculator Routine.
Ksigma	Double	A correction for depth. From the Atrigger Calculator.
MSF	Double	A magnitude scaling factor. From the Atrigger Calculator.
Atrig	Double	The acceleration required to trigger liquefaction. From the Atrigger Calculator Routine.

liqtrig	Integer	Indicates if liquefaction was triggered. (the acceleration at the site was greater than that required to trigger liquefaction). From the Atrigger Calculator Routine.
T15	Double	The thickness of the spreadable layer (m). From the Layer Merger (15Calc) Routine
D5015	Double	The average mean grain size D5015 for the spreadable layer. From the Layer Merger (15Calc) Routine
F15	Double	The average fines content for the spreadable layer. From the Layer Merger (15Calc) Routine
zLiqTop	Double	The depth at the top of the liquefiable layer. From the Layer Merger (15Calc) Routine
zLiqBot	Double	The depth at the bottom of the liquefiable layer. From the Layer Merger (15Calc) Routine
DHS	Double	The gently sloping terrain model predicted value of lateral spreading (m). From the Lateral Spread Calculator Routine.
DHW	Double	The free face model predicted value of lateral spreading (m). From the Layer Merger (15Calc) Routine.
Comments	Text	A field for generic comments.
Footnote	Text	References the Footnote table when it is needed
TESTS	Text	Indicates other tests done on the soil at that depth. Not Required
Recovery	Double	The percent of the sample that was recovered. Not Required
Lithology	Integer	1= the record is just there as a soil description, but should not be used in the analysis. Not Required.
ERRORDUWorGS	Integer	Indicates if an estimate of 15 kN/m3 needed to be used for the Dry Unit Weight, or if 2.7 was needed to be used for the specific gravity in the Routines. Created by the Stress Calculator routine.