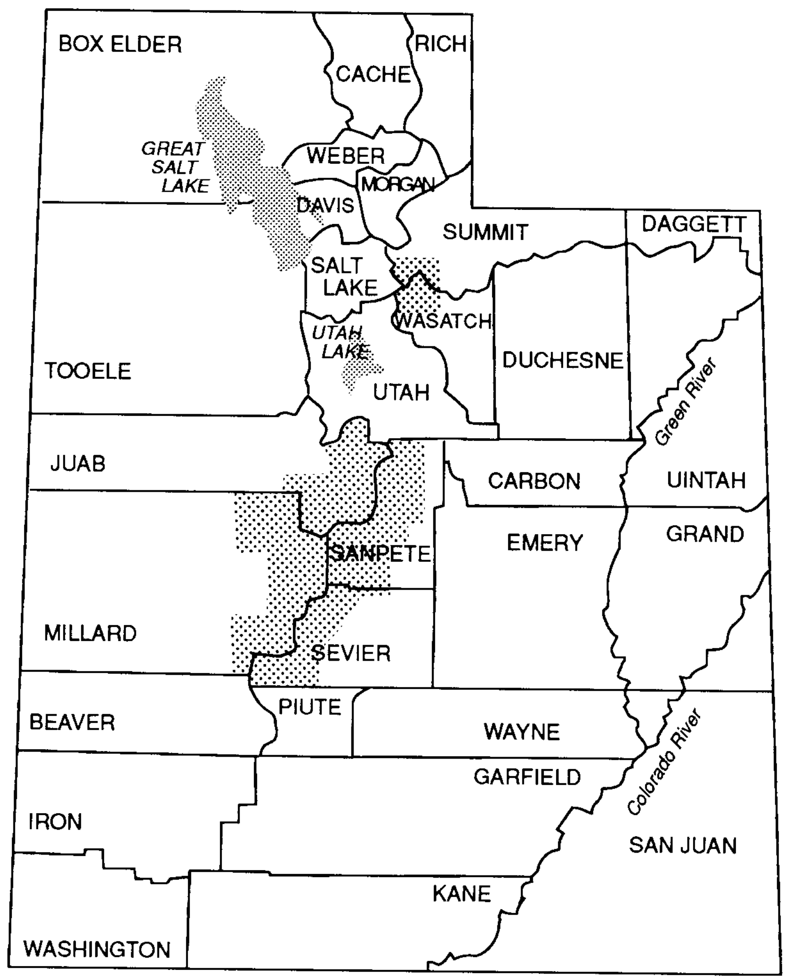
LIQUEFACTION POTENTIAL MAP FOR CENTRAL UTAH NON-TECHNICAL SUMMARY

by

Loren R. Anderson

Utah State University



CONTRACT REPORT 94-5 June 1994

UTAH GEOLOGICAL SURVEY

a division of

UTAH DEPARTMENT OF NATURAL RESOURCES

LIQUEFACTION POTENTIAL MAP FOR CENTRAL UTAH NON-TECHNICAL SUMMARY

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1/Introduction

It is well-known that a major earthquake causes tremendous damage and loss of life. The earthquake damage comes from one or more of the following consequences: rupture of the ground surface along fault traces, ground shaking, subsidence, liquefaction, landslides, tsunamis and seiches, flooding from dam failure, and fire and blasts. These potential causes of damage must be considered in assessing earthquake risk in a given region. We must consider the chance that an earthquake will occur, and if an earthquake does occur, determine whether or not communities in the area would be vulnerable to these causes of damage.

Damage potential from any one of the earthquake consequences listed above depends a great deal on the area that is involved. For example, ground surface rupture generally occurs during moderate to large magnitude earthquakes, magnitude six or larger, but the direct damage from the rupture only occurs to buildings and structures located directly on the rupture zone. Strong ground shaking, on the other hand, occurs over a large area and affects structures more than a hundred miles from the earthquake source. Because of this large affected area, strong ground shaking causes most of the damage from earthquakes.

Liquefaction is a phenomenon that occurs in loose saturated sandy soils as a result of ground shaking. When soil liquefies, it behaves like quicksand--it loses its ability to support buildings; it causes landslides to occur; it causes buried tanks to rise to the surface; and it causes the ground surface to shift up to several tens of feet (lateral spread landslide). Structures that are supported on soils that liquefy can be severely damaged and buried utilities can be ripped apart. Since liquefaction is caused by ground shaking, the damaged area can be extensive.

Soil liquefaction has been a major cause of property damage in many historic earthquakes such as the 1906 San Francisco earthquake; the 1964 Niigata, Japan and Anchorage, Alaska earthquakes; the 1971 San Fernando Valley earthquake; and the 1989 Loma Prieta (San Francisco Bay area) earthquake. Liquefaction induced lateral spreading occurred in San Francisco's Marina District during the Loma Prieta earthquake causing the collapse of a number of two and three story wood framed structures. Juvenile Hall, in the San Fernando Valley, was ripped apart and underground utilities were broken from the lateral spreading that occurred during the 1971 earthquake. In Niigata, Japan large apartment buildings tipped over when the liquefied soil below the building lost its bearing capacity. The loss of underground utilities due to lateral spreading can lead to further damage from the loss of the utility's service. The fire that followed the 1906 earthquake in San Francisco burned essentially unchecked because the loss of water mains from the lateral spreading of liquefied soil made it impossible to fight the fire. Many railroad and highway bridges have also been lost during past earthquakes when liquefied soils have caused the supporting abutments and piers to move enough to allow the bridge deck to fall. The loss of these transportation lifelines can significantly delay the recovery time from the damaging effects of earthquakes. The damage attributed to liquefaction-induced failures in Niigata, Japan was near $1 billion. In Anchorage, Alaska nearly 60% of the estimated $300 million in damages was due to liquefaction-induced failures.

Liquefaction is also a concern along the Wasatch Front because the soil, ground water, and seismic conditions make the region vulnerable to liquefaction-induced ground failure. This phenomena was observed in the 1901 Richfield earthquake, the 1934 Hansel Valley earthquake, and in the 1962 Cache Valley earthquake. There is strong geological evidence that prehistoric earthquakes have caused large liquefaction-induced lateral spread landslides in Salt Lake, Weber and Davis Counties.

This non-technical summary is the result of a study (sponsored by the U. S. Geological Survey) that developed liquefaction potential maps for Central Utah. These maps can be used for land-use planning purposes, for assessing the need for a more detailed liquefaction evaluation, and for assessing liquefaction risk. The original reports that were prepared for the U. S. Geological Survey describe the methodology for evaluating liquefaction potential and the details for preparing the liquefaction potential maps. Subsurface conditions and the local seismicity of the area are also described in the reports.

2/Methodology

We can evaluate liquefaction potential by considering whether or not the soil is "susceptible" to liquefaction, and whether or not the soil will be shaken enough to give the soil the "opportunity" to liquefy. Both of these factors must be considered in order to describe the liquefaction potential.

Whether or not a soil is susceptible to liquefaction depends on the type of soil, the density of the soil, and its saturation. Thus, the liquefaction susceptibility of soils can be determined by drilling holes (borings) into the ground and running tests on the soils located at various depths. An evaluation is made based on soil type, soil density, soil age, and whether or not it has been subjected to ground shaking. The soils that are the most susceptible to liquefaction are saturated loose fine-grained sandy soils. Coarse gravel soils generally don't liquefy nor do most clay soils.

To evaluate liquefaction susceptibility, we obtained field and laboratory information from geotechnical investigations by private consulting firms, state and local government agencies, and the geotechnical program conducted as part of this study. The liquefaction susceptibility for each boring location was then quantified by calculating the earthquake-induced acceleration (ground motion) that would be required to cause liquefaction. This acceleration was referred to as the "critical acceleration."

The liquefaction opportunity was characterized by evaluating the seismicity of the area. This was described by the probability of exceeding various levels of ground surface accelerations (intensity of shaking) in a period of 100 years. Consideration was given to the activity of earthquake faults in the area and the location of those faults. For small areas the seismicity was considered uniform, but for large areas the seismicity (and hence liquefaction opportunity) could vary significantly. For example, in describing the liquefaction opportunity for Davis County the seismicity was considered to be the same for the entire county. On the other hand, the seismicity of Logan in Cache County was evaluated to be significantly less than the seismicity of Brigham City in Box Elder County because Logan is farther from the Wasatch Front than Brigham City.

The liquefaction potential at each boring location was then defined by considering both liquefaction susceptibility and opportunity. This was done by determining the probability of exceeding the critical acceleration in 100 years. The boring site was described as having high, moderate, low, or very low liquefaction potential as defined in Table 1.

Table 1. Liquefaction Potential Rating System

Liquefaction Potential	Probability of Exceeding the Critical Acceleration
High	>50%
Moderate	10-50%
Low	5-10%
Very Low	<5%

The critical acceleration values for each boring site were plotted on an area map. Then a two-step procedure to develop the Liquefaction Potential Map was used. First, contoured lines that represented equal critical acceleration were drawn, then the study area was divided into zones of high, moderate, low and very low liquefaction potential as defined in Table 1. After the liquefaction potential zones were identified from the critical acceleration contours, they were adjusted to reflect the geology of the area. This adjustment was important because subsurface data and critical acceleration values were available only at selected locations and did not reflect geologic features such as stream beds and Lake Bonneville shorelines.

3/Interpretation of Maps

The liquefaction potential maps that accompany this report describe the mapped areas on a regional basis. The maps are accurate to scale of 1:48,000. This means they can be used for activities such as land-use planning and for identifying high liquefaction hazard areas that may require further study. The maps are not intended to be used for site-specific evaluations.

In general, sites classified as high liquefaction potential are likely to have liquefiable soils below the ground surface. However, whether or not the occurrence of liquefaction would lead to ground failure depends on factors determined by a site-specific geotechnical investigation. Furthermore, when the final contours on the map were drawn, boring sites with low liquefaction potential may have been located within a high liquefaction area if they did not appear to be representative of the general area. At the scale that the liquefaction potential was mapped, it was determined that showing small islands of low liquefaction potential in a sea of high liquefaction potential would be misleading.

4/Use of Maps

The liquefaction potential maps can be used for regional planning and ordinance purposes, but as explained above, **the maps should not be for site-specific evaluations**. Additionally, when using the liquefaction potential maps other natural hazards must not be ignored. Avoiding a liquefaction risk by unknowingly relocating a facility to an area with a high risk of flooding, for example, may increase the risk of damage.

It is irresponsible to ignore a natural hazard that is known to exist. However, when it is determined that a facility may be exposed to a natural hazard, the response should depend on the type and use of the facility. For example, the consequences of liquefaction-induced ground failure(and hence the economic risk and the risk of life loss) will be much greater for a critical facility or high occupance structure than for a single family dwelling. Salt Lake County recognized the importance of this concept. Consequently, in 1989 the Salt Lake County Commissioner approved a Natural Hazards Overlay as part of the County's Zoning Ordinance. In dealing with the liquefaction hazard, the ordinance uses Table 2 to specify whether or not a liquefaction report will be required for a proposed development. If the type and use of a facility and the particular liquefaction potential zone indicate that a liquefaction report is required, then a geotechnical investigation addressing the problem must be conducted. The results of the site-specific investigation will then be used to determine further actions. It may turn out that the site has a low liquefaction potential and further consideration is not warranted. On the other hand, the liquefaction potential may be confirmed to be high. In this case, the site-specific investigation can be used to study alternative risk-reduction strategies. The method used to mitigate the problem can then be selected by the owner with county approval.

If a site-specific investigation shows that a certain facility is located in an area with high exposure to a natural hazard, there are several acceptable responses: understand the hazard and accept the risk, mitigate the hazard, modify what is at risk (design to accommodate the hazard), or avoid the hazard. In no case should the hazard be ignored.

5/Conclusions

Building codes attempt to protect structures against the effects of earthquakes by requiring minimum design standards. The need for building codes has been well established and the use of these codes in the United States has contributed significantly to the ability of many modern structures to resist the strong ground shaking forces induced by earthquakes. Unfortunately, other natural hazards--such as liquefaction--have not received the attention that building codes give to ground shaking. Ground failure caused by liquefaction is a primary hazard associated with earthquakes in Utah and **cannot be ignored**. The first step in dealing with a liquefaction hazard is knowing where liquefaction might occur. Therefore, Liquefaction Potential Maps have been developed for Central Utah, showing areas where liquefaction is most likely to occur.

Table 2. Is a Liquefaction Report Required?

PROPOSED LAND USE (Type of Facility)	LIQUEFACTION POTENTIAL AREA: HIGH and MODERATE	LIQUEFACTION POTENTIAL AREA: LOW and VERY LOW
CRITICAL FACILITIES(Essential and Hazardous Facilities, and Special Occupancy Structures; as defined in NHO Section 19.75.020-C)	YES	YES
INDUSTRIAL & COMMERCIAL BUILDINGS (>2 stories or >5,000 sq. feet)	YES	NO
MULTI-FAMILY RESIDENCES (4 or more units per acres) and ALL OTHER INDUSTRIAL and COMMERCIAL	YES	NO
RESIDENTIAL SUBDIVISION, SINGLE LOTS, and MULTI-FAMILY DWELLINGS (less than 4 units/acre)	*NO	NO
*Although No Special Study is Required, Disclosure is Required		

LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION		
LIQUEFACTION POTENTIAL	CRITICAL ACCELERATION	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	< .07 g	> 50 %
MODERATE	.07 - .17 g	50 - 10 %
LOW	.17 - .22 g	10 - 5 %
VERY LOW	> .22 g	< 5 %

UTAH STATE UNIVERSITY

LIQUEFACTION POTENTIAL

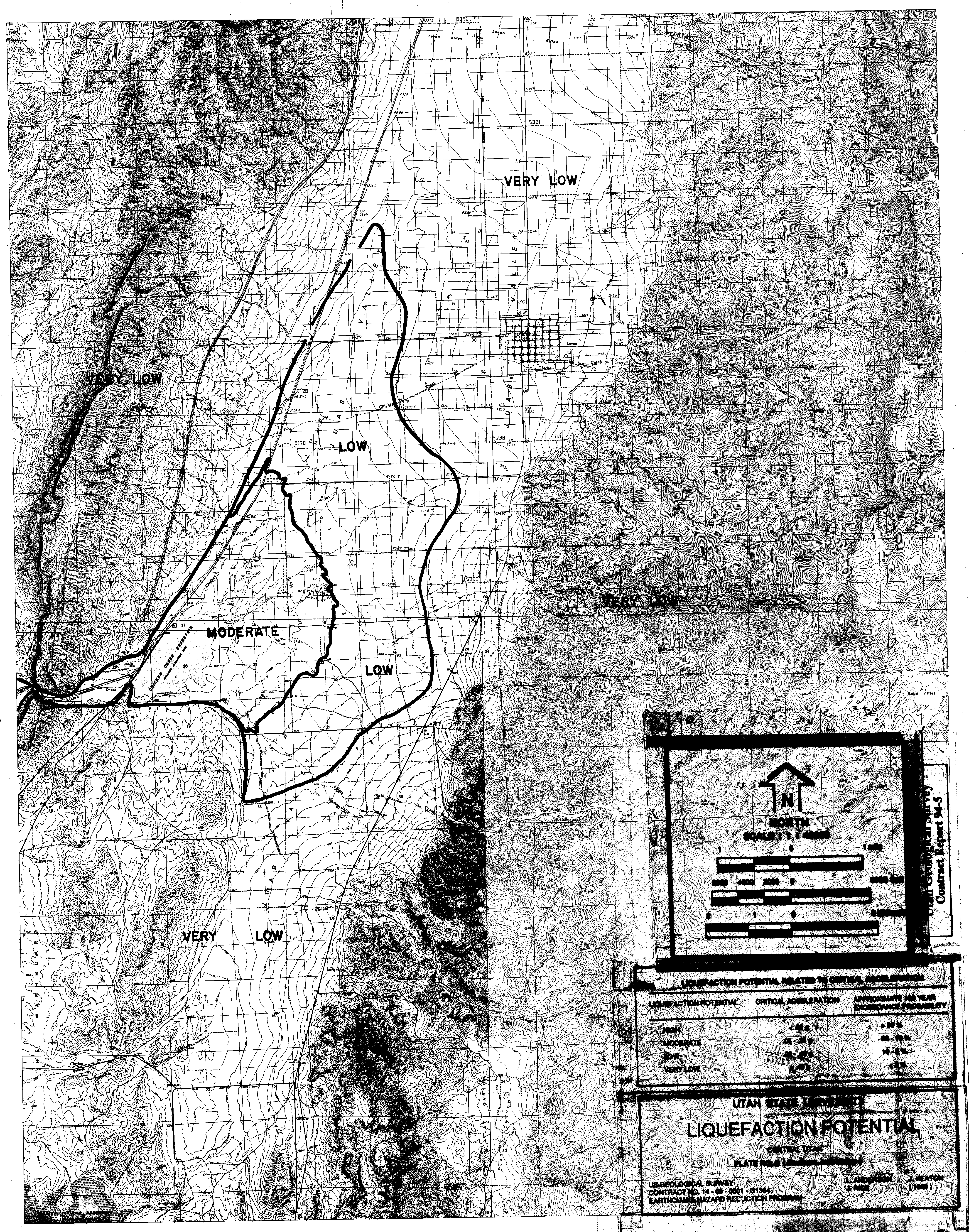
CENTRAL UTAH

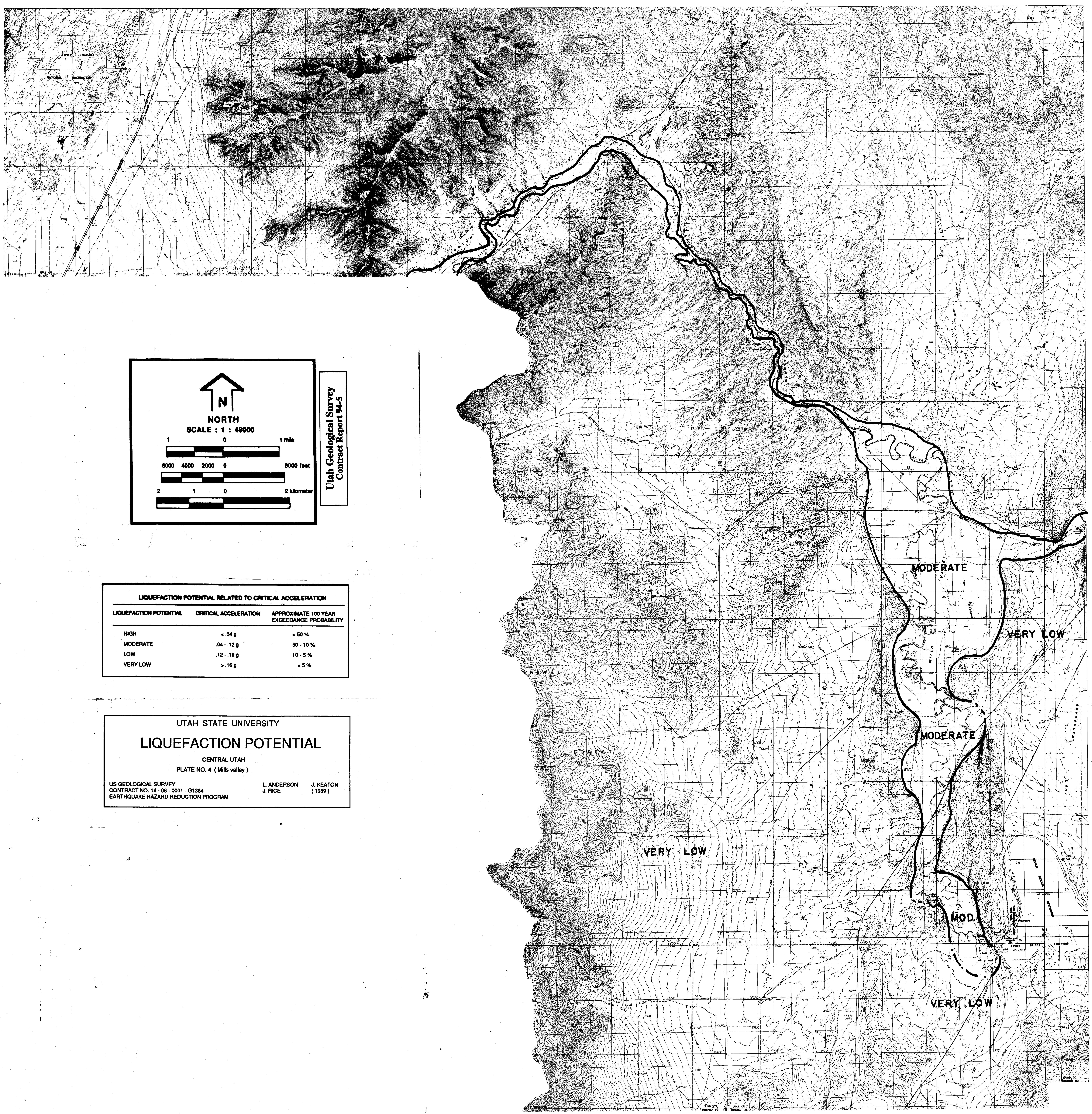
PLATE NO. 1 (Park City - Heber)

US GEOLOGICAL SURVEY
CONTRACT NO. 14 - 08 - 0001 - G1384
EARTHQUAKE HAZARD REDUCTION PROGRAM

L. ANDERSON J. KEATON
J. RICE (1989)


N
NORTH
SCALE : 1 : 48000
1 0 1 mile
6000 4000 2000 0 6000 feet
2 1 0 2 kilometer
Utah Geological Survey
Contract Report 94-5
LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION
LIQUEFACTION POTENTIAL | CRITICAL ACCELERATION | APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH | < .08 g | > 50 %
MODERATE | .08 - .26 g | 50 - 10 %
LOW | .26 - .4g | 10 - 5 %
VERY LOW | > .4g | < 5 %
UTAH STATE UNIVERSITY
LIQUEFACTION POTENTIAL
CENTRAL UTAH
PLATE NO. 2 (Northern Juab Valley)
US GEOLOGICAL SURVEY
CONTRACT NO. 14 - 08 - 0001 - G1384
EARTHQUAKE HAZARD REDUCTION PROGRAM
L. ANDERSON
J. RICE
J. KEATON
(1989)
MODERATE
VERY LOW
NL 2119
CS1
65
12
16
NL 2121
NL 2120
NL 2122
NL 2118
MODERATE
NL 2116
NL 2117
VERY LOW
NL 2302
BH3
NL
NL 2115
VERY LOW
MODERATE
27
1251
5.9
BH2
NL 2304
50
55
NL 2312
2111
NL 2313
VERY LOW
45
NL 2110
JUAB VALLEY


VERY LOW
VERY LOW
LOW
MODERATE
LOW
VERY LOW
VERY LOW
VALLEY
Chicken Creek
NORTH
Utah Geological Survey
Contract Report 94-5
LIQUEFACTION POTENTIAL
CRITICAL ACCELERATION
HIGH
MODERATE
LOW
VERY LOW
UTAH STATE
LIQUEFACTION POTENTIAL
CENTRAL UTAH
US GEOLOGICAL SURVEY
CONTRACT NO. 14 - 08 - 0001 - G1364
EARTHQUAKE HAZARD REDUCTION PROGRAM



LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION

LIQUEFACTION POTENTIAL	CRITICAL ACCELERATION	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	< .04 g	> 50 %
MODERATE	.04 - .12 g	50 - 10 %
LOW	.12 - .16 g	10 - 5 %
VERY LOW	> .16 g	< 5 %

UTAH STATE UNIVERSITY

LIQUEFACTION POTENTIAL

CENTRAL UTAH

PLATE NO. 4 (Mills valley)

US GEOLOGICAL SURVEY
CONTRACT NO. 14 - 08 - 0001 - G1384
EARTHQUAKE HAZARD REDUCTION PROGRAM

L. ANDERSON J. KEATON
J. RICE (1989)

NORTH
SCALE : 1 : 48000

1 0 1 mile
6000 4000 2000 0 6000 feet
2 1 0 2 kilometer

Utah Geological Survey
Contract Report 94-5

LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION

LIQUEFACTION POTENTIAL	CRITICAL ACCELERATION	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	< .04 g	> 50 %
MODERATE	.04 - .14 g	50 - 10 %
LOW	.14 - .18 g	10 - 5 %
VERY LOW	> .18 g	< 5 %

UTAH STATE UNIVERSITY

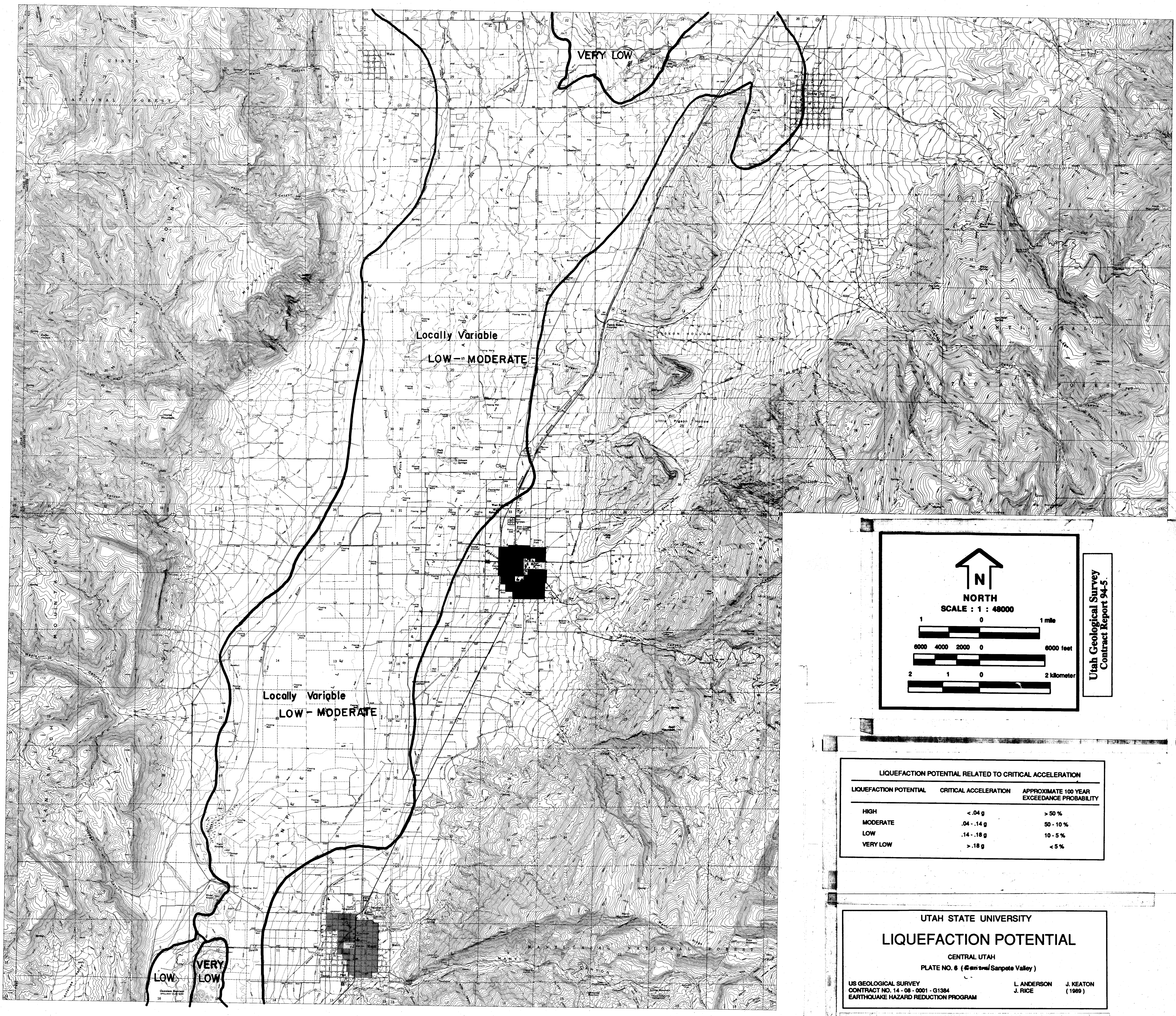
LIQUEFACTION POTENTIAL

CENTRAL UTAH

PLATE NO. 5 (northern Sanpete Valley)

US GEOLOGICAL SURVEY
CONTRACT NO. 14 - 08 - 0001 - G1384
EARTHQUAKE HAZARD REDUCTION PROGRAM

L. ANDERSON J. KEATON
J. RICE (1989)



LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION

LIQUEFACTION POTENTIAL	CRITICAL ACCELERATION	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	< .04 g	> 50 %
MODERATE	.04 - .14 g	50 - 10 %
LOW	.14 - .18 g	10 - 5 %
VERY LOW	> .18 g	< 5 %

UTAH STATE UNIVERSITY

LIQUEFACTION POTENTIAL

CENTRAL UTAH

PLATE NO. 6 (~~Central~~ Sanpete Valley)

US GEOLOGICAL SURVEY
CONTRACT NO. 14 - 08 - 0001 - G1384
EARTHQUAKE HAZARD REDUCTION PROGRAM

L. ANDERSON J. KEATON
J. RICE (1989)

Utah Geological Survey
Contract Report 94-5

LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION (Sanpete Valley)

LIQUEFACTION POTENTIAL	CRITICAL ACCELERATION	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	< .04 g	> 50 %
MODERATE	.04 - .14 g	50 - 10 %
LOW	.14 - .18 g	10 - 5 %
VERY LOW	> .18 g	< 5 %

LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION (North.Seveir Valley)

LIQUEFACTION POTENTIAL	CRITICAL ACCELERATION	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	< .03 g	> 50 %
MODERATE	.03 - .11g	50 - 10 %
LOW	.11 - .15 g	10 - 5 %
VERY LOW	> .15 g	< 5 %

UTAH STATE UNIVERSITY

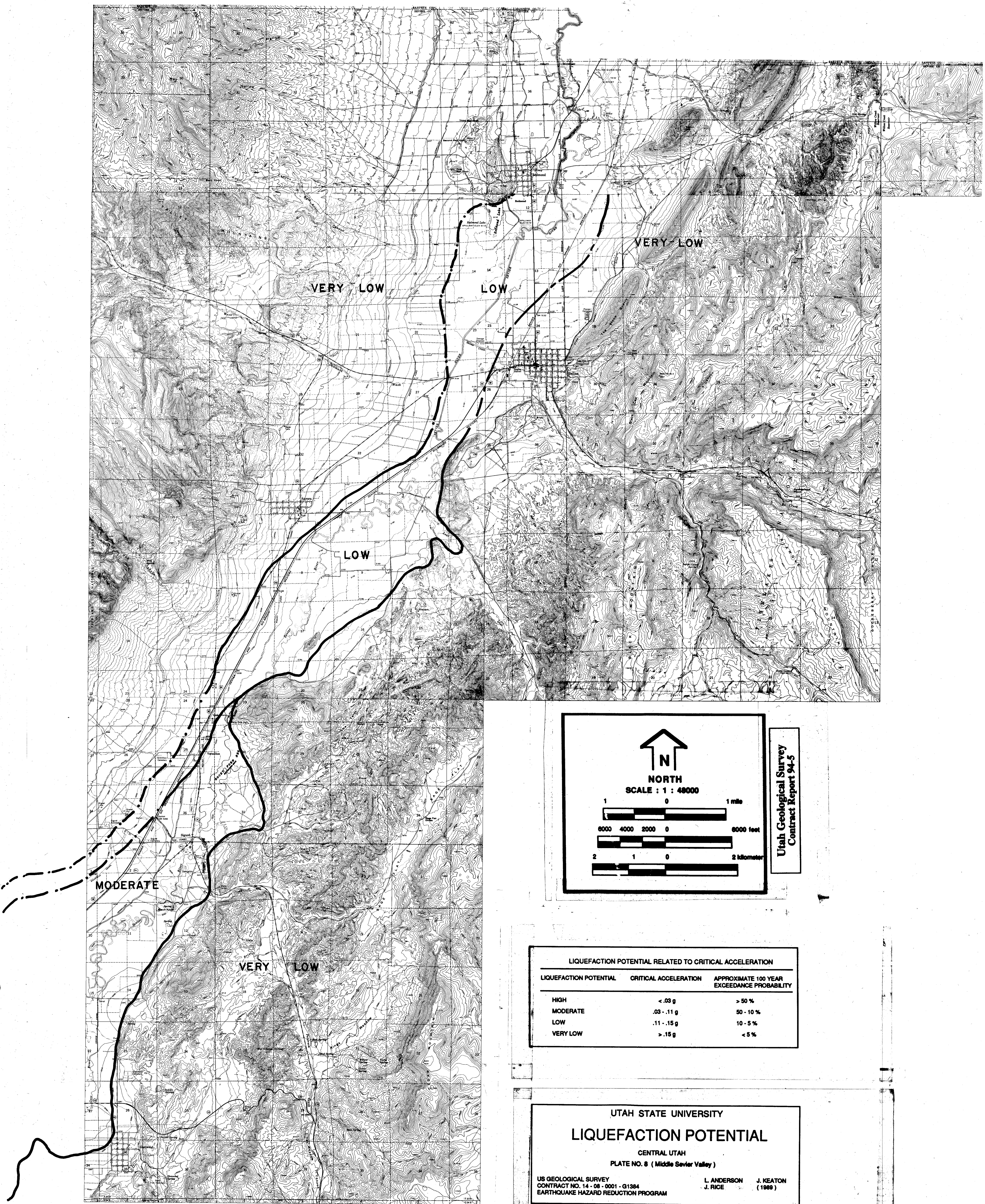
LIQUEFACTION POTENTIAL

CENTRAL UTAH

PLATE NO. 7 (Southern Sanpete & Northern Sevier Valley)

US GEOLOGICAL SURVEY
CONTRACT NO. 14 - 08 - 0001 - G1384
EARTHQUAKE HAZARD REDUCTION PROGRAM

L. ANDERSON J. KEATON
J. RICE (1989)



Utah Geological Survey
Contract Report 94-5

LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION		
LIQUEFACTION POTENTIAL	CRITICAL ACCELERATION	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	< .03 g	> 50 %
MODERATE	.03 - .11 g	50 - 10 %
LOW	.11 - .15 g	10 - 5 %
VERY LOW	> .15 g	< 5 %

UTAH STATE UNIVERSITY

LIQUEFACTION POTENTIAL

CENTRAL UTAH

PLATE NO. 8 (Middle Sevier Valley)

US GEOLOGICAL SURVEY
CONTRACT NO. 14 - 08 - 0001 - G1384
EARTHQUAKE HAZARD REDUCTION PROGRAM

L. ANDERSON J. KEATON
J. RICE (1989)

Utah Geological Survey
Contract Report 94-5

N
NORTH
SCALE : 1 : 48000

1 0 1 mile
6000 4000 2000 0 6000 feet
2 1 0 2 kilometer

LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION

LIQUEFACTION POTENTIAL	CRITICAL ACCELERATION	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	< .08 g	> 50 %
MODERATE	.08 - .24 g	50 - 10 %
LOW	.24 - .30 g	10 - 5 %
VERY LOW	> .30 g	< 5 %

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LIQUEFACTION POTENTIAL

CENTRAL UTAH

PLATE NO. 9 (Southern Sevier Valley)

US GEOLOGICAL SURVEY
CONTRACT NO. 14 - 08 - 0001 - G1384
EARTHQUAKE HAZARD REDUCTION PROGRAM

L. ANDERSON J. KEATON
J. RICE (1989)

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Contract Report 94-5

LIQUEFACTION POTENTIAL

UTAH STATE UNIVERSITY

CENTRAL UTAH

PLATE NO. 10 (Southern Pavant Valley)

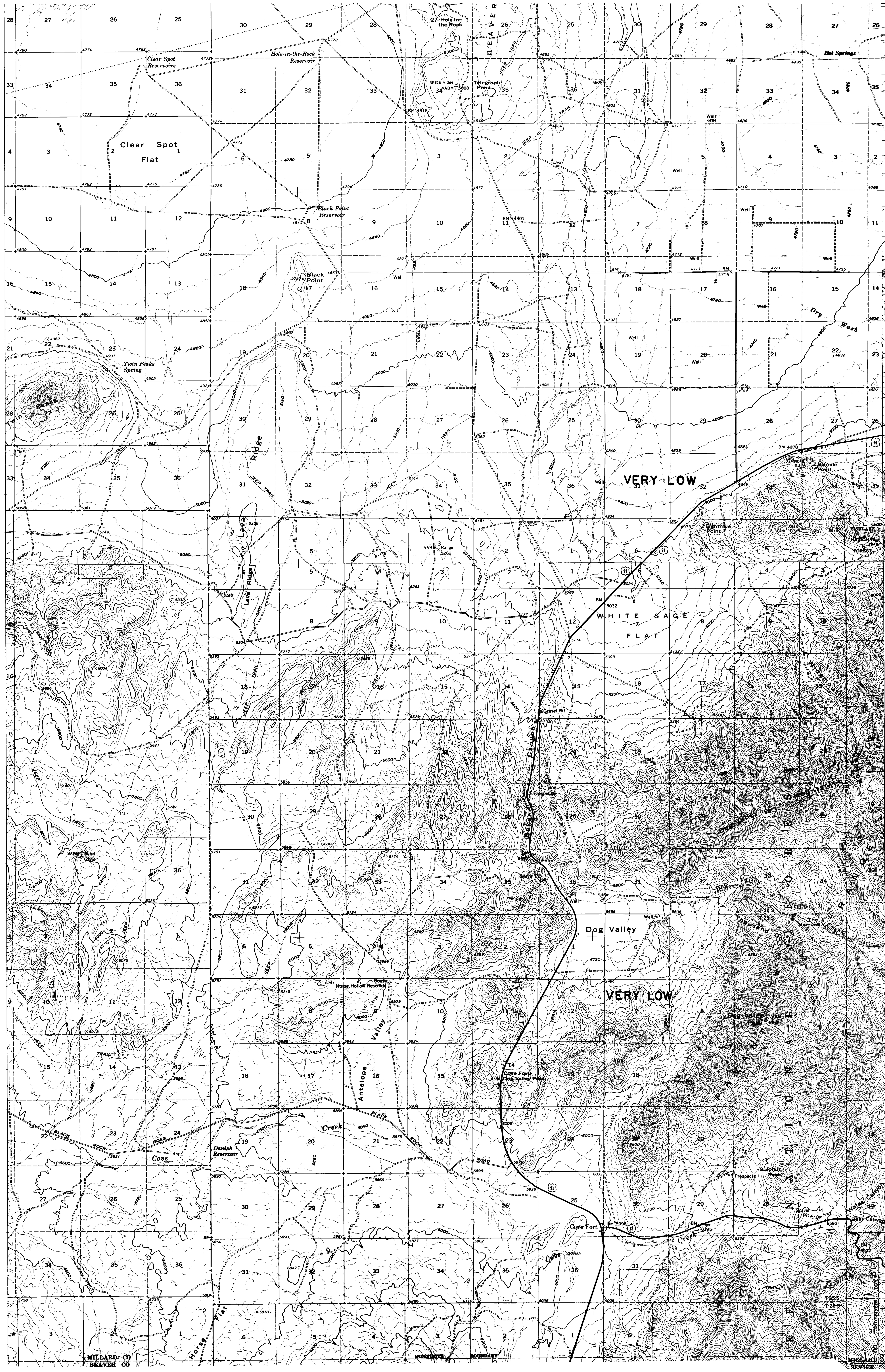
US GEOLOGICAL SURVEY
CONTRACT NO. 14 - 08 - 0001 - G1384
EARTHQUAKE HAZARD REDUCTION PROGRAM

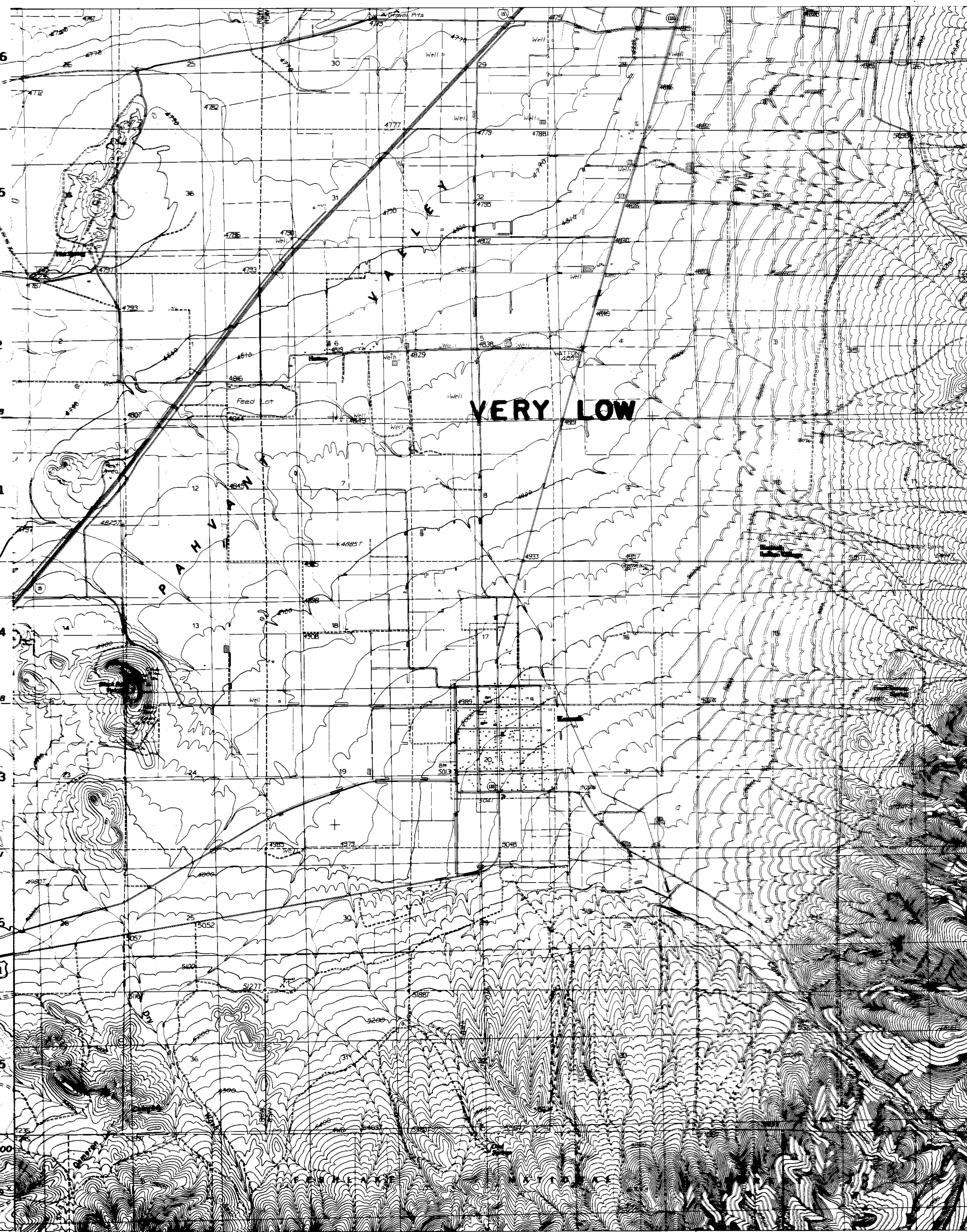
L. ANDERSON J. KEATON
J. RICE (1989)

LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION

LIQUEFACTION POTENTIAL	CRITICAL ACCELERATION	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	< .04 g	> 50 %
MODERATE	.04 - .10 g	50 - 10 %
LOW	.10 - .13 g	10 - 5 %
VERY LOW	> .13 g	< 5 %

NORTH
SCALE : 1 : 48000
1 0 1 mile
6000 4000 2000 0 6000 feet
2 1 0 2 kilometer





NORTH

SCALE : 1 : 48000

1 0 1 mile

6000 4000 2000 0 6000 feet

2 1 0 2 kilometer

Utah Geological Survey
Contract Report 94-5

LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION

LIQUEFACTION POTENTIAL	CRITICAL ACCELERATION	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	< .04 g	> 50 %
MODERATE	.04 - .10 g	50 - 10 %
LOW	.10 - .13 g	10 - 5 %
VERY LOW	> .13 g	< 5 %

UTAH STATE UNIVERSITY

LIQUEFACTION POTENTIAL

CENTRAL UTAH

PLATE NO. 11 (Northern Pavant Valley)

US GEOLOGICAL SURVEY
CONTRACT NO. 14 - 08 - 0001 - G1384
EARTHQUAKE HAZARD REDUCTION PROGRAM

L. ANDERSON J. KEATON
J. RICE (1989)

Utah Geological Survey
Contract Report 94-5
NORTH
SCALE : 1 : 48000
1 0 1 mile
6000 4000 2000 0 6000 feet
2 1 0 2 kilometer
LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION
CRITICAL ACCELERATION
APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
< .04 g
> 50 %
.04 - .10 g
10 %
.10 - .13 g
10 - 5 %
> .13 g
< 5 %
UTAH STATE UNIVERSITY
LIQUEFACTION POTENTIAL
CENTRAL UTAH
PLATE NO. 12 (Western Sevier Desert)
L. ANDERSON
J. RICE
J. KEATON
VERY LOW
LOW
VERY LOW
LOW
VERY LOW
LOW
VERY LOW
Delta
Hinckley
Abraham
Sutherland
Deseret
Oasis
SEVIER RIVER

NORTH

SCALE : 1 : 48000

1 0 1 mile

6000 4000 2000 0 6000 feet

2 1 0 2 kilometer

Utah Geological Survey
Contract Report 94-5

LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION

LIQUEFACTION POTENTIAL	CRITICAL ACCELERATION	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	< .04 g	> 50 %
MODERATE	.04 - .10 g	50 - 10 %
LOW	.10 - .13 g	10 - 5 %
VERY LOW	> .13 g	< 5 %

UTAH STATE UNIVERSITY

LIQUEFACTION POTENTIAL

CENTRAL UTAH

PLATE NO. 13 (Eastern Sevier Desert)

US GEOLOGICAL SURVEY
CONTRACT NO. 14 - 08 - 0001 - G1384
EARTHQUAKE HAZARD REDUCTION PROGRAM

L. ANDERSON J. KEATON
J. RICE (1989)

LIQUEFACTION POTENTIAL RELATED TO CRITICAL ACCELERATION

LIQUEFACTION POTENTIAL	CRITICAL ACCELERATION	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	< .04 g	> 50 %
MODERATE	.04 - .12 g	50 - 10 %
LOW	.12 - .16 g	10 - 5 %
VERY LOW	> .16 g	< 5 %

UTAH STATE UNIVERSITY

LIQUEFACTION POTENTIAL

CENTRAL UTAH

PLATE NO. 14 (Scipio Valley)

US GEOLOGICAL SURVEY — L. ANDERSON — J. KEATON
CONTR[redacted] ([illegible])
EARTHQ[redacted]