FINAL TECHNICAL REPORT

Award Number 05HQGR0043

COMMUNICATING STRONG GROUND MOTION IN MID-AMERICA

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ABSTRACT

In Mid-America, quantifying and communicating strong ground motion in real-time has its challenges. This work investigated the use and understanding of the USGS ShakeMap product for the central United States. A survey of emergency management personnel, public information officers, and state geologists was developed to explore cognition, perception and interpretation of ShakeMap. Data collected here provides a baseline of information needs and uses for specific ShakeMap consumers. Findings suggest that different groups interpret ShakeMap output with different levels of confidence and accuracy. Responses identify a series of features that could enhance the interpretability of this valued information source. Fundamentally, when disseminating a product to consumers with multiple needs and multiple skill sets minimizing assumptions of familiarity with map features seems critical. Therefore, two main recommendations of this study are to include: One, a legend of symbols and two, a workshop with companion manual for specific user groups. The workshop in particular should have a peer-to-peer component that facilitates exchange between Emergency Managers from regions in the west with peers living and working in the Central and Eastern US. Legends should conform to accepted cartographic standards but we see here that the color scale of shaking was clearly defined but that symbols such as those for faults and seismic stations are not defined.

INTRODUCTION

In recent years increased access to relevant hazards information through the mass media and the Internet delivered scientific information directly from information generators to information consumers, without necessarily delivering the skills required to interpret and use the information. As residents, public officials, educators and engineers rely more heavily on this available hazards information, it becomes increasingly important to assess how information related to hazards and risks are approached and interpreted by members of each audience. This research explored the ways that ShakeMap hazards information was interpreted and valued.

Communicating uncertainty in scientific information, particularly probability information can be complex. Such information will potentially be interpreted by audiences in ways that scientists generating the information may not intend. The communication of global warming information is one such example where the public and decision makers interpret uncertainty in science in multiple ways. This example highlights how the interpretation process can influence the message received by the audience, the decisions made, and the credibility of future messages. Communicating risks associated with strong ground motion is another example where the interpretation of a single message by multiple audiences commonly results in potentially conflicting interpretations. Establishing the ways recipients interact with and interpret products can aid in serving information consumers, promoting understanding of phenomena, and generating derived products matched with user skills and needs.

ShakeMap was developed by the U.S. Geological Survey Earthquake Hazards Program in cooperation with regional seismic network operators (Wald et al., 2004). Its purpose is to rapidly produce and disseminate maps of ground motion and shaking intensity following significant earthquakes to provide a variety of audiences with additional information in which to make better informed decisions.

RESEARCH QUESTIONS

1. Does ShakeMap meet the earthquake information needs of specific information consumers?

2. How do ShakeMap users prefer to receive uncertainty information associated with a given ShakeMap?

3. What steps could be taken to most effectively maximize the utility of the ShakeMap product and minimize misinterpretation?

STUDY AREA

The Mid-America region, as defined by the Advanced National Seismic System (ANSS) served as the study area for this work (Figure 1). The urban areas of Memphis Tennessee, St. Louis Missouri, Evansville Indiana, Charleston South Carolina, and the Knoxville-Chattanooga Tennessee corridor are equipped with strong ground motion sensors and are targets for ShakeMap implementation. At the time of this study, ShakeMap implementation for portions of the New Madrid Seismic Zone was complete and therefore the specific area illustrated in Figure 2 provided the focus of this study.

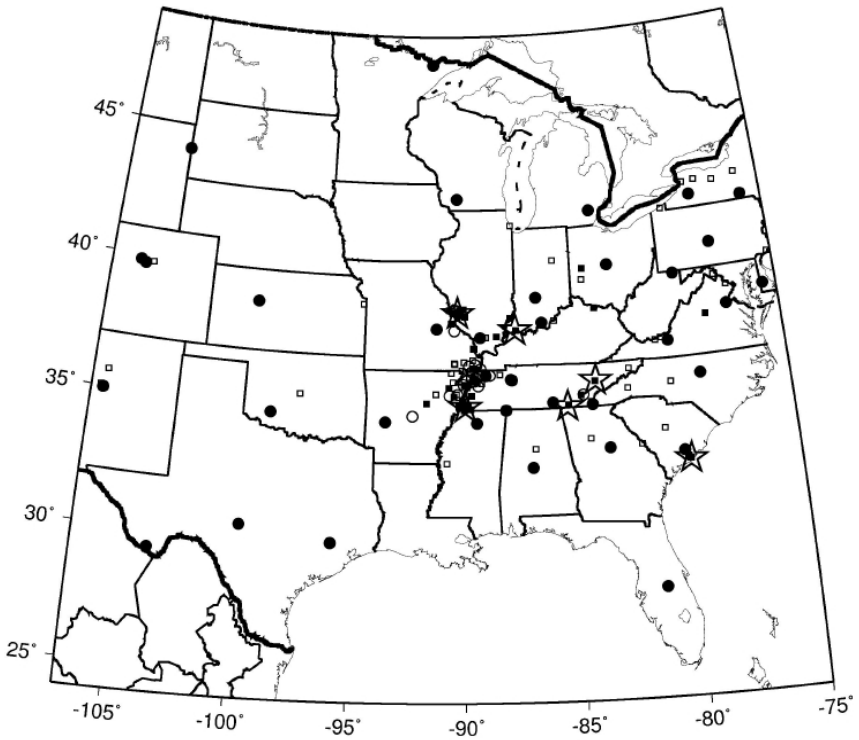


Figure 1: ANSS Mid-America Region. Stars designate metropolitan areas targeted for urban strong motion instruments by ANSS. Open Circles = broad band stations; Closed Circles = National Network Stations. Open squares = National Strong Motion Program stations; Closed squares = real-time strong motion.

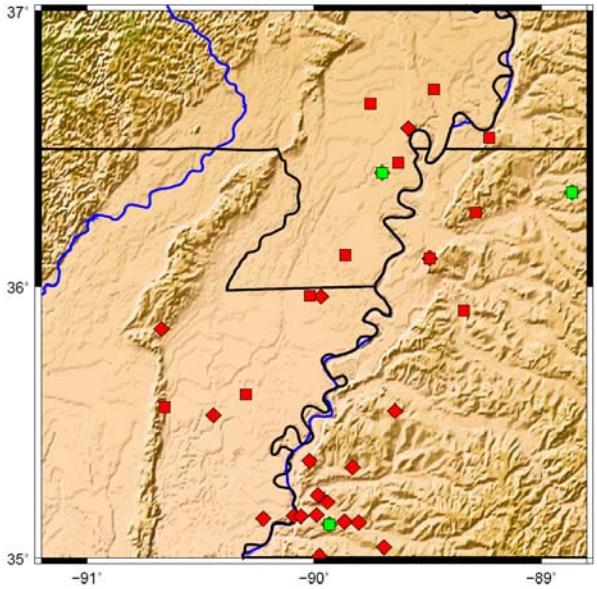


Figure 2: Map of ShakeMap coverage in the Central U.S. All stations currently available for ShakeMap are displayed on the topography background. Red diamonds designate strong motion stations operated by CERI, squares represent broad band stations where green are operated by Saint Louis University and the red are operated by CERI. State boundaries are black lines and blue lines designate rivers.

STUDY AUDIENCES

ShakeMap is available to multiple audiences, simultaneously. Each audience represents a stake-holder and the information needs and skill set can influence the way the map is interpreted. For the purpose of this work four audiences or groups of decision-makers were considered (Figure 3). This selection of audiences insured data collection from the breadth of potential users of ShakeMap and allowed for comparisons to be made between groups at the local and state level as well as between profession types and therefore training and skill set (Table 1).

Table 1: Sampling Strategy Details

Audience	Response Rate
County Emergency Managers	43%
State Geologists	78%
State Emergency Management Agency Public Information Officers	40%
State Earthquake Program Managers	75%

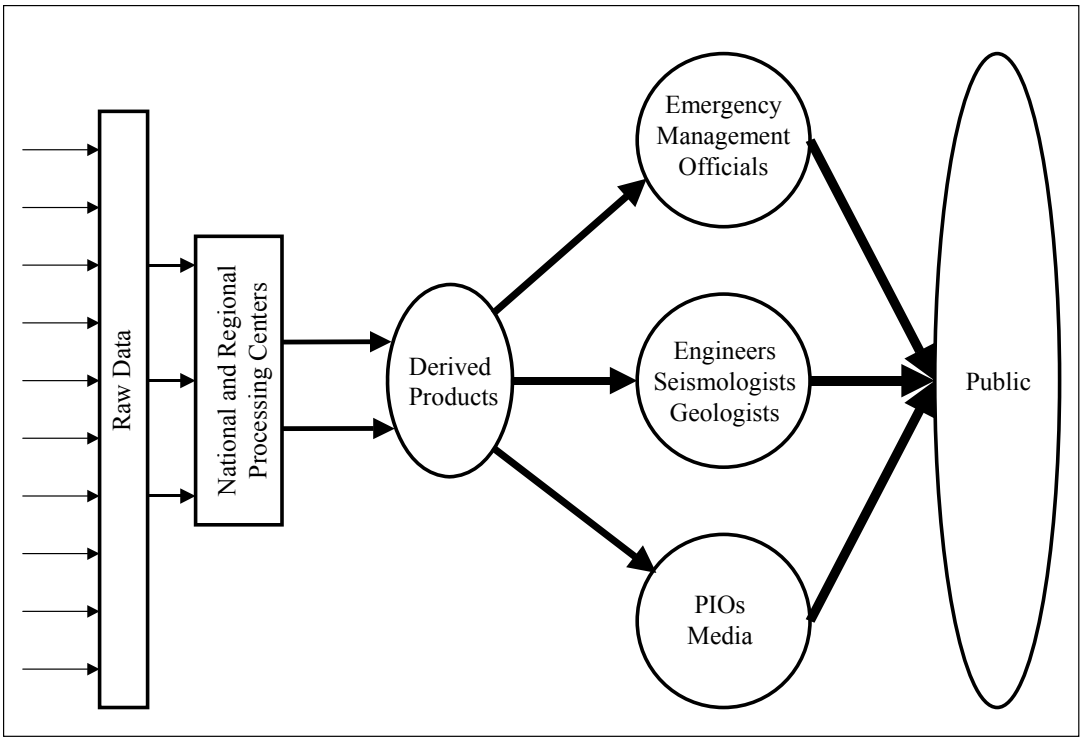


Figure 3: Conceptual diagram of information flow. Data and information flow from left to right. Generally, the level of processing and interpretation increases from left to right.

Emergency Management Agency Public Information Officers and State Earthquake Program Managers from the Central United States Earthquake Consortium (CUSEC) states comprised the first audience in this study. These CUSEC states include: Alabama, Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee. In addition to emergency management officials at the state level, emergency managers at the county level were also surveyed. This audience represents not only an important set of hazard product users but also a group of communicators and information sources themselves. The third audience, State Geologists, considered in this study represents a set of technical users.

METHOD

A survey instrument was designed to collect data for use in this study. The survey instrument had three sections. The first gathered information on what sources of earthquake hazard information

the respondent uses and the extent to which specific sources meet their information needs. This section also established map reading skills and knowledge of the sources of uncertainty in a generated ShakeMap. The second part of the instrument presented strong ground motion information generated by ShakeMap for the central US. Respondents were asked specific questions about the information conveyed in a selection of scenario ShakeMaps. Four formats or styles of ShakeMap output were presented: the media map, rapid instrumental intensity map, and peak acceleration and peak velocity maps (Figure 4). Comfort with each ShakeMap output format and the likelihood of using each were explored. The survey also established output features considered to provide improvements to the product. The final section of the survey collected control variables about respondents including: years in current job, level of education and percent of time allocated to earthquakes or earthquake risk. The survey instrument used is provided as an appendix for review.

Following human subjects approval through the University of Memphis Institutional Review Board the survey instrument was tested with graduate students in the Department of Earth Sciences at the University of Memphis. This testing insured that the survey instrument was clear to study participants and that responses supported quantification of the intended characteristics.

Survey implementation followed the Dillman Method (Dillman, 1978). Surveys were mailed by First Class in a 9" by 11" envelope with a University of Memphis letterhead label. The package mailed included a cover letter; a self-addressed return envelope stamped with first class postage; and the survey instrument. The cover letter explained that the recipient was contacted based on the sampling strategy referred to in Table 1. The purpose of the survey was introduced and confidentiality of participants was assured (Appendix A). The letter conveyed to recipients that results would be shared with the USGS and participants. The cover letter was printed on University of Memphis letterhead, personally addressed and individually signed by the Principal Investigator. The survey instrument itself (Appendix B) was coded with an identification number to facilitate matching responses to the appropriate study and to send follow-up prompts for participation when necessary. Finally, follow-up correspondence in the form of a postcard (Appendix C) was mailed one week following the initial mailing to encourage participation.

After another week, a second complete survey package with a replacement survey was mailed in a final attempt to collect data.

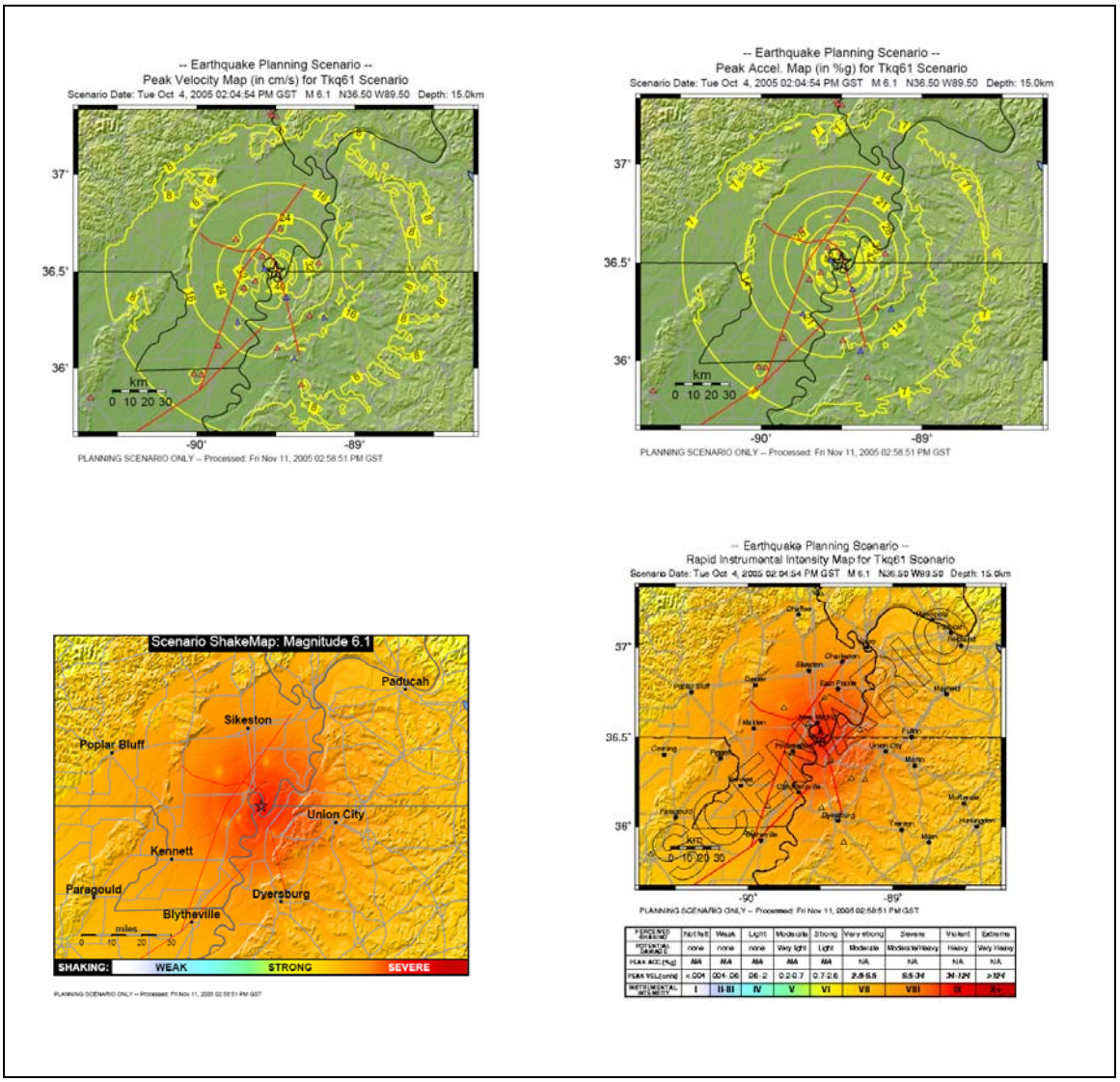


Figure 4: Examples of ShakeMap Output Formats.

The survey data was collected using, in part, a Likert one-dimensional scaling method where respondents select from a list of responses, such as the example provided in Table 2.

Table 2: Example of Likert Scaling Protocol

Scale	Description/Prompt
1	Strongly unfavorable to the concept
2	Somewhat unfavorable to the concept
3	Undecided
4	Somewhat favorable to the concept
5	Strongly favorable to the concept

A data entry form was designed using Microsoft Access and data entered as each survey instrument was returned to PIs. Statistical analyses were conducted using SPSS and SAS statistical software. Analyses were conducted on aggregated responses to protect the identity of individual respondents. Content analysis was performed on the open ended questions related to interpretation of ShakeMaps.

FINDINGS

Sources of information and information needs

The internet was the primary form of communication that respondents rely on when accessing earthquake information. When asked if the sources of information respondents currently used meet their needs, responses indicated that each audience has their favored and trusted sources and that those sources meet their needs "very well". For local emergency managers, the most likely accessed sources were the state or local emergency management agency. This source was reported to meet needs very well. Responses indicate that local emergency managers are least likely to consult local seismic networks or the USGS directly for their earthquake hazard information. This trend was correlated with reports of the perception of how these sources meet their information needs.

At the state level, state earthquake program managers and public information officers used the Center for Earthquake Research and Information (CERI) as their most likely accessed source of recent earthquake information and that the source meets information needs "well". State geologists look to the USGS and CERI as the "most likely" used sources of earthquake information and report that the USGS meets their needs "very well" and CERI "well".

These patterns in responses are not surprising as different audiences are looking for different types of information and belong to different professional networks. This information was collected as a reference for questions related to how ShakeMap met their needs and provided information they would be likely to access in the course of their job activities. If we look in detail at the variation in responses with audience we see that local emergency managers are perhaps less certain of their use of ShakeMap in the future (Table 3). Given the intended purposes of ShakeMap this finding is a significant one.

Table 3: Summary of Responses to Likelihood of Using ShakeMap.

What is the likelihood of you using ShakeMap in the context of your job after an earthquake?	**Low 1**	**2**	**3**	**4**	**High 5**	**No Response**
Local Emergency Managers	0	0	0	17%	59%	24%
State Geologists	0	0	0	8%	92%	0
State Public Information Officers and Earthquake Program Managers	0	0	0	14%	86%	0

Interpreting ShakeMap

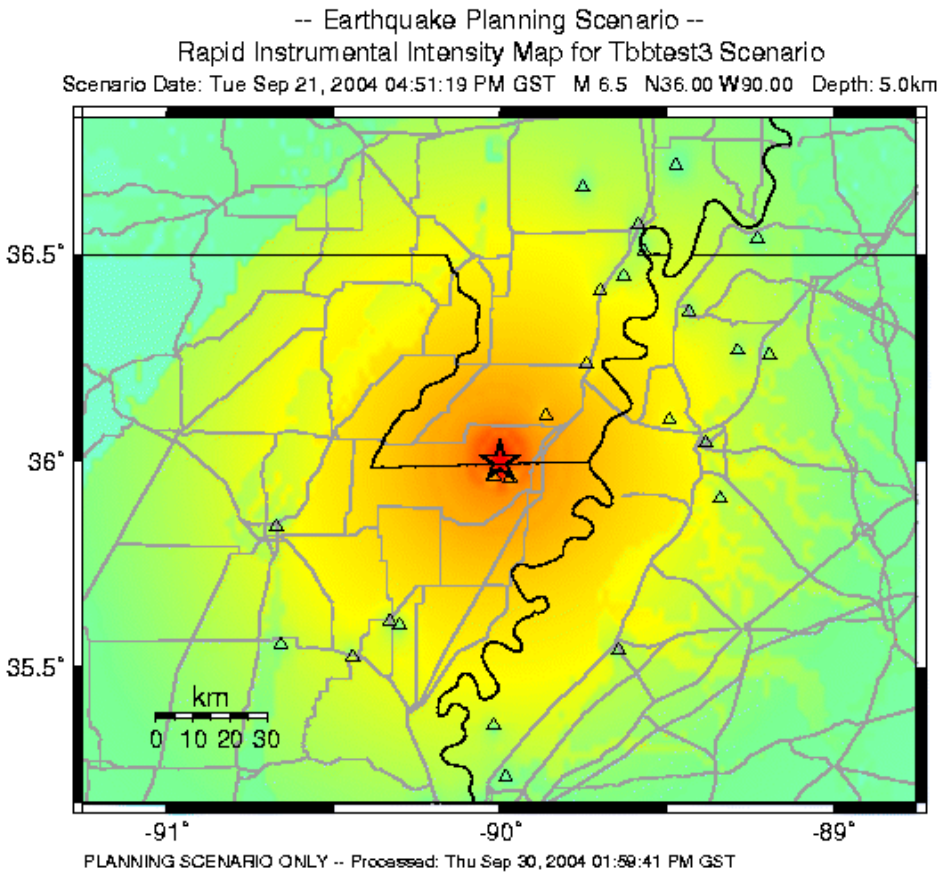
Given the multiple map formats of ground motion communicated through the ShakeMap product, we asked respondents to rate their map readings skills as a way to explain variations in comfort, ease, and accuracy of interpreting ShakeMap products. Responses document a significant difference between the self-reported skills of the study sample populations/audiences. State geologists report the strongest proficiency with map reading and local emergency managers, public information officers and earthquake program managers considered their skills to be moderate.

Interpretation of ShakeMap examples revealed significant variations between groups but not among groups. Skill set and experience with maps did account for much of the variation observed. State geologists reported the most comfort and had the fewest inaccuracies in their interpretations. Local emergency managers were more likely to provide no response to interpretation questions or to select the “not applicable” response option. A legend would have helped in many cases as some respondents noted. Interpretation by geologists, arguably the most

familiar with both the features and symbology of ShakeMap maps, could be expected to be the least influenced by a lack of legend details.

A series of open ended questions were asked about different ShakeMap formats. First, the Rapid Instrumental Intensity Map of a scenario Magnitude 6.5 event, as illustrated in Figure 5, was presented. In the survey instrument the map was presented in a manner similar to a rapid dissemination mode were little background information or explanation would be bundled with the map. When asked if the ShakeMap presented an adequate amount of information 20% responded that it did. One respondent volunteered: "almost, I always appreciate a legend of map symbols". A total of forty-five percent of the survey population did not feel the map communicated an adequate amount of information. Of these, a public information officer stated that "a 6.5 would have been felt over a larger area" seeming to question the accuracy of the product or revealing perceptions of what could be expected. Several participants observed that features such as cities with labels, political boundaries for reference, and a legend to define the triangles would be useful improvements. A county emergency manager suggested that the map did not provide enough information for laypersons: "They may need more than State boundaries, roads and seismic stations to interpret the intent of the product". This did leave 35% of the study population with no response to this question, a majority of which were local emergency managers.

When asked if the map conveyed information in a form that met their professional needs, 28% responded that it did meet their needs. Comments volunteered to the open ended question included: "generally" or "mostly" meets needs. Some participants responded that they were not familiar with the term "instrumental intensity", would prefer miles rather than kilometers, and that population centers would make a useful addition. A local emergency manager responded: "Yes. I can see where areas of higher potential damage may be found after this event" suggests that ShakeMap succeeds in meeting the product's primary purpose. For the 37% that did not find their needs met, the lack of county boundaries, cities with labels for reference, and confusion related to the link between MMI color scheme and HazUS style planning maps made the product less useful.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+...

Figure 5: Survey Rapid Instrumental Intensity map for Participant Interpretation

Respondents were then asked to describe the shaking experienced at the location marked with the arrow on the figure. Respondents could select their description from the perceived shaking, potential damage, peak acceleration, peak velocity, or instrumental intensity. A total of 35% of respondents did not provide a response. A single respondent referenced the peak acceleration correctly. No one referenced the peak velocity, and a majority referred to the perceived shaking value. One respondent combined all features into this response: Very strong to severe shaking associated with moderate damage and an instrumental intensity of VII. Ten percent of survey

respondents were unsure or didn't know the answer and five percent were incorrect with responses that were not explainable. Variability was consistently found between groups with State Geologists having the fewest misinterpretations and county emergency managers and public information officers the greatest. Instrumental Intensity was reported the most useful part of the legend, by far, though some reported being unsure of what that value represented.

Suggestions to improve the usability of the Rapid Instrumental Intensity Map version of ShakeMap were primarily related to features and cartographic representations of the features. These included: width and color of lines for state and county boundaries should be different and streams and rivers should be blue. A legend of symbols, such as the triangles, and labels for at least one or two cities and states was suggested by individuals from all groups. Several respondents prefer miles rather than kilometers. In general the legend was described as inadequate and that terms such as PGA need to be defined.

A second ShakeMap output format was presented for respondents to interpret and comment on. This second version was a Peak Velocity Map for a magnitude 5.0 event where yellow contour lines depict the peak velocity distribution associated with the ground motion (Figure 6). Respondents were less proficient and less comfortable dealing with this format. When asked to describe what the yellow lines represented, responses varied widely (Table 4). Again, responses from State Geologists were significantly different than for other users and consistently accurate.

Table 4: Description of the Yellow Lines

Selected Comments	**Percent of Responses**
No Response	32.5
Area of damage & amount of damage	12.5
Depth	2.5
Distance	5
Peak Velocity	10
Intensity	17.5
Needs explanation, not sure, unclear	7.5
severity of the quake	2.5

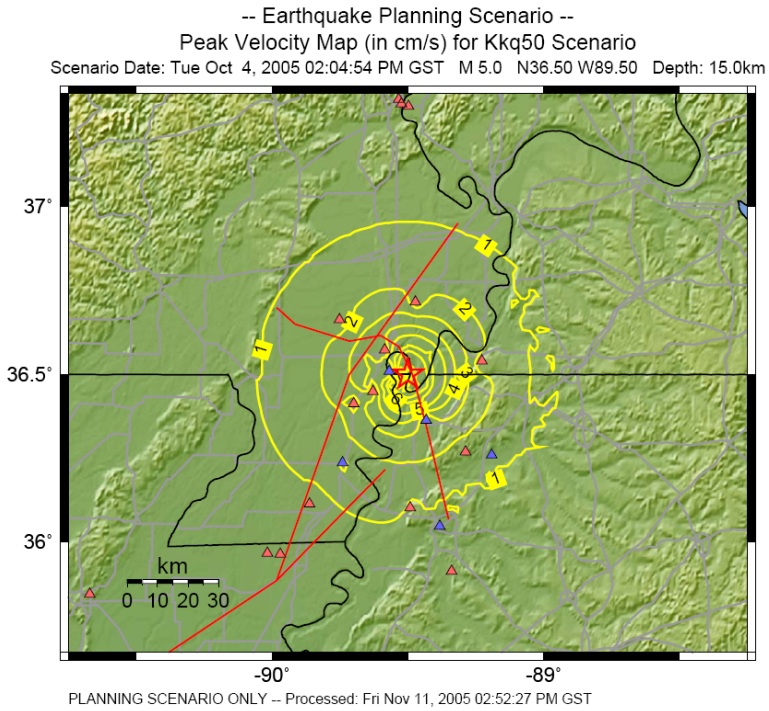


Figure 6: Survey Peak Velocity Map Presented for Participant Interpretation

Compared to the Rapid Instrumental Intensity map that 28% of respondents felt conveyed information in a form that met their needs, only 17.5% of respondents felt this version of ShakeMap met their information needs. Most respondents defined presence of a legend; labels other than latitude and longitude to determine relative location; and explanation of contours were required to boost the usefulness of the product.

When asked to select which of four ShakeMap output formats or versions (Figure 4) respondents were most comfortable interpreting, basing decisions on, and which most closely meets their needs, findings were clear and consistent (Tables 5a, 5b, and 5c). The Rapid Instrumental Intensity map was the favored ShakeMap output format for all user groups. This is explained in part by the flexibility of the map as it includes multiple descriptions in the legend so viewers can select the element of the legend they prefer to use. This output version also has the most extensive legend and the gradational color format is more familiar to viewers than contour lines.

Table 5a: Comparison of ShakeMap Output Formats

Which map format are you most comfortable interpreting?	**County EMA**	**Geologists**	**PIO/EPM**
Peak Velocity Map	0	0	0
Peak Acceleration Map	6%	8%	0
Media Map	24%	25%	43%
Rapid Instrumental Intensity Map	35%	67%	57%

Table 5b: Comparison of ShakeMap Output Formats

Which map format are you most comfortable basing your decision on?	**County EMA**	**Geologists**	**PIO/EPM**
Peak Velocity Map	0	0	0
Peak Acceleration Map	6%	0%	0
Media Map	18%	8%	0
Rapid Instrumental Intensity Map	29%	67%	100%

Table 5c: Comparison of ShakeMap Output Formats

Which map format most closely meets your needs?	**County EMA**	**Geologists**	**PIO/EPM**
Peak Velocity Map	6%	0	0
Peak Acceleration Map	6%	8%	0
Media Map	12%	8%	0
Rapid Instrumental Intensity Map	35%	83%	100%

Future use of ShakeMap

When asked to rank the likelihood of using ShakeMap in the context of job activities on a scale from 1 to 5 where 1 was the lowest and 5 was the highest, a majority of all respondents, 68% responded the highest likelihood, 5. Some of the local or county level emergency managers were unsure of the value at the local level.

Enhancements to ShakeMap

By far the most recommended enhancement to ShakeMap was a legend of symbols. While clear to the ShakeMap producers that red lines are fault lines and that triangles are seismic stations – diverse consumers of ShakeMap have diverse skill sets and the assumption that these features

would be recognized did lead to misinterpretations. When prompted to rank functions considered the greatest improvements to ShakeMap all users had the same preferences:

1. ability to click areas of the map for explanation, including the legend,
2. ability to zoom in to local areas, and
3. the ability to generate pop-up dialog boxes with explanations as the cursor rolls over portions of the map.

The survey also sought to determine if and how map users would like to receive information related to the uncertainty in ShakeMap output and products. First, we documented perceptions of the sources of uncertainties in constructing ShakeMap. Earthquake Program Managers and Public Information Officers were most likely to not respond or circle the not applicable box. County Emergency Managers ranked uncertainty in epicenter location, magnitude estimates, and models of attenuation as the highest ranked sources of uncertainty in ShakeMap. State Geologists cited uncertainty in maps of geology (and subsurface geology), station coverage, and models of attenuation as the greatest sources of uncertainty. Study population group did explain the variance in responses.

After establishing this understanding of what surveyed individuals attribute uncertainty to, a series of questions were asked that related to if and how they would like uncertainty information to be provided. Table 6 documents the responses to the question if viewers would like to receive uncertainty information associated with the generation of a ShakeMap. Overwhelmingly viewers would like access to this information. The opinion was less clear for emergency managers and perhaps supplementing the information with an explanation of how the information might be used and what the sources are would make the information more useful to this audience.

Table 6: Demand for Uncertainty Information

Given the uncertainties in the ShakeMap product, would you like to know what the uncertainty is for each ShakeMap generated?	**Yes**	**No**	**Don't Know**	**No Response**
County Emergency Manager	59%	12%	6%	23%
State Geologist	83%	0	17%	0
Public Information Officer Earthquake Program Manager	71%	0	29%	0

Finally, there are a number of ways that uncertainty associated with a map can be communicated. Rather than an open ended question seeking input from the survey respondents the project team attempted to develop a list of options that seems reasonable to implement and perhaps would be useful to ShakeMap consumers. County emergency managers preferred the shaded map depicting uncertainty across the ShakeMap area or a table listing a quality score (A- F) assigned to communities or areas. Both the state geologist and the earthquake program manager and public information officer groups preferred the option of a table with error estimates for each community, followed by the table with qualitative scores and the shaded map.

CONCLUSIONS AND RECOMMENDATIONS

While products designed to communicate such information have improved dramatically in recent years, those improvements may not translate directly into improvements required to match the needs of each target group. Meeting the needs of the audience is arguably of greater importance in a modern information age.

The first research question asked if ShakeMap met the earthquake information needs of specific information consumers? The answer found was that ShakeMap did meet needs and that where it did not it has the potential to with some minor modifications. These modifications essentially address assumptions and cartographic elements. The assumptions addressed include recognizing features on the mapped output without a legend. While some groups seemed more impacted by the legend assumption when local experts were polled they struggled for details as well. Another example assumption to address would be: describing red as “severe shaking” in a legend and then displaying a ShakeMap where shaking was not severe and faults were the only red features on the display. For some users it was not obvious that the red lines were faults but that could be clarified with a legend description of all cartographic elements.

The second research question this work sought to address was how ShakeMap users prefer to receive uncertainty information associated with a given ShakeMap. A majority of participants want to know where the map is certain and where it may be less certain. The preferred ways of

communicating that information would be a table assigning quality scores or a table of error estimates. Linking this table to communities or areas of the map was seen as useful as well.

Finally, this work investigated the steps that could be taken to most effectively maximize the utility of the ShakeMap product and minimize misinterpretation. Here again results indicate that the legend was the primary issue. Given the variability in responses by audience group it also seems that peer-to-peer exchange of experiences would be valuable. In particular experienced EMAs from California or Washington might effectively communicate to their peers in the Central and Eastern United States. In the west experience with ShakeMap is more extensive as is experience and focus on the earthquake hazard.

Summary of Specific Observations and Recommendations

1. ShakeMap is considered a useful tool to make decisions about earthquakes. The Rapid Instrumental Intensity Map was reported the most useful by the study population.

2. Emergency Managers in the Central United States would benefit from an information exchange workshop. The workshop would connect the product to their needs and enhance the relevance of information conveyed while also addressing interpretation challenges. Inviting Emergency Managers from other regions where ShakeMap is routinely used would foster an exchange of best-practices and practical experience specific to this group of ShakeMap consumers.

3. A legend defining all symbols is a required enhancement.

4. Interactive descriptive functions are considered useful improvement to ShakeMap.

5. The needs and wants of end-users of hazard information and outreach products are variable.

6. End-users and the producers of ShakeMap have different knowledge, skills and experience with maps and with earthquakes. Language, symbols, and choice in scale representation can influence the value of the product.

7. The relatively low occurrence rate of earthquake and subsequently less experience with earthquakes in Mid-America plays a key role in the needs and wants of the end user. ShakeMap complemented by other hazard information may be useful in this region.

8. Including the ShakeMap fact-sheet (FS-087-03) on the ShakeMap webpage, similar to the way that the Scientific Background information is handled, as part of the software distribution would be quite valuable.

PUBLICATIONS/PRESENTATIONS

Bateman, J. M., A. A. Hill, and M. M. Withers. 2007. Communicating Strong Ground Motion in Mid-America: ShakeMap Users Survey. *Association of American Geographers Annual Meeting*. San Francisco, CA.

ACKNOWLEDGEMENTS

Authors gratefully acknowledge Thomas Brackman for generating the scenario ShakeMap output included in the survey instrument. Jeremy Bateman assisted with survey instrument design and survey implementation. Data entry form creation and data entry were performed by Jackson Gilman. The work would not have been possible without the voluntary participation of the survey respondents.

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Wald. D., B. C. Worden, V. Quitoriano, and K. L. Pankow (2004). ShakeMap Maula: Users Guide, Technical Manual, and Software Guide, USGS Open File Report, 128 pp.

APPENDIX A: Cover letter

February 27, 2007

<<Name>>
<<Title>>
<<Organization>>
<<Address>>
<<City>>, <<State>> <<Zipcode>>

Dear <<Name>>:

In recent years, earthquake information available for decision support as well as education and outreach has increased. To date, there has been little systematic effort to understand how this information meets the needs of user groups. This letter accompanies a survey developed to explore how one specific earthquake hazard information product is interpreted and used. The survey is the core of a project titled "Communicating Strong Ground Motion in Mid-America" and is funded by the United States Geological Survey. The purpose of the study is to document and understand the ways that survey respondents use and interpret the ShakeMap product.

You are being asked to participate in our study based on your professional role as an earthquake program manager, emergency manager, public information officer, or state geologist. If you decide to participate, all we need is for you to complete the enclosed questionnaire on issues related to the ShakeMap product and return it to us in the self addressed, stamped envelope.

To keep your personal information confidential, the data collected will be kept private to the extent allowed by law. Your responses will be recorded with a code number and the code numbers are only accessible by the project directors. Your completed survey will be kept in locked files and only study staff will be allowed to access it. The results of the study will be presented in aggregate form which will protect all personal identities. A summary of the results will be shared with all participants upon completion of the project and made available through the final project report submitted to the United States Geological Survey.

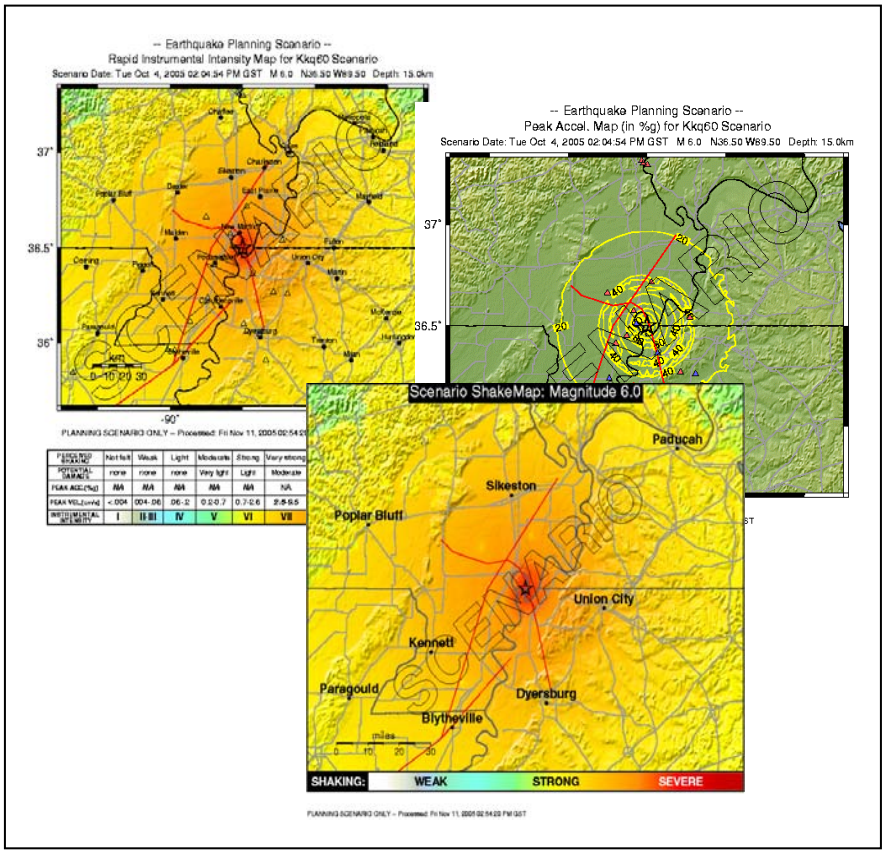
We hope you will help us with the study, and anticipate that results will be useful in assessing current information products and in developing future products.

Sincerely,

Arleen A. Hill, Ph.D.
Project Director
Assistant Professor
Department of Earth Sciences

Mitchell M. Withers, Ph.D.
Project Co-Director
Associate Professor
Center for Earthquake Research
and Information

Communicating Ground Motion with ShakeMap in the Central United States



Survey Instrument
2007

Please share your responses. This survey instrument is designed to explore the use of the United States Geological Survey (USGS) ShakeMap product. Questions are designed to collect data associated with earthquake information sources, the ShakeMap information source, and respondent background information. Your responses allow us to explore the functionality of ShakeMap as a means to communicate strong ground motion in the Central U.S.

Confidentiality. Responses will remain completely confidential. We will keep track of responses by an identification number. Identification numbers and names will remain separate and secure. Under no circumstances will individual responses be matched to names in reporting of results. Individual responses will be combined and aggregate data analyzed and reported.

Instructions. Please answer these survey questions from the perspective of your professional position and role. Answers will take the form of circling the best response, checking the appropriate box and in some cases supplying more open-ended responses based on your observations. For each question if you don't know or feel the question does not apply to you please mark N/A.

1. Which sources are you most likely to access for recent earthquake information?	Least				Most	N/A
a. Center for Earthquake Research &Information	1	2	3	4	5	6
b. Central United States Earthquake Consortium	1	2	3	4	5	6
c. Federal Emergency Management Agency	1	2	3	4	5	6
d. Local Media (TV, print, radio, or internet)	1	2	3	4	5	6
e. Local Seismic Network	1	2	3	4	5	6
f. National Media (TV, print, radio, or internet)	1	2	3	4	5	6
g. State or Local Emergency Management Agency	1	2	3	4	5	6
h. State Geological Survey	1	2	3	4	5	6
i. United States Geological Survey	1	2	3	4	5	6
j. University (please define) _____	1	2	3	4	5	6
k. Other (please define) _____	1	2	3	4	5	6

2. How well do the sources you access meet your information needs?	Poorly				Very Well	N/A
a. Center for Earthquake Research &Information	1	2	3	4	5	6
b. Central United States Earthquake Consortium	1	2	3	4	5	6
c. Federal Emergency Management Agency	1	2	3	4	5	6
d. Local Media (TV, print, radio, or internet)	1	2	3	4	5	6
e. Local Seismic Network	1	2	3	4	5	6
f. National Media (TV, print, radio, or internet)	1	2	3	4	5	6
g. State or Local Emergency Management Agency	1	2	3	4	5	6
h. State Geological Survey	1	2	3	4	5	6
i. United States Geological Survey	1	2	3	4	5	6
j. University (please define) _____	1	2	3	4	5	6
k. Other (please define) _____	1	2	3	4	5	6

3. When accessing sources of recent earthquake information, which form of communication do you typically use?	Least				Most	N/A
a. Personal communication	1	2	3	4	5	6
b. Internet	1	2	3	4	5	6
c. Listserve email alert, cell pone, text message, pagers	1	2	3	4	5	6
d. Television or Radio	1	2	3	4	5	6
e. Paper (bulletins, newsletters, memos, etc.)	1	2	3	4	5	6
	Weak				Strong	N/A
4. How would you rank your map reading skills?	1	2	3	4	5	6

5. To what extent do you find each of the following to be a credible source of earthquake information?	Least				Most	N/A
a. Center for Earthquake Research &Information	1	2	3	4	5	6
b. Central United States Earthquake Consortium	1	2	3	4	5	6
c. Federal Emergency Management Agency	1	2	3	4	5	6
d. Local Media (TV, print, radio, or internet)	1	2	3	4	5	6
e. Local Seismic Network	1	2	3	4	5	6
f. National Media (TV, print, radio, or internet)	1	2	3	4	5	6
g. State or Local Emergency Management Agency	1	2	3	4	5	6
h. State Geological Survey	1	2	3	4	5	6
i. United States Geological Survey	1	2	3	4	5	6
j. University (please define) _____	1	2	3	4	5	6
k. Other (please define) _____	1	2	3	4	5	6
6. When interpreting a map, how useful do you find each of the following reference elements?	Least				Most	N/A
a. Churches	1	2	3	4	5	6
b. Cities with labels	1	2	3	4	5	6
c. County boundaries with labels	1	2	3	4	5	6
d. Hospitals	1	2	3	4	5	6
e. Interstate highways with labels	1	2	3	4	5	6
f. Latitude and longitude marks with labels	1	2	3	4	5	6
g. North arrow	1	2	3	4	5	6
h. Rivers	1	2	3	4	5	6
i. Schools	1	2	3	4	5	6
j. State boundaries with labels	1	2	3	4	5	6
k. State and US highways with labels	1	2	3	4	5	6
l. Topography	1	2	3	4	5	6
7. In constructing a map there are uncertainties introduced from various sources. In your opinion, how much would each of the following sources contribute to uncertainty in a ShakeMap?	Least				Most	N/A
a. Epicenter determination error	1	2	3	4	5	6
b. Magnitude estimates	1	2	3	4	5	6
c. Map of geology	1	2	3	4	5	6
d. Models of attenuation	1	2	3	4	5	6
e. Seismic station coverage	1	2	3	4	5	6
f. Subsurface geology knowledge	1	2	3	4	5	6
g. Finite fault directivity	1	2	3	4	5	6
h. Proximity of earthquake to seismic station	1	2	3	4	5	6

8. With reference to Figure 1 below, match each of the features in the left column with the symbols labeled in the right column. Each symbol may be used once, more than once, or not at all.

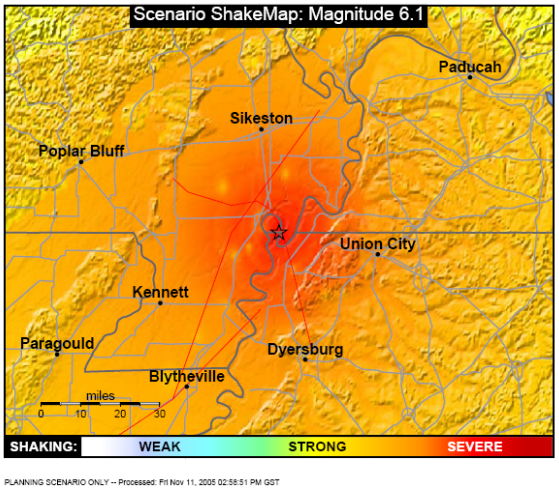
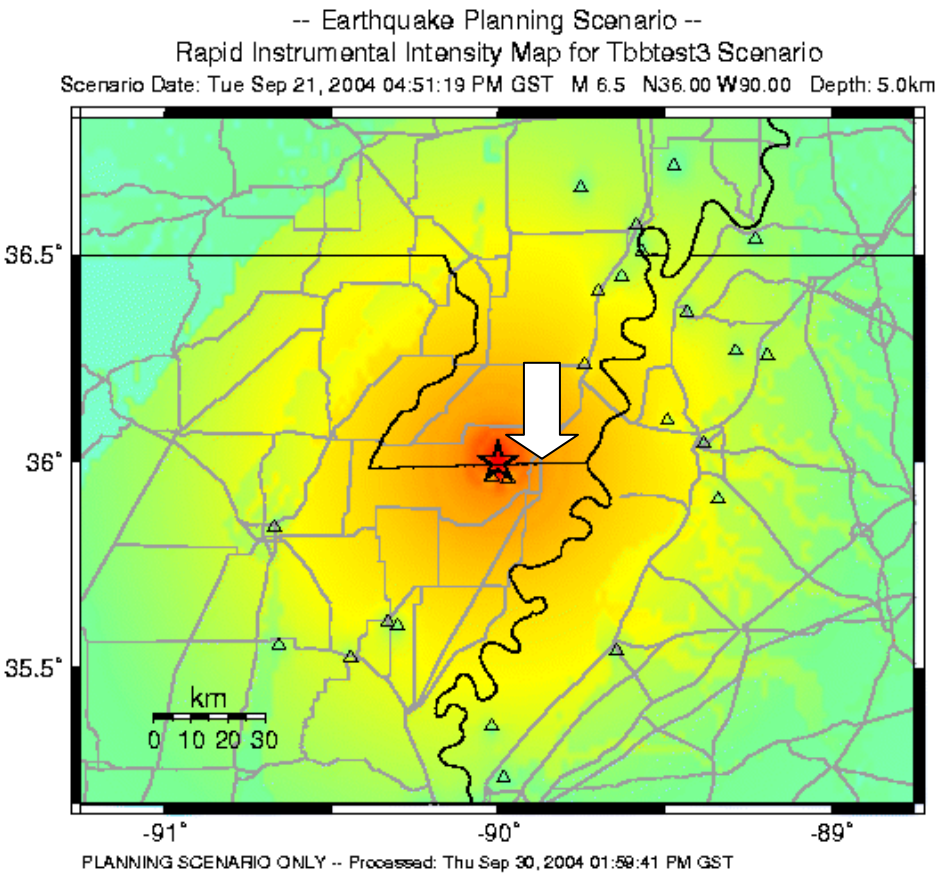


Figure 1:
Sample Scenario ShakeMap – *for survey purpose only.*

Map Feature	**Symbol**
_____ City location(s)	A. Red lines
_____ Epicenter	
_____ Seismic Station	B. Light grey lines
_____ Fault(s)	
_____ Roads	C. Dark grey lines
_____ Rivers	
_____ State Boundaries	D. Black Circles
_____ County Boundaries	
_____ Severe Shaking	E. Red Star

9. With reference to the ShakeMap displayed in Figure 2 below, please provide your opinion for each of the questions on the facing page.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+...

Figure 2: Earthquake Planning Scenario – *for survey purposes only.*

9. With reference to the ShakeMap on the facing page, please provide your opinion for each of the following questions.

a. Does this map communicate an adequate amount of information?

_____.

b. Does this map communicate too much information?

_____.

c. Does this map convey information in a form that meets your needs?

_____.

d. How much time would you estimate you spend extracting the information you need from this map?

_____.

e. Describe the shaking experienced at the *arrow* on the map?

_____.

f. Which part of the legend do you consider the most useful?

_____.

g. Are there any changes you would suggest to improve the usability of this product?

_____.

10. With reference to the ShakeMap displayed in Figure 3 below, please provide your opinion for each of the following questions.

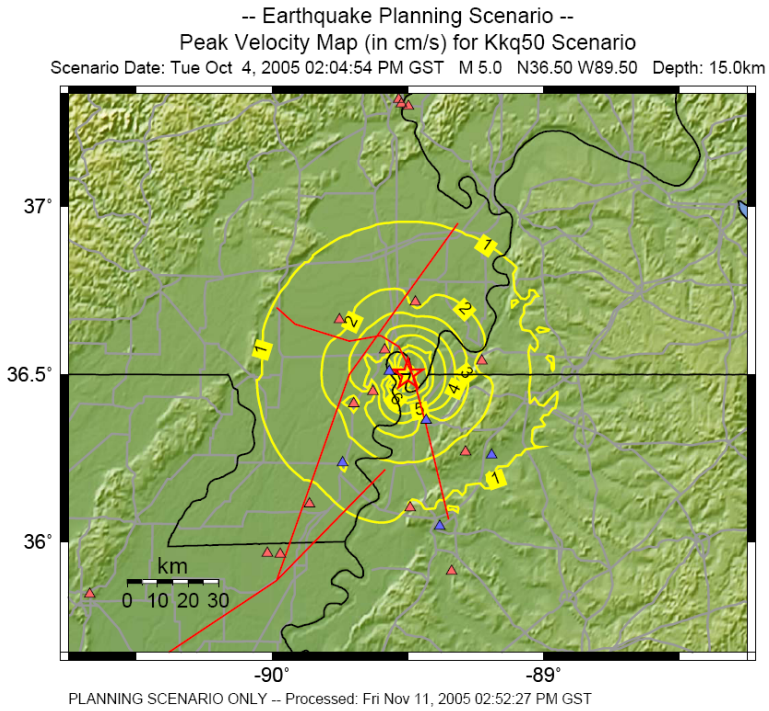


Figure 3: Earthquake Planning Scenario ShakeMap – *for survey purposes only.*

10. With reference to the ShakeMap on the facing page, please provide your opinion for each of the following questions.

a. What do the yellow lines on this map represent?

_____.

b. Does this map communicate an adequate amount of information?

_____.

c. Does this map communicate too much information?

_____.

d. Does this map convey information in a form that meets your needs?

_____.

e. How much time would you estimate you spend extracting the information you need from this map?

_____.

f. Describe the shaking experienced at the *arrow* on the map?

_____.

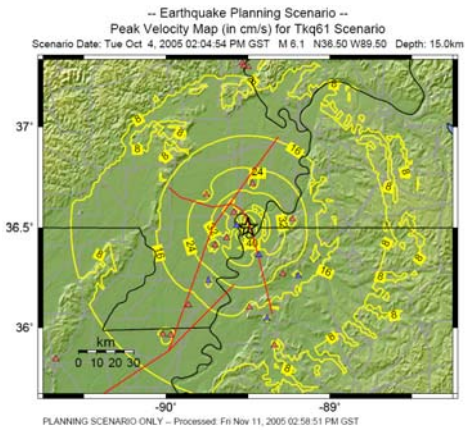
g. Are there any changes you would suggest to improve the usability of this product?

_____.

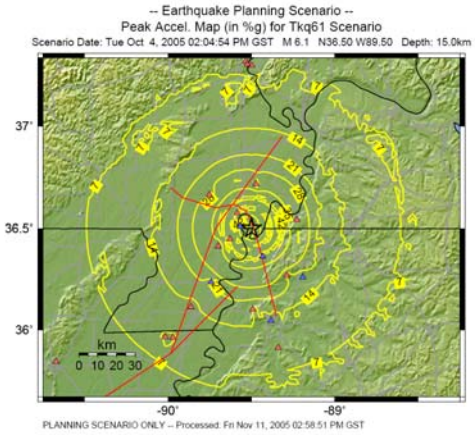
11. With reference to the maps displayed in Figure 4 below, please provide your opinion for each of the questions on the facing page.

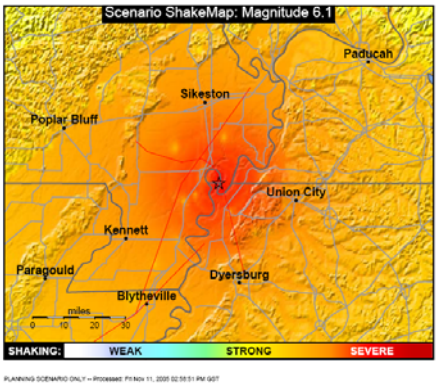
.

A

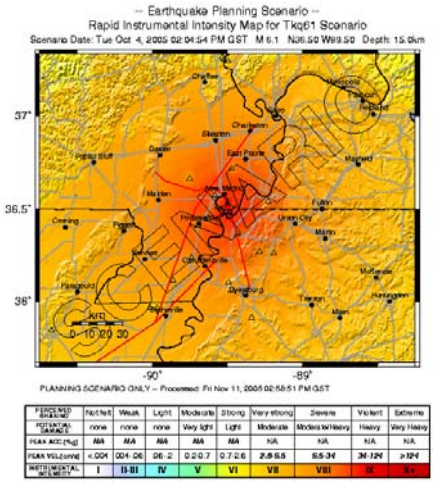


B





C



D

Figure 4: ShakeMap output for the same earthquake parameters presented in different formats - *for survey purpose only*

11. Each of the maps displayed in Figure 4 on the facing page (A, B, C, and D) depict the same ShakeMap parameters displayed in different output formats.

Of the maps displayed in figure 4 (4a, 4b, 4c, 4d) which are you the most comfortable …?	Why?
a. Interpreting _____	
b. Readings _____	
c. Basing your decision on _____	
d. which most closely meets your needs? _____	

12. What features or functions would you consider the greatest improvements to ShakeMap?	Least				Most	N/A
a. Ability to click areas on the map for explanation	1	2	3	4	5	6
b. Ability for user to zoom into local areas	1	2	3	4	5	6
c. An address locator function	1	2	3	4	5	6
d. A legend that can be clicked on to provide additional explanation	1	2	3	4	5	6
e. On-line ShakeMap tutorial for new users	1	2	3	4	5	6
f. Ability to roll-over map items to generate information/explanation pop-ups	1	2	3	4	5	6
g. Other (please define) _____	1	2	3	4	5	6
	Low				High	N/A
13. How would you rank the likelihood of you using ShakeMap in the context of your job after an earthquake?	1	2	3	4	5	6

14. Which of the following presentations of uncertainty information would you find most useful?	Least				Most	N/A
a. A shaded map depicting uncertainty across the ShakeMap area.	1	2	3	4	5	6
b. A table with error estimates for each community across the ShakeMap area.	1	2	3	4	5	6
c. A table with the quality of the ShakeMap for each community – A to F with A being the highest quality and F the lowest.	1	2	3	4	5	6
d. Error bars on the ShakeMap.	1	2	3	4	5	6
e. Other (please define) _____	1	2	3	4	5	6
f. Other (please define) _____	1	2	3	4	5	6

	Yes	No	Don't Know
15. Given the uncertainties in the ShakeMap product would you like to know what the uncertainty is for each ShakeMap generated?	☐	☐	☐

The following questions help us to analyze survey respondents and identify patterns in responses – all information is treated confidentially.

16. What is your age?	_____Years
17. What is your sex?	
18. How many years have you been in your current position?	_____Years
19. How many years have you resided in the area?	_____Years
20. What is your highest level of education?	
21. Have you experienced an earthquake? If yes, where? _____	
22. What percentage of time on your job is spent focused on earthquakes or earthquake risk?	

THANK YOU FOR YOUR HELP!

APPENDIX C: Post-card

March 12, 2007

Last week a survey regarding earthquake hazard information was mailed to your office. You were asked to participate in our study based on your professional role as an Earthquake Program Manager, Emergency Manager, Public Information Officer, or State Geologist.

We encourage you to participate. If you have already completed and returned the survey to us, please accept our thanks. We are grateful for your help, which will be useful in assessing the usefulness of current information products.

If you did not receive a survey, or if it was misplaced, please call us at 901-678-2195, and we will get another one in the mail to you today.

Arleen Hill, University of Memphis – Department of Earth Sciences
Mitch Withers, Univ. of Memphis – Center for Earthquake Research & Information