13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 1030

# IMPROVED POST-EARTHQUAKE PORTFOLIO LOSS ESTIMATION

Akshay GUPTA[1], John D. OSTERAAS[2]

## SUMMARY

An improved post-earthquake event portfolio loss estimation methodology is summarized. The methodology aggregates information from the U.S. Geological Survey, prominent catastrophic loss estimation models, and post-event field damage and loss data collected for a selected subset of the portfolio to provide improved damage and loss estimates for particular portfolios within 7-days of the earthquake event. The results obtained from the methodology are reflective of the particular portfolio characteristics and its performance in the particular event. A web-based GIS system, based on the developed methodology, is implemented for acquisition, processing, and dissemination of the information on a round-the-clock basis. The methodology and system present themselves as useful tools that facilitate more skillful post-event financial planning by providing loss estimates that are more representative of the actual incurred losses.

## INTRODUCTION

Multiple catastrophic loss estimation models (CAT models), such as ATC-13 [1], HAZUS [2], and various proprietary models, provide probabilistic damage and loss estimates for a portfolio of structures as a forecast of the risk, or deterministically as an estimate of the actual incurred damage and loss in the post-earthquake event scenario. Differences in methodology between the various CAT models (e.g., different loss functions, treatment of uncertainty, among others), coupled with differences in the treatment of portfolio data, simulation of seismic effects (e.g., modeling of earthquake mechanism, attenuation relationships, soil effects, etc.), can not only result in significantly different damage and loss estimates between the various models, but can also result in the estimates being significantly different from the actual incurred losses. For example, three weeks after the January 17, 1994, Northridge Earthquake, the insured losses were estimated to be about $2.5 billion, with the number being revised to $9 billion by December 1994 per ISO [3], to $12.3 billion by March 1995 per the California Department of Insurance [4], and by common accounts, the current estimate for the insured losses from the Northridge Earthquake

[1] Managing Engineer, Exponent Failure Analysis Associates, 149 Commonwealth Drive, Menlo Park, CA 94025, USA. Email: agupta@exponent.com.
[2] Principal Engineer, Exponent Failure Analysis Associates, 149 Commonwealth Drive, Menlo Park, CA 94025, USA. Email: osteraas@exponent.com.

stands at about $15 billion. Financial planning and decision-making by the insurance sector can be quite difficult in such a scenario.

To facilitate the decision-making process by portfolio owners and insurers in the immediate aftermath of an earthquake, a post-earthquake loss estimation system (EARLE system) and methodology is developed, which focuses on providing the user with a reliable estimate of the insured loss to the portfolio in question. The methodology is developed to provide information on a continuous basis from the time the event occurs, with the final estimate of the loss becoming available within 7-days of the earthquake event. This paper provides an overview and brief summary of the methodology and its implementation.

The fundamental building blocks of the methodology are the use of earthquake ground motion data available from the U.S. Geological Survey (USGS), an evaluation of the leading CAT models, analyses carried out by the CAT models, actual loss adjustment of a representative subset of the portfolio (field data), near real time calibration of the CAT models based on the field data, and information transfer through a web-based GIS interface. The conceptual methodology is somewhat similar to EPEDAT proposed by Eguchi et al. [5]; the EARLE System methodology differs in its details and implementation, and reasons for its genesis. The fully implemented EARLE system, which will be automated and available on a round-the-clock basis, serves as the information acquisition, processing, and dissemination vehicle.

## METHODOLOGY FRAMEWORK

The various aspects of the methodology along with the timeline during the 7-day period following an event are presented in Figure 1. The interdependencies flowchart for the EARLE System is shown in Figure 2. As seen in Figure 1, the portfolio data is resident on the EARLE System and updated every quarter, ensuring that the latest portfolio dataset is available when the system needs to be initiated. The system continuously polls the USGS websites and servers to ascertain when an earthquake of interest has occurred, i.e., when a pre-defined magnitude threshold is exceeded. The system timeline starts at this point at time T=0 hours. The data associated with the particular event is then automatically retrieved from the USGS servers, and updated as and when updates become available on the USGS servers to ensure that the ensuing analyses are based on the latest earthquake ground motion information.

Basic processing of the earthquake and portfolio data, in the Geographical Information Systems (GIS) domain, is started as soon as the earthquake data is retrieved from the USGS servers. The processing results in the development of shaking intensity maps (intensity, peak ground acceleration, etc., similar to those produced by the USGS), maps that show the spatial overlay of the insured portfolio on the shaking intensity maps (e.g., Figure 3 shows a portfolio of properties overlaid on the intensity map for an hypothetical Newport-Inglewood event), and assessment of the portfolio's exposure for the given event (e.g., number of insured properties within different intensity bands, total replacement cost, a rough damage estimate using ATC-13, etc.). The system allows the user to zoom in on any particular property whereupon selecting the property opens a window listing the characteristics of the property (from the portfolio database) and the earthquake information at the grid points closest to the property. A query system, by address and latitude/longitude, is also available.

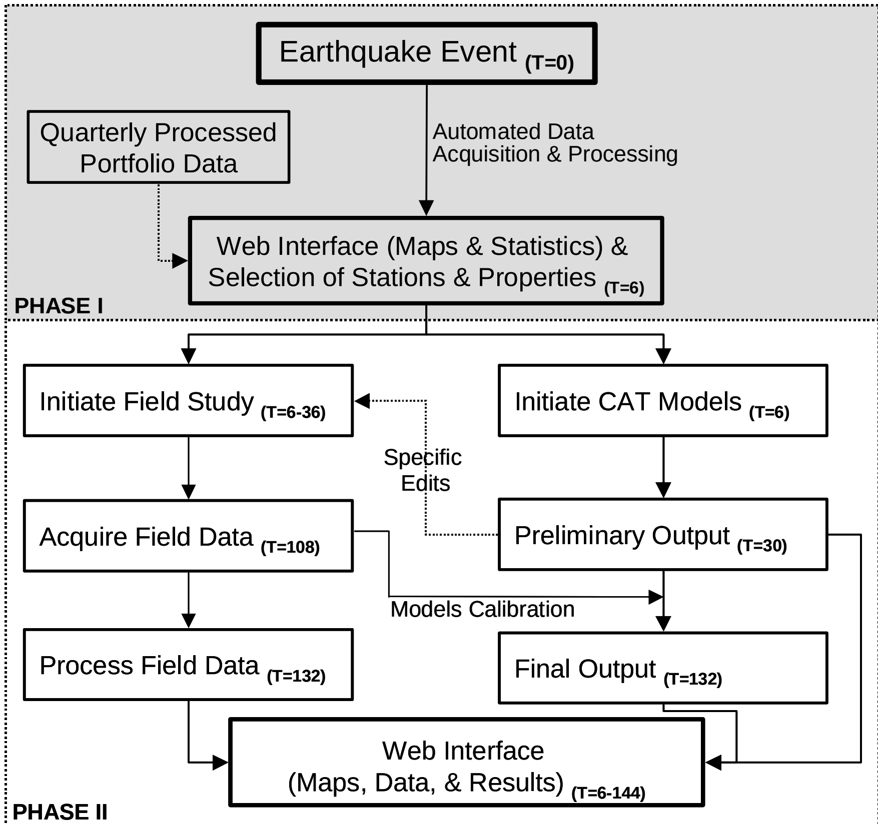


**Figure 1. EARLE System methodology.**

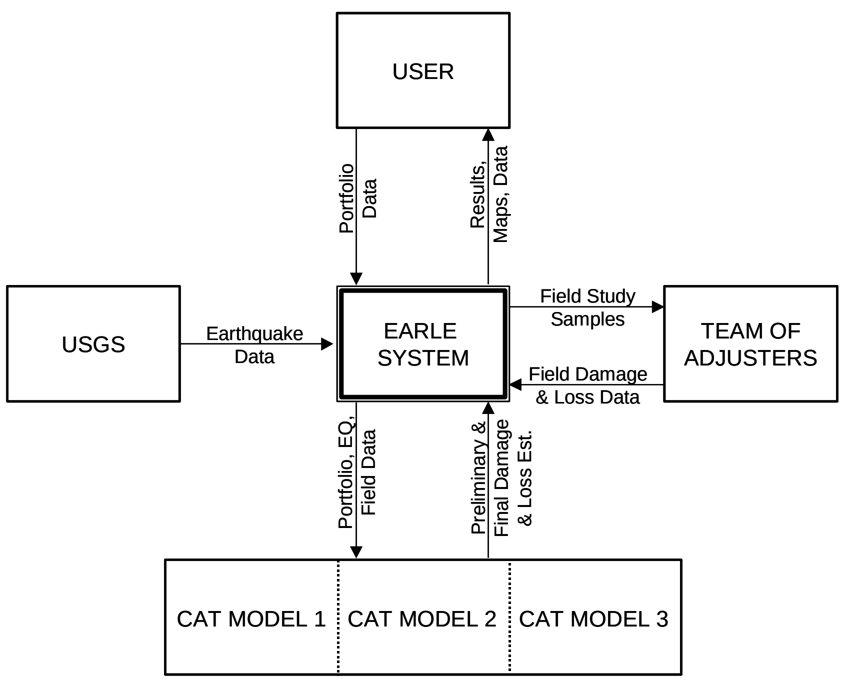


**Figure 2. Interdependencies flowchart for the EARLE System.**

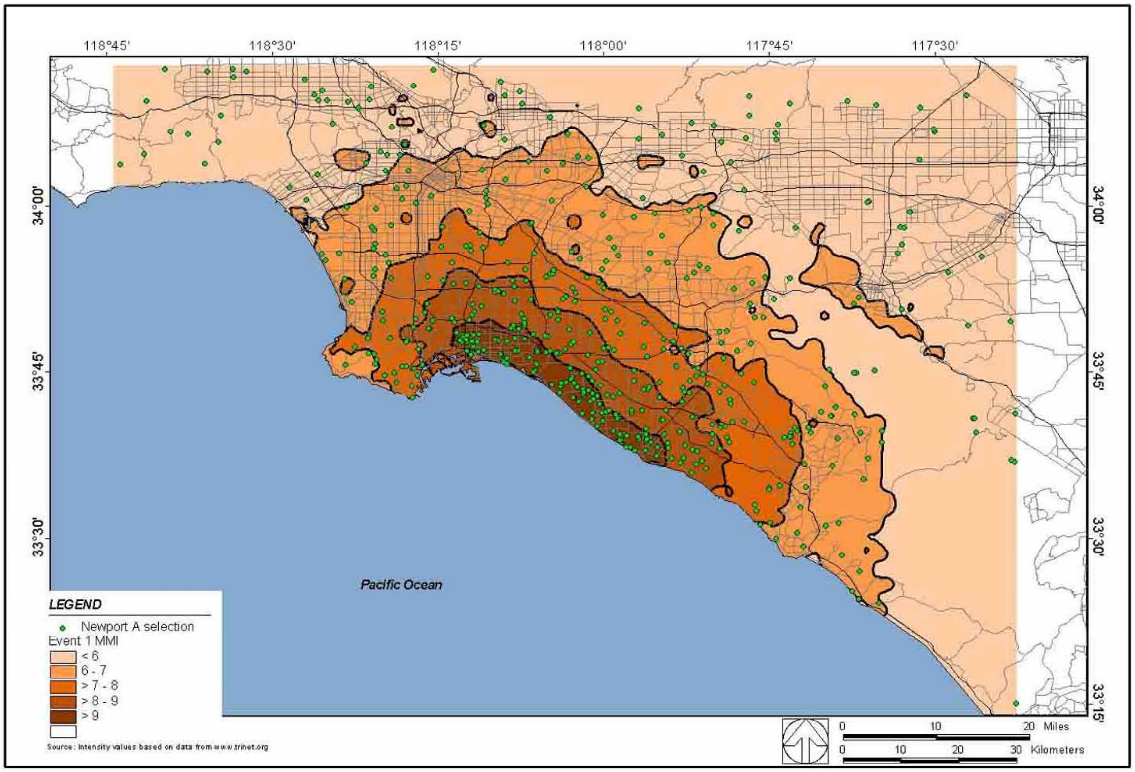


**Figure 3. Overlay of a portfolio of properties on the intensity map for a hypothetical Newport-Inglewood event (100 properties per intensity band).**

The entire set of operations described above takes place shortly after the earthquake data is available from the USGS. The timeline indicates the processed data as being available at T=6 hours to allow for some stabilization of the USGS earthquake data; the system, however, continuously processes and updates the results on the website. The data acquisition, processing, and representation through T=6 hours is automated and runs on a continuous basis. The selection of ground motion recording stations and properties, which is discussed later, is also carried out within the first six hours though it is used only if Phase II of the system is initiated (discussed below).

At T=6 hours, designated as Phase I in Figure 1 (shaded box), given the basic processed information, the user determines whether or not to activate Phase II of the system. For example, if the basic processed information indicates low exposure then the entire system would not be activated. However, if Phase II of the system is activated, then multiple activities take place as follows:

1. The earthquake ground motion data is sent to the CAT models that provide the damage and loss estimates to the EARLE System. The fully implemented EARLE System is envisioned to obtain input from three independent CAT models. The CAT models already have the latest portfolio dataset and a set of instructions related to the analysis to be carried out. The preliminary output from the CAT models is returned to the EARLE System by T=30 hours (e.g., Figure 4 shows the results from one particular analysis, which would then be available from the EARLE System web interface).

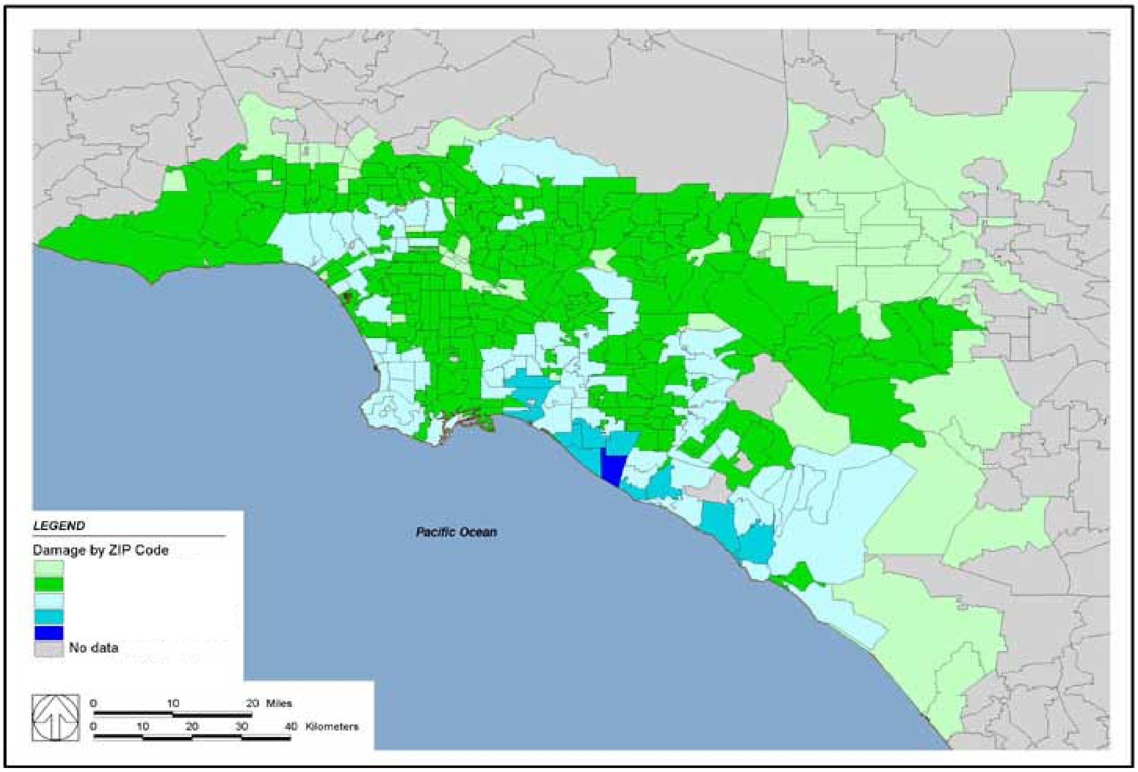


**Figure 4. Example of results available on the EARLE System website (damage per zipcode for a hypothetical portfolio of properties subjected to a hypothetical Newport-Inglewood event).**

2. A representative sample of insured properties is selected from the portfolio. The selection process is discussed later in the paper. The selected properties are sent to a team of adjusters by time T=36 hours, identified as the "Initiate Field Study" box in Figure 1.

3. A subset of a minimum one-half of the selected properties is subjected to a damage and loss adjustment in the field by the adjusters per the governing policy language. The assessment is similar to an assessment that would conventionally be carried out following an earthquake event and the reporting of a claim. This damage and loss data is returned back to the EARLE System by T=108 hours. As is evident, the maximum time during the 7-day process is reserved for acquisition of the field data.

4. The field damage and loss data for the surveyed properties is evaluated vis-à-vis the estimates provided by the CAT models at T=30 hours for those particular properties. The evaluation results in a set of calibration factors that are then applied, at the property level, to the entire set of preliminary damage and loss estimates provided by the CAT models. The result is a damage and loss estimate, per property, for the entire affected portfolio and reflects the performance of the portfolio in that particular event. The calibration is carried out within the EARLE System through T=132 hours.

5. The field damage and loss data is also sent to the CAT models, wherein they calibrate their models independently of the EARLE System and return an updated final estimate of the portfolio damage and loss to the EARLE System by T=132 hours.

6. The final portfolio damage and loss data obtained from the CAT models is reviewed vis-à-vis the estimate obtained through the calibration process within the EARLE System.

7. The final damage and loss estimates, and maps, are then made available to the end user through the web interface at T=144 hours. This step represents the final step in the EARLE System methodology.

8. The estimates are then subjected to a financial analysis, and evaluation by a group of actuaries, at which point it results in the loss estimate for the portfolio for the particular event. T=168 hours.

As is evidenced from the methodology, the system works with and utilizes information from a variety of sources such as the USGS, CAT models, and the team of adjusters (Figure 2). Agreements and understandings between the various parties, for example in terms of data requirements, data flow, analyses, accessibility, confidentiality, etc., have been pre-negotiated for the purposes of the EARLE System. Since the system is required to operate on 24/7 basis, redundancy is built into the system by requiring all parties to provide a secondary machine that is fully configured to take over should the primary machine go down (for example, the EARLE System servers are physically housed in two different states). The various servers are regularly accessed to ensure that the servers are operational. The USGS sites are considered stable as they can deliver the data from various locations. The following sections discuss some of the facets of the methodology and implemented system.

## CATASTROPHIC LOSS ESTIMATION MODELS (CAT MODELS)

A detailed evaluation of the CAT models was carried out to identify the primary causes for the differences observed in the damage and loss estimates returned by the different models for the same portfolio for a given event. The evaluation included various analyses and discussions with the modelers regarding the methodology and data used by the CAT models.

The causes for differences in the estimates can be broadly categorized as 1) those related to the development of fragility and damage functions contained in the models (underlying data, processing, calibration, etc.), treatment of various uncertainties, variability, and correlations, among others; and 2) those related to simulation of ground motion data, treatment of site soil effects, resolution of analysis (e.g., site level or zip code level), assumptions related to use of portfolio data, among others.

The first set of causes identified above reflect issues that are intrinsic to a CAT model's methodology; they result in each CAT model being a unique model and for these reasons different CAT models will result in differing damage and loss estimates. Some level of difference in the results is healthy, and required, as the differences in the final estimates can be seen as being representative of the inherent idiosyncrasies associated with earthquake engineering and risk analysis. For example, while the models use the available data from previous earthquakes, the quality and quantity of data makes it open to various interpretations; furthermore, different approaches (all similarly valid) can be used for various engineering evaluations, e.g., attenuation of ground motions. Thus, it may so happen that one model may turn out to be better suited for estimating the loss to a particular type of portfolio for a particular event, while being a poor estimator for a different portfolio and a different event. Thus, it is quite difficult to assess and qualify a model as being "correct" except in a deterministic post-event scenario.

The second set of causes identified above reflect issues that can be standardized between the different models, as has been done within the EARLE System's methodology. For example:

1. All CAT models are required to use the same set of ground motion data as opposed to independently generating the information using different attenuation relationships and modeling of the earthquake event. Furthermore, the ground motion data is obtained from the USGS, which for the more populated regions of California is based on information from an extensive array of ground motion recording stations. The effect of this standardization is discussed separately later in this paper.

2. The resolution of the analysis is standardized between the various models, with all models required to perform the analysis at the site level and then aggregating the results to provide the portfolio damage and loss estimates. The difference in results between aggregating the portfolio at the zipcode level and then performing the analysis versus performing the analysis at the site level and then aggregating the losses to the zipcode level was observed to be substantial in a test case that was analyzed.

3. The USGS data accounts for site soil effects at the grid point level, which is a one-minute by one-minute grid. A standard approach is defined to interpolate between the grid points to result in the ground-shaking estimate at the site level.

4. Any assumptions included by the models related to the portfolio data are standardized.

While carrying out the steps outlined above reduces/removes some sources of easily corrected differences between the models, the estimates between the various models can still be vastly different for the same portfolio subjected to the same defined event, as presented later in the paper.

For confidentiality reasons, the CAT models participating in the EARLE System are not being identified in this paper. Similarly, absolute damage and loss results are not being presented, results are presented as ratios between various models and within the same model with and without consideration of specific effects. The CAT modelers' input into the development of the system, and actual operation of the system is gratefully acknowledged.

## EARTHQUAKE GROUND MOTION INFORMATION

An evaluation of the various CAT models quickly pointed to the process of simulation of the ground shaking information as a potential source of variability in the damage and loss estimates between the various models, with different models modeling the event and the ground motion attenuation in different ways. Differences also exist between the basic soil information used and the treatment of soil effects, i.e., modification of ground shaking information based on site soils.

Since the focus of the system being developed is on post-event damage and loss estimation, and the ground shaking data associated with the event is available from the USGS shortly following the event, the methodology required the use of this data by all CAT models for the portfolio damage and loss estimation. This step removed the differences associated with the modeling of the earthquake mechanism, ground motion attenuation, and incorporation of site soil effects (the USGS data accounts for the grid point soil characteristics). Furthermore, the USGS data is based on recorded ground motion information for the more populated regions of California.

A test case was analyzed wherein the same portfolio was subjected to the USGS data for a particular event, and also subjected to a simulation of the ground motion data by the CAT model. The difference in the mean damage estimate for this particular case was about 40%. Another test case was run wherein the simulation of the ground motion data for a hypothetical event was carried out by the USGS and a CAT model, damage estimates were computed by the same CAT model and the results found to vary by almost 100%. Clearly, the variability associated with the process of modeling the earthquake mechanism and simulating ground motion information can have a substantial effect on the portfolio damage and loss estimates. Use of the USGS data, based on the recorded ground motion information, is seen as an attractive easy solution to the problem in cases where the recorded ground motion information is available.

The USGS data is at a one-minute by one-minute grid level, which then needs to be interpolated to the site level, accounting for the variations in site soils that may occur within a grid. Various methods may be used to achieve this objective (e.g., simple weighting based on distance from grid point, de-amplification to base rock at grid points followed by interpolation to site level followed by amplification for site soil effects, etc.). Test cases analyzed indicated that it is necessary to, at a minimum, interpolate the grid point data to obtain the ground shaking at the site, with minimal additional improvement introduced by accounting for any differences in the soil conditions at the site versus the grid points. For example, the difference in a portfolio damage estimate using the closest grid point data versus using interpolated grid point data was about 25%. In contrast, additionally accounting for differences in soil conditions between the grid points and the site resulted in less than 5% difference in the damage and loss estimates.

## PORTFOLIO DATA[3]

Additional differences in the analysis results are introduced between the different CAT models because of assumptions included by the models regarding the portfolio and policy information. Furthermore, different models may use different attributes of the data (for example, one model may use the square footage to compute the contents value, whereas another may take the contents value as a percentage of the replacement value of the structure). A set of guidelines addressing the common assumptions included in the CAT models is generated to result in improved consistency in using the portfolio and policy information.

## COMPARATIVE ANALYSIS BETWEEN CAT MODELS

Subsequent to addressing issues related to the ground motion information, effect of site soil effects, issues associated with assumptions related to the portfolio, issues related to the level at which analyses were to be carried out, etc., various analyses were carried out using different CAT models, and hypothetical portfolios of structures. The ratio of the mean damage estimates obtained from the different models (the damage estimates for each model are normalized to the lowest damage estimate amongst the different models) ranges from 1.2 to 2.8 depending on the earthquake event being considered. The ratio of the 90$^{th}$ percentile damage ranges from 1.0 to 1.6. Corresponding range of results for the mean loss is 1.1-5.0, and for the 90$^{th}$ percentile loss is 1.1-2.4. These results indicate that 1) there can be large differences in the mean damage and loss estimates between various models, and 2) that the standard deviation associated with the mean damage and loss estimates also varies significantly between different models. Clearly, the models are fundamentally different in their methodologies, as indicated by the results for the same hypothetical portfolios subjected to the same events. Thus, for post-event evaluation further

---

[3] It should be noted that the results discussed in this paper are for a portfolio of single-family wood-frame structures, which is abstracted from the global portfolio of an insurance carrier. The results, thus, may not be reflective of the performance of the entire portfolio.

improvements need to be introduced to result in a better assessment of the portfolio damage and loss estimates for the particular event.

## FIELD STUDY AND CALIBRATION OF MODELS

As shown in Figure 1 and discussed previously in the paper, the EARLE System's methodology includes a field damage and loss assessment component wherein a representative sample of insured properties is selected for actual loss adjustment. The results from the field study are used to calibrate the CAT models, and their output to reflect the performance of the particular portfolio in that particular event. The calibration process is as follows:

1. A set of earthquake ground motion recording stations is selected over the footprint of the earthquake, immediately following the event. The selected stations geographically cover the footprint of the earthquake. For example, for the hypothetical event shown in Figure 3, the selected stations would be as shown in Figure 5. The selection is obviously dependent on the distribution of recording stations in the footprint of the earthquake.

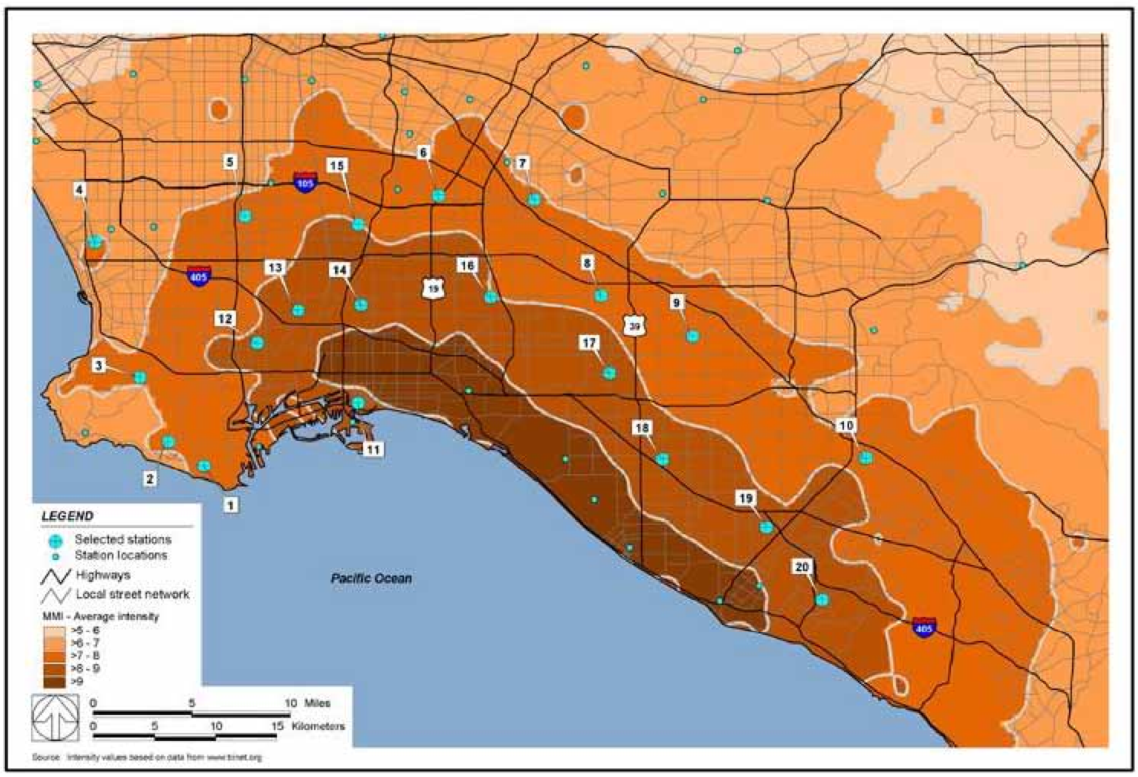


**Figure 5. Selection of ground motion recording stations over the footprint of the earthquake (in this figure the selection is confined to intensity 7 and 8 bands).**

2. Insured properties are selected around each recording station, with the constraint that the total sample of selected properties represents the entire affected portfolio in terms of intensity of ground shaking, vintage of properties, and geographical location of properties. Thus, properties would be selected around the stations shown in Figure 5, such that the total sample

conforms to the constraints identified above. Figure 6 shows a close up around one recording station, with twenty insured properties identified within the "circle." The sample selected for the field study can be modified at T=30 hours based on the preliminary output from the CAT models. The field study sample is more heavily weighted in the intensity bands where larger variability is observed in the CAT models damage functions.

The selection of the properties is carried out around recording stations as these represent the best source for the recorded ground motion information, i.e., additional variability associated with any interpolation or attenuation of ground shaking is not introduced in the field data set. The total size of the field study sample is conditional on the characteristics of the total portfolio, resources available for the field study, and earthquake characteristics.

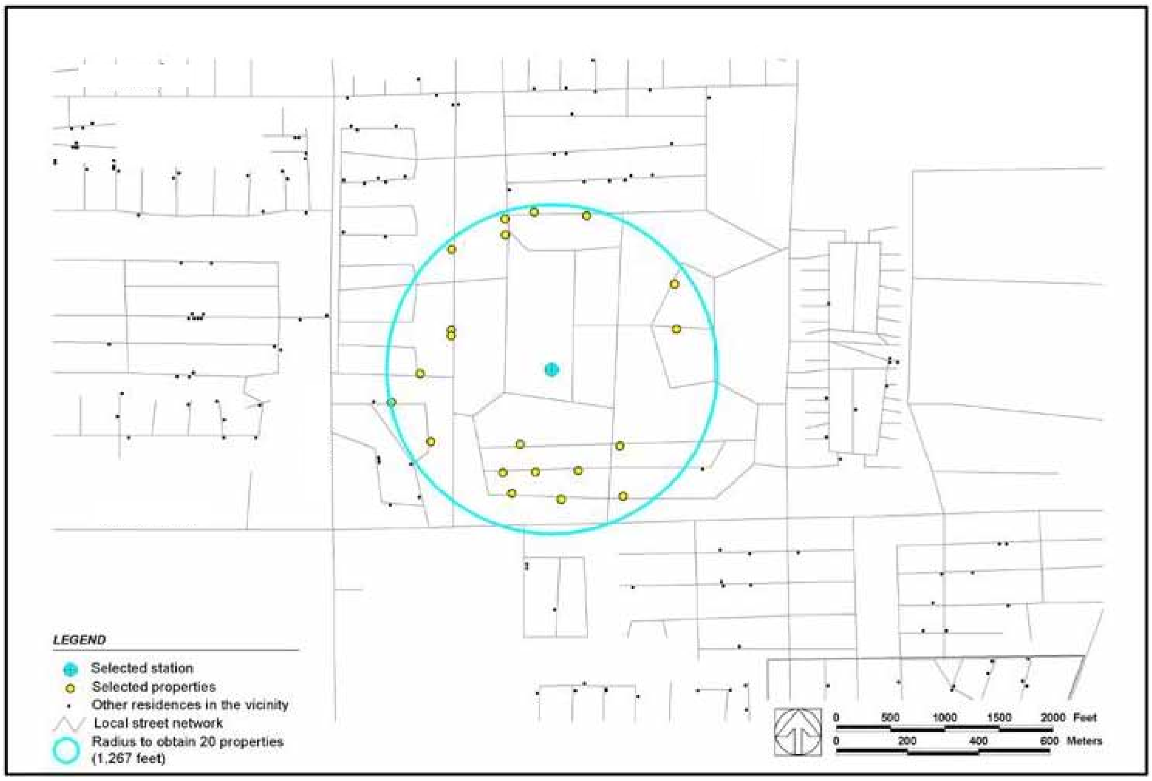


**Figure 6. Example showing the selection of 20 properties around a recording station.**

3. Adjusters are sent to the various "circles" to adjust the damage and loss to these properties. The process followed by the adjusters should represent typical adjustment practices adopted following a claim for earthquake loss by an insurance carrier. Thus, the data collected by the adjusters reflects the damage and loss adjusted in the field for a representative sample of properties for the particular earthquake and specific policy language in effect. It is expected that the adjusters would have access to at least half of the properties in each sample, i.e., 10 out of every 20 properties selected around an earthquake ground motion recording station.

4. The damage and loss data is fed back into the EARLE System. The field data is evaluated vis-à-vis the preliminary output from the CAT models for the particular properties to obtain

sets of CAT model specific calibration factors. A methodology for obtaining these calibration factors has been developed but is not presented in this paper.

5. The CAT models preliminary output (provided at T=30 hours) is modified at the property level for the entire portfolio using the calibration factors developed, and the results aggregated to provide a portfolio level damage and loss estimate that reflects the performance of the particular portfolio in the particular event.

6. Each of the CAT models also carry out the above two steps independently to result in updated damage and loss estimates for the portfolio.

The expectation is that after the CAT models have updated their damage functions to reflect the field data for the particular event, the damage and loss estimates between the various models will not be as different as observed and discussed previously. The results are expected to be different between the models to the extent that represents the inherent uncertainty associated with the process of portfolio damage and loss estimation. The independent calibration factors developed within the EARLE System and their use with the preliminary output from the CAT models is used to provide an independent check on the process.

## IMPLEMENTATION

A web-based GIS system is developed that serves as the data acquisition, processing, and dissemination center. The system is automated and available on a 24/7 basis, with redundancy built into the system to ensure uninterrupted operation. The system allows the user to access the information easily in near real time through a simple web interface thereby providing the user with the information required for making more informed decisions regarding their portfolios in the immediate aftermath of an earthquake event.

## CONCLUSIONS

The EARLE System and methodology improves upon the current state-of-the-art in post-event portfolio damage and loss estimation by removing/reducing some of the sources of differences and uncertainty between the results obtained from different CAT models, and calibrating the models' damage and loss functions to reflect the performance of the portfolio in the particular earthquake event and the specific policy in effect. The second step is done in near real-time and results in the models estimating the damage for the particular portfolio based on a representative sample's performance in that event. Thus, the risk of the estimate deviating significantly from the actual incurred portfolio losses is reduced. The system allows the user to access the information in near real-time thereby assisting the user in making a more skillful and informed decision regarding their portfolio in the aftermath of an earthquake event.

While the EARLE System has been developed specifically for earthquakes in California, the methodology and system have the potential to be expanded to assist with emergency response, to be applied to different geographical areas, for different natural hazards, and to portfolios of varying sizes and characteristics. The EARLE System is currently in the final phase of development and implementation, and is designed to provide a refined loss estimate within one week of the occurrence of the earthquake event.

## REFERENCES


1. ATC-13, "Earthquake Damage Evaluation Data for California," Applied Technology Council, Redwood City, CA, 1985.
2. HAZUS-99, "Earthquake Loss Estimation Methodology," Federal Emergency Management Agency, Washington, D.C., 1999.
3. "Catastrophes: Insurance Issues Surrounding the Northridge Earthquake and Other Natural Disasters," ISO, 1994. www.iso.com/studies_analyses/study005.html.
4. Al-Faris K, Tan, B. "Northridge Earthquake Insurance Loss Report," California Department of Insurance, 1996.
5. Eguchi RT, Goltz JD, Seligson HA, Flores PJ, Blais NC, Heaton TH, Bortugno E. "Real-Time Loss Estimation as an Emergency Response Decision Support System: The Early Post-Earthquake Damage Assessment Tool," Earthquake Spectra 1997; 13(4): 815-32.