EARTHQUAKE MODELING UNIT 5

RMS® CCRA® Training Program

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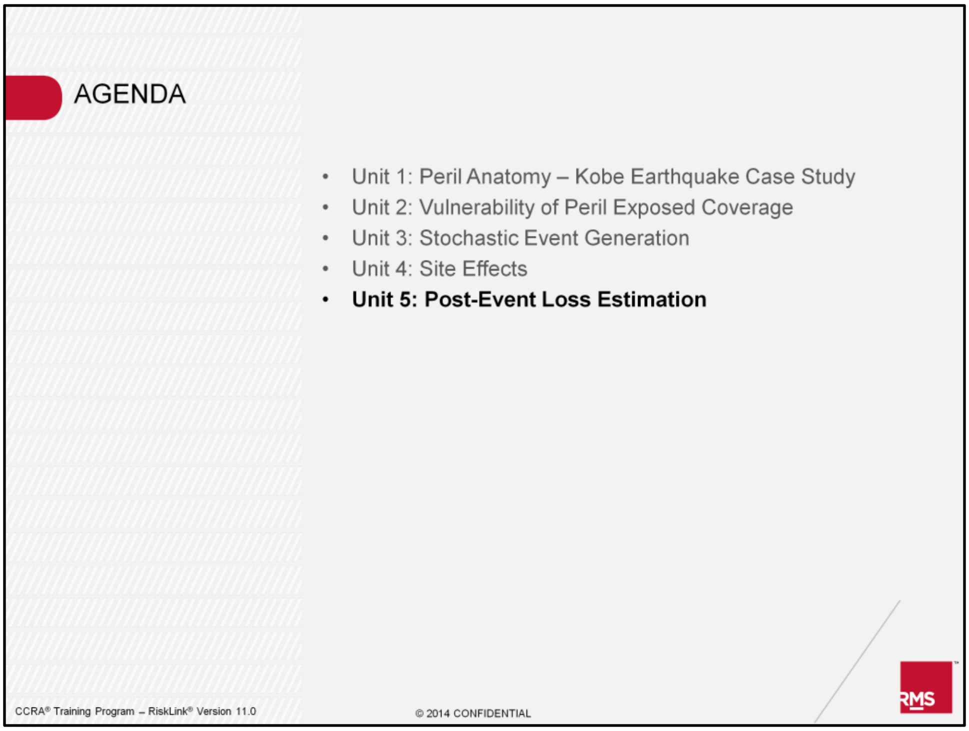
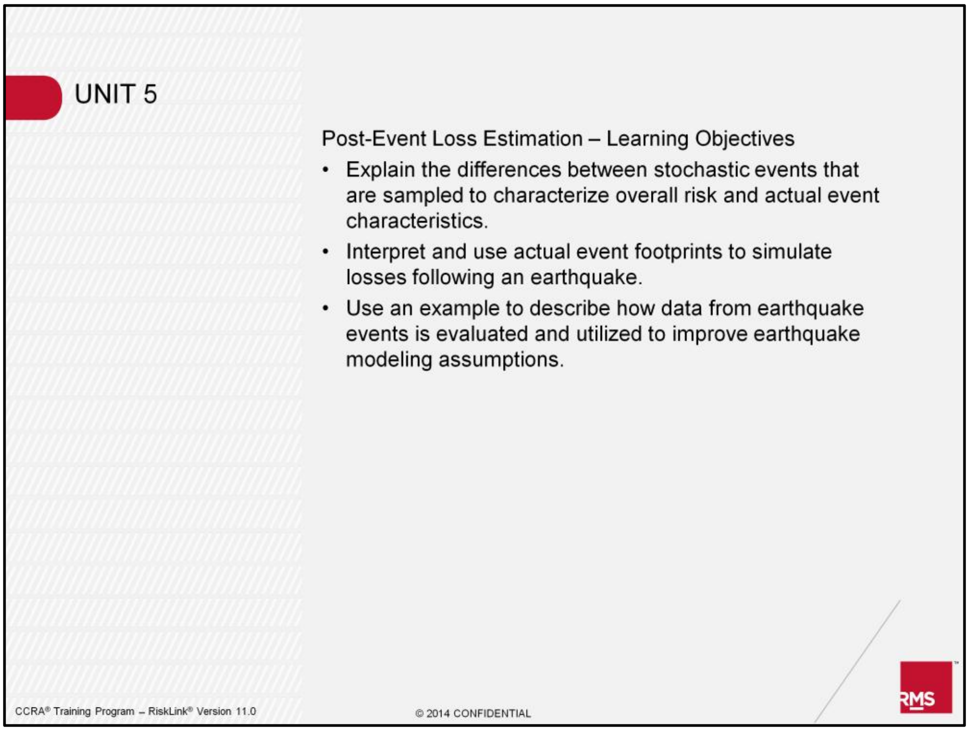
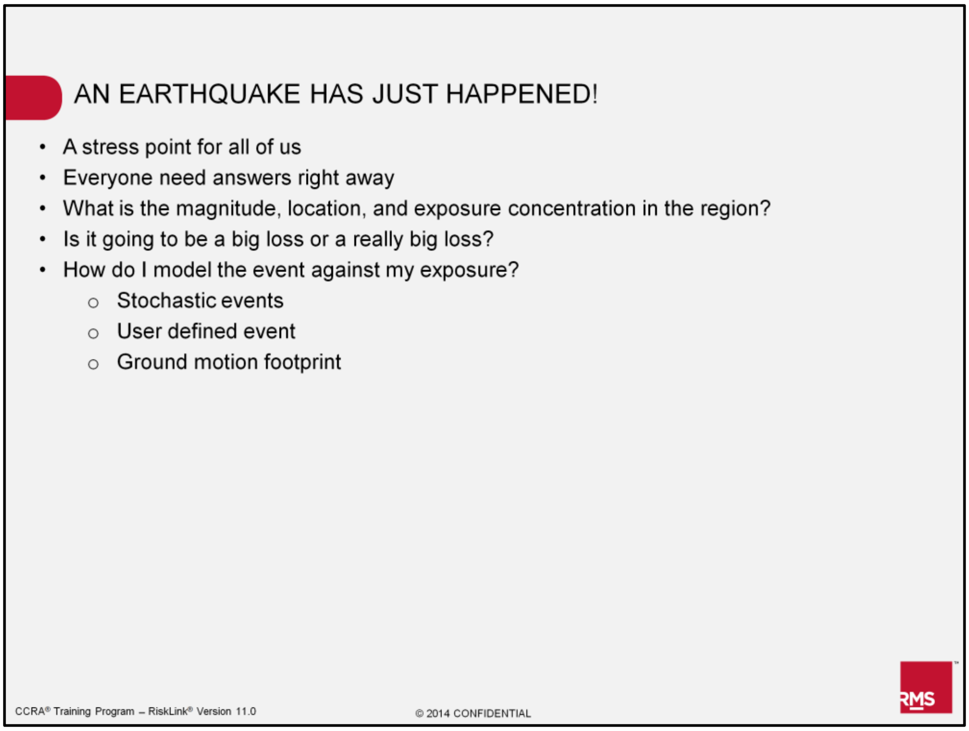


In Unit 5 we will look at a post-event loss estimation. We will use the Nisqually earthquake as a case study. We will examine everything that goes on when an event has happened. We will look at how stochastic events are sampled, we will look at footprints, and we will talk about how data from the event impacts future modeling.



By the end of this unit you should have a good understanding of each of the three learning objectives listed on this slide.



When an earthquake happens it is quite a stress point for everyone at RMS and presumably for you too. There are many people who want answers right away. The first questions that are asked are centered on where the earthquake occurred, how big it is, what exposure it has impacted, and the size of the loss. Shortly after an event, people want to know how to model their exposure. There are three different ways you can run the event: you can run a stochastic event, a user defined event, or a ground motion footprint. We will walk through how we get through this process right after an event.

GLOBAL EARTHQUAKE CAT RESPONSE

- Magnitude and location of earthquake determines response level

Threshold	Region	Modeling Information
Mw 5.5 or larger	U.S. (except Alaska)	- Stochastic events - User defined event - Accumulation footprint
Mw 6.0 or larger	RMS earthquake model regions	- Stochastic events - User defined event - Accumulation footprint
Mw 6.5 or larger	Alaska and Japan	- Stochastic events - User defined event - Accumulation footprint
Mw 7.0 or larger	U.S. (except Alaska)	- Footprint for RiskLink® analysis - Stochastic events - User defined event - Accumulation footprint

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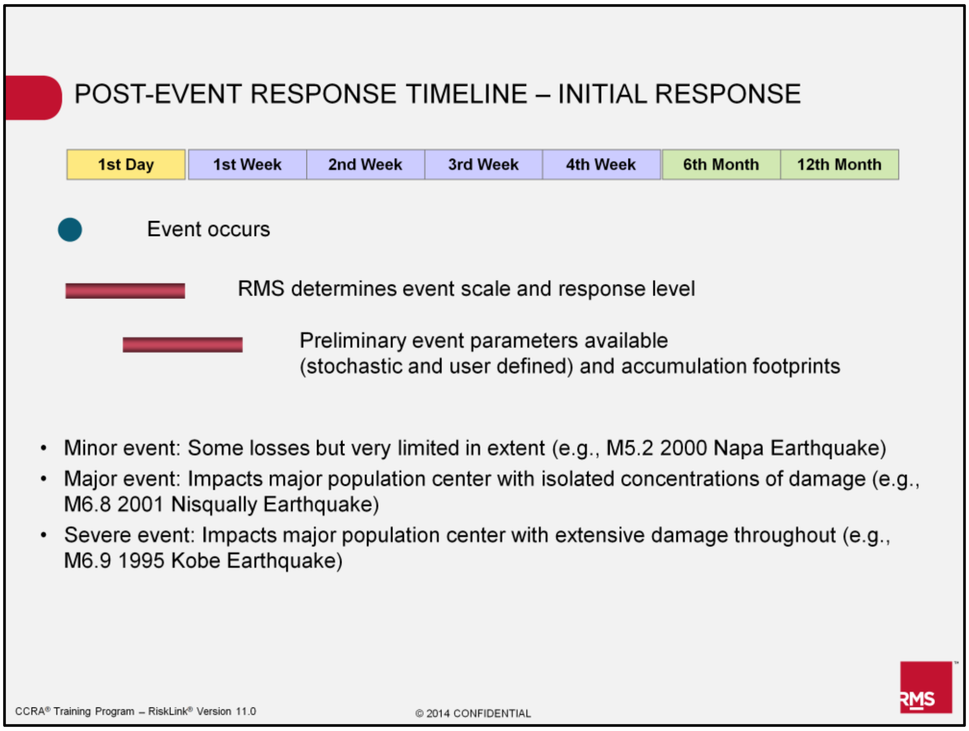
When a real time earthquake event occurs, the deliverables issued by RMS will vary based on the magnitude and location of the event. Footprint files will only be available for events in the U.S. larger than Mw 7.0. Elsewhere in the world and for smaller events in the U.S., RMS would typically issue stochastic events, user defined events, and an accumulation footprint that would be based on the USGS shake map and damage reports.

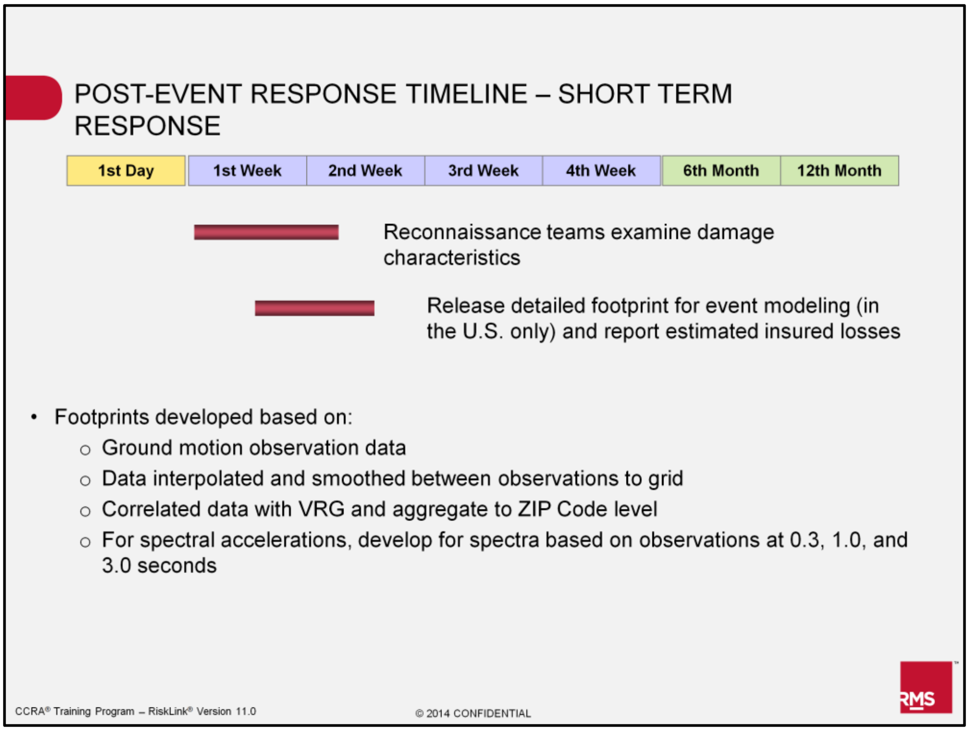


There are three components to the timeline of how RMS responds to events. Immediately after the event happens is the initial response where we need to determine exactly what the scale of the event is. Some different scales of events are described on the bottom of this slide. A minor event is an event that causes some loss but is very limited in extent. An example would be the earthquake that happened in Napa, California in 2000. While it was only a magnitude 5.2 event, it caused a number of chimneys to collapse in the Napa area and there were some injuries due to the collapsing chimneys. Overall the losses were fairly small and the exposure concentration was not great in that immediate area.

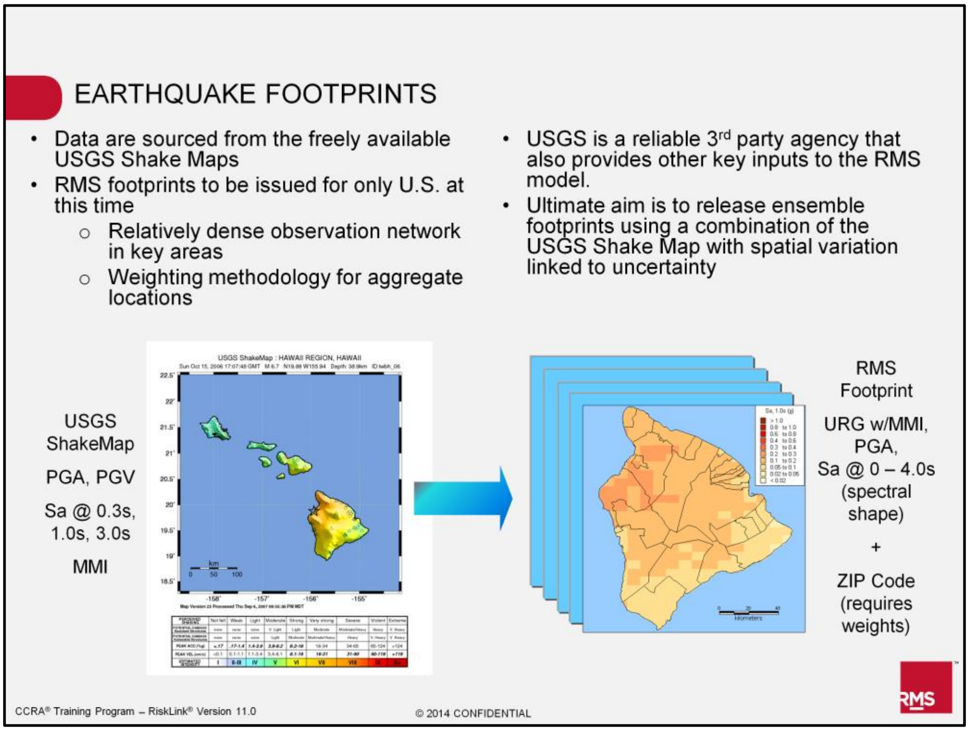
An example of a major event is the Nisqually earthquake, which we will walk through in this unit. It impacted a major population center. Fortunately, because it was a relatively deep event, there were only isolated concentrations of damage.

The final example is the severe event. It is important to understand that the magnitude does not really drive the difference between major and severe events. The example of a severe event given here is the Kobe earthquake, which had about the same magnitude as the Nisqually earthquake. It also impacted a major population center but caused extensive damage throughout. The difference is that the Kobe event was a shallow crustal event while the Nisqually earthquake was deeper. Because it was deeper, the ground motions were somewhat mitigated.

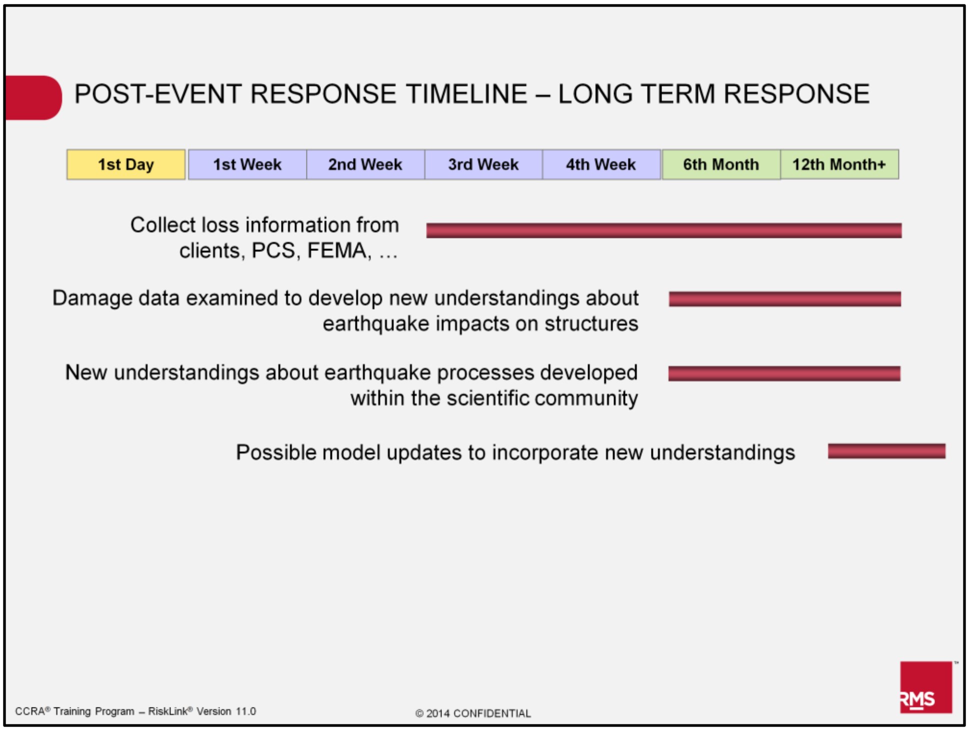
We have to determine how big the event is and what kind of response we are going to have but almost immediately we try to come up with some parameters to determine what kind of loss level may be experienced. We will release these preliminary parameters in two different types. We choose an event that most closely matches this actual event from the stochastic event set. That provides a way to look at analyses already run and look at that particular event and be able to estimate losses from it immediately. In many cases, though, the events in the stochastic event set do not match the character of the individual event exactly. Perhaps the magnitudes and/or locations are slightly different. So we also produce user defined parameters. We provide coordinates for the center of the rupture and provide information on the length of the rupture. That allows you to use the user defined interface to run an event that might more closely match the exact character of the event.



In the few weeks following the event we have the short term response. If it is a major or severe event we will likely send a reconnaissance team to examine the damage characteristics. We want to be able to understand what happened on the ground and get a good sense of what types of structures experienced damage. This will also give us a better sense of what kind of ground motions those structures experienced. For events in the U.S., we put together a detailed footprint to model that event. This allows us to have a much better model of exactly what kind of ground motions that event produced. Attenuation equations are good at giving us a mean understanding of potential events that could happen but when we look at the footprint for an individual event it is going to have a different character than the attenuation equation might predict. So it is important for us to be able to capture those differences between the attenuation relationship and the footprint. This footprint is going to give a much better estimation of the insured losses.



The development of the footprint in the U.S. is based on ground motion observations. In the U.S., we get the data from the United States Geological Survey (USGS). The data has been interpolated and smoothed between the observations at the VRG level and then aggregated up to the ZIP Code level. We also need to interpolate between the different spectral acceleration frequencies. The USGS releases their data at 0.3, 1.0, and 3.0 seconds. To be able to understand how buildings of different heights and different periods are impacted we need to interpolate between these different spectral response values in order to provide a full spectral shape.



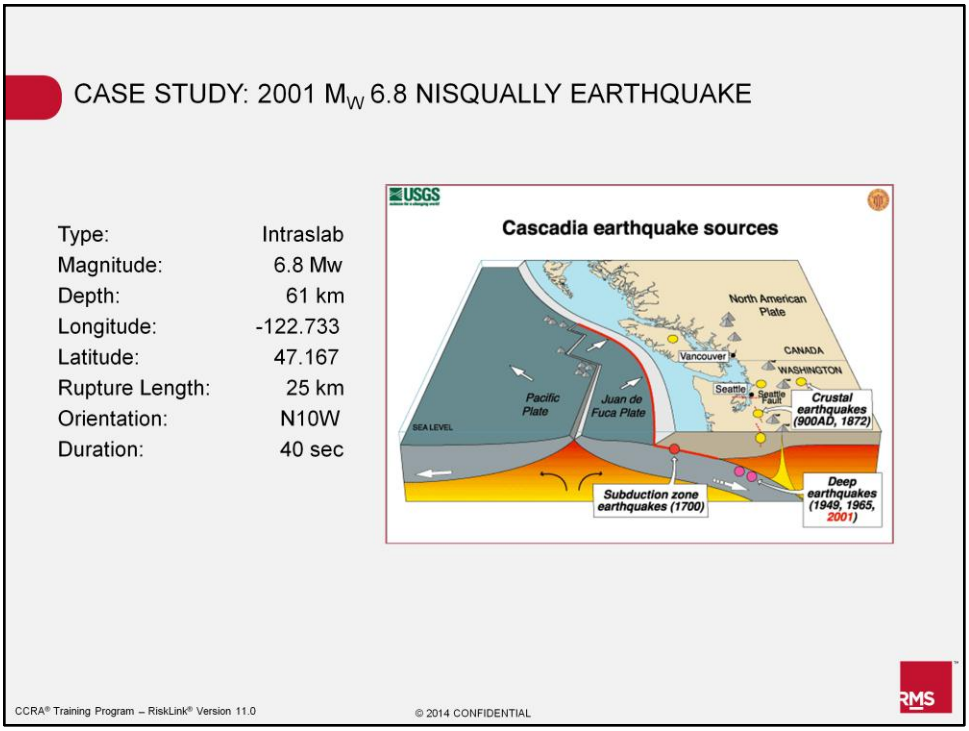
RMS does a loss estimation for all major events in RMS modeled regions. For the long term response, we collect as much information as possible about the damage for that event. We collect information from clients and we also look at other sources of estimation of insured loss such as PCS. In addition, we try to get information from government agencies such as FEMA.

Next we examine the damage data to helps us with any new information about how structures are impacted by earthquakes. We also look at the data from that event to see if there is any new information about earthquake processes or ground motions, and we look at rates for structures in that area that should be incorporated in future model versions. Depending on when that model is likely to be updated, those new understandings may be incorporated.

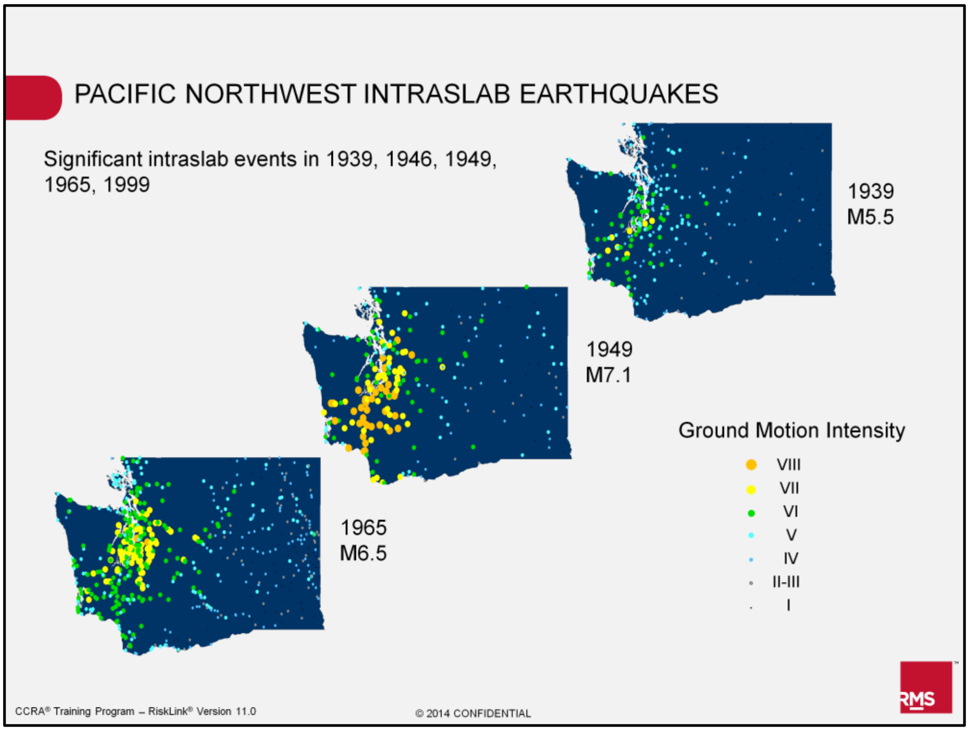
POST-EVENT LOSS ESTIMATIONS

- Initial estimates determined based on stochastic events that closely match the event
- In some cases, a user defined event can better match the characteristics of an event.
- As more information about ground motion observations becomes available, footprint files are generated to run instead of using ground motion attenuation relationships.
- Damage observations used to calibrate the ground motion further to improve the relationship between ground motions and damage

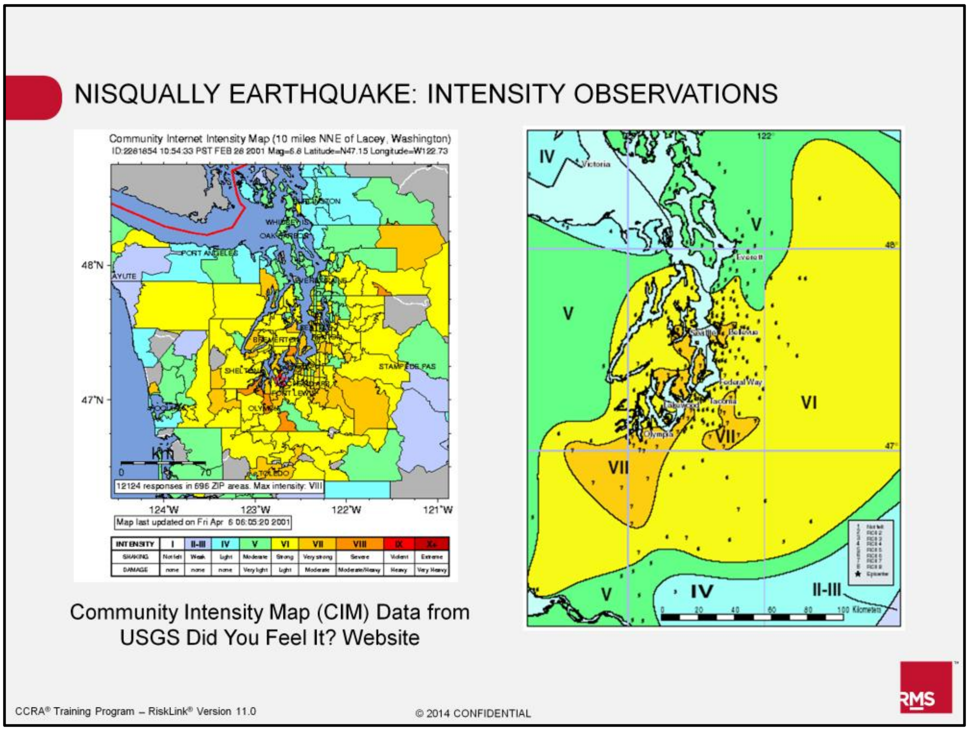
The post event loss estimation process is an iterative process. First, we look at the stochastic events to find a match and we would use the standard ground motion model to generate those first estimates. We would then also look at user defined events to see if we can match the character of the event a bit more closely. The observed ground motions are collected over the first couple of weeks and validated against the observed damage levels. Ultimately, we want to be able to develop footprint files that can be used to capture the true complexity of the ground motions for the individual events. When the ground motion footprints are developed they are interpolated between observation sites. By going out and looking at damage we can say more about how that data could be interpolated and refine the overall relationship between the ground motion and the damage.



Next we will talk about the Nisqually earthquake and some of the lessons learned from that event. Nisqually was an intraslab earthquake that happened under the Puget Sound area. It was a deep event that happened at 61 kilometers. It had a magnitude of 6.8 and the duration of shaking was 40 seconds, a fairly significant shaking event. The Nisqually earthquake was very similar to several other instraslab events that had happened in the region.

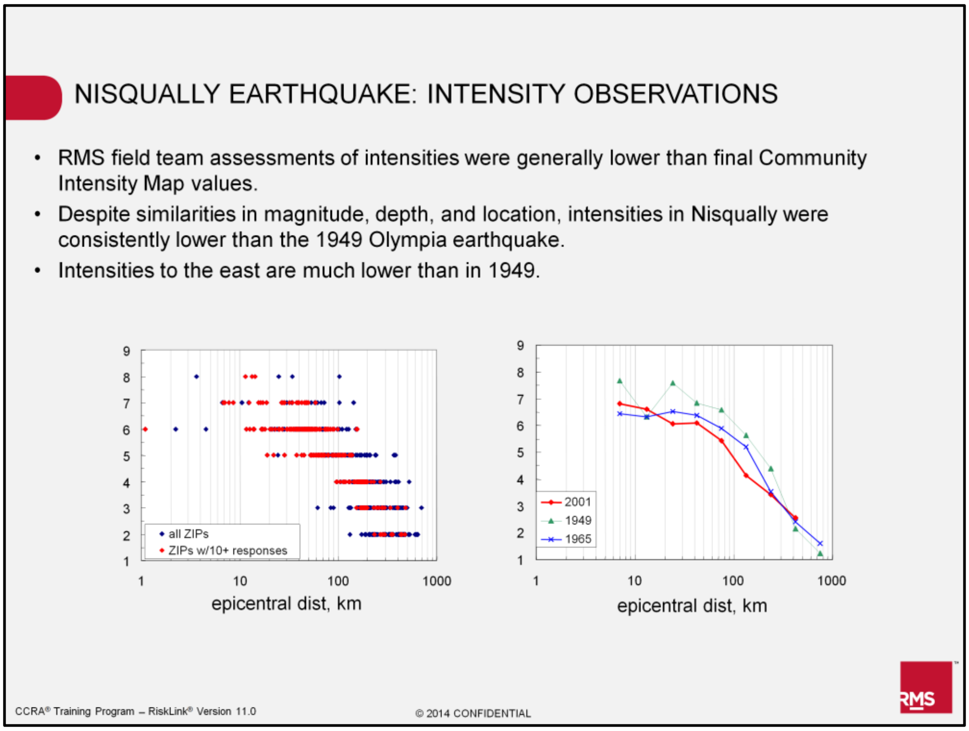


There had been significant intraslab events in the area in 1939, 1946, 1949, 1965, and 1999. Because we had all this data we felt confident that we knew something about these types of events in that area and we felt we would be able to replicate the ground motions for it well. This slide shows plots of ground motion intensity for three of the historic events. The orange circles represent intensity eight, the yellow circles represent intensity seven, and the intensities get lower and lower as the colors get cooler. The 1949 event, which was a magnitude 7.1, has a lot of intensity eight. Of the historic events, this one was most similar to the Nisqually earthquake. It was only slightly larger, it was at the same depth and at a relatively similar location.



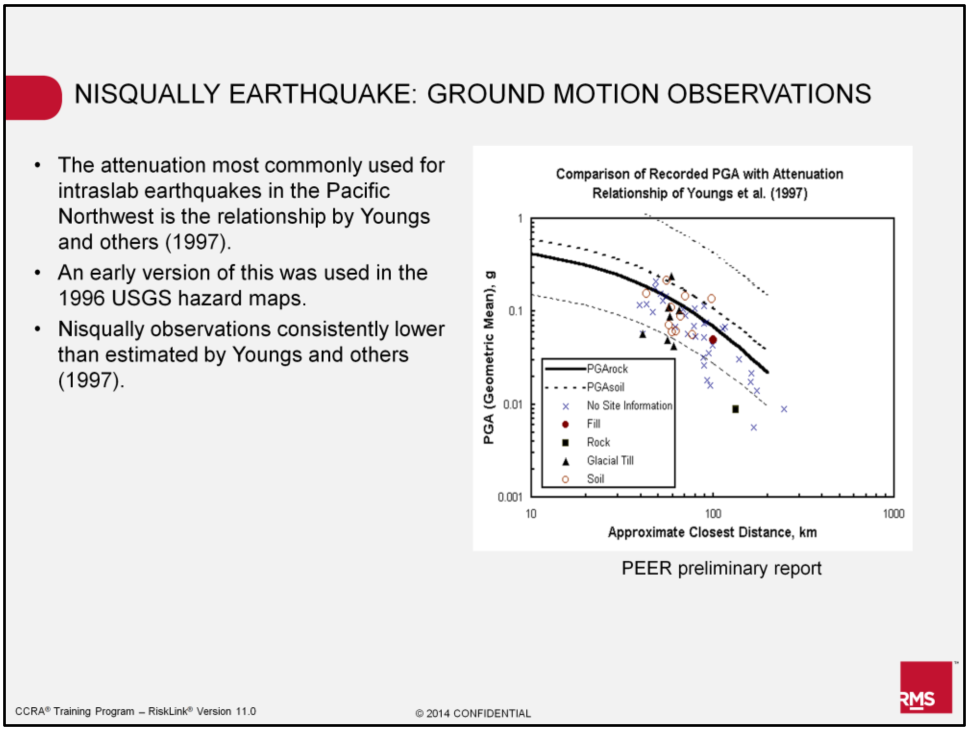
The map on the left is from the USGS “Did you feel it” website. This is a web site the USGS put together to collect information from anyone with access to a computer who has experienced an earthquake in the United States. When you log into the website you complete a 20-question questionnaire asking you about your experience of the earthquake. From “how did it make you feel” to “how did it make the contents in the structure you were in respond” to “how did the building you were in respond.” The responses to these questions produce an assessment of the intensity value for that location. This map shows 12,000 responses for the ZIP Codes that surround the Puget Sound area. You can see there is a lot of intensity seven, which is represented by the lighter orange. Intensity eight is represented by the dark orange. There are several of these intensities and those intensities are usually related to much loss, particularly unreinforced masonry structures, of which there are many in the Pacific Northwest. The yellow represents intensity six and you can see there is a pretty wide range of intensity six reported.

The map on the right shows the observed intensity for this event once people went out and actually looked at individual structures. The first thing that becomes clear is that the extent of perceived intensity seven and eight is much higher than was actually observed. We started to realize this when our reconnaissance team was in the field and they were not seeing the level of high intensities that the community intensity map from the USGS was indicating. We began to understand that the ground motions from this event might be lower than expected.

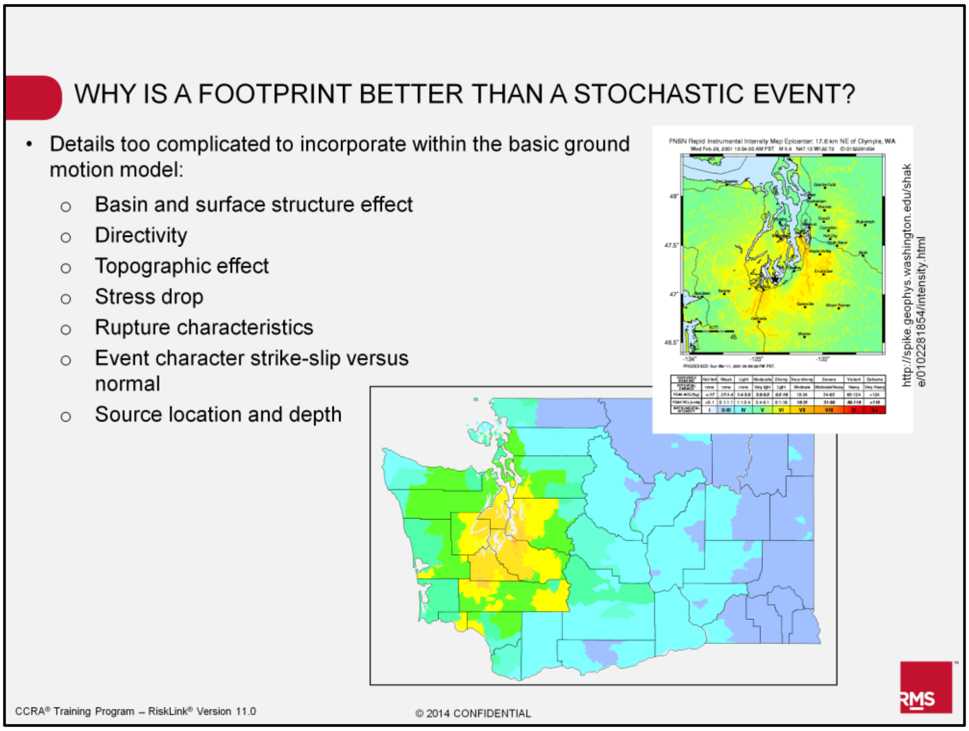


The reconnaissance team was finding there were generally lower intensities in the field than they expected. They used the community intensity map to get a sense of where they should go to look at high intensity areas and they found that the losses or the damage did not seem to be that high. So despite similarities between the magnitude, depth, and location with the 1949 earthquake, it appeared that the Nisqually earthquake would be consistently lower in intensity.

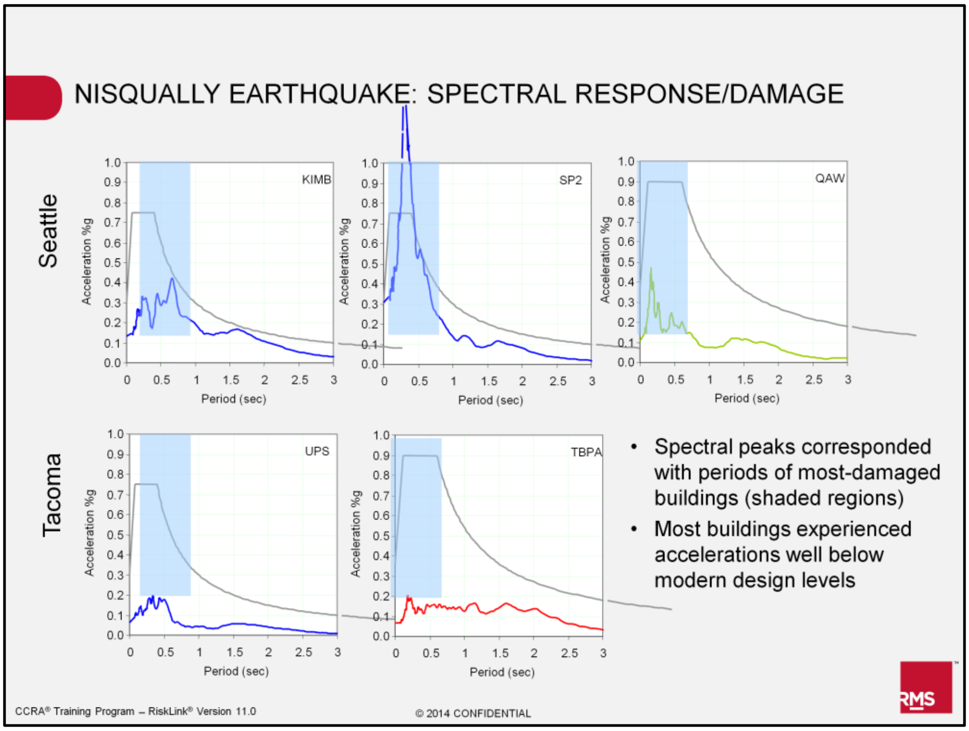
The plot on the lower left has taken all of the community intensity data that was collected for the ZIP Codes and organized it by distance and intensity. You can see that there is much scatter for each of the intensities. However, when we take the mean value, which is plotted on the right in red, and look at the individual intensities for that event, they are significantly lower than 1949, which is plotted in green, and 1965, which is plotted in blue.



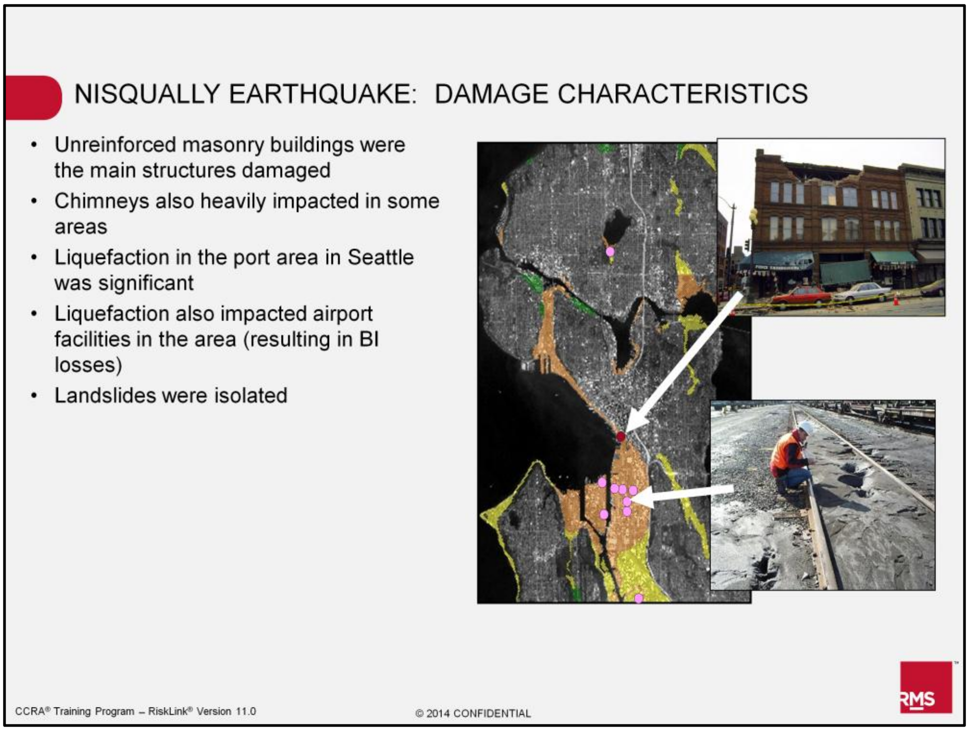
We were beginning to see that the ground motions that were used to model the stochastic event and for the user defined event for the Nisqually earthquake were probably too high to match this particular event. The attenuation most commonly used in the Pacific Northwest at the time was Youngs and others. This was pretty commonly used across the various models as well as in the National Seismic Hazard maps. The plot on this slide shows a solid line for site conditions of rock. Above it is the attenuation relationship when you look at a firm soil site condition. You can see that all of the observation points for this event are falling below that line and we would expect there to be scatter around those lines. We were seeing that the Nisqually event was consistently lower than those estimated by the standard attenuation equation for the region.



Clearly we needed a ground motion footprint to model this event rather than using the ground motions associated with the most similar stochastic events. There are many things that go into the footprint that cannot be captured when we do the attenuation relationship approach to ground motions for a stochastic event. Missing are the complexities of what happens to ground motions within basins and within surface structures. Directivity is another issue; it depends on whether an event ruptures toward a location or away. Topography can also be an issue. Sometimes hills see higher ground motions than other areas. And then looking at the stress drop or the character of the event, we can see that there are variations in ground motions as well. This complexity can be captured within an individual event ground motion footprint because it can be observed, while the details of these processes are not well enough understood to be modeled by the current suite of available ground motions models.



We developed that footprint based on our observations in the field and the observed data. Here are some of the spectral response curves for what we observed for different locations in the area. The plots on the top are in Seattle and the two on the bottom are in Tacoma. Each individual plot shows a spectral response curve for a site. The curves are in blue, green, and red. The gray lines are the design spectras, the spectra that is used to define individual structures. The blue zone on each chart is the period over which most of the structures that were damaged in the Nisqually earthquake fall. Also, the blue lines are locations on rock, the green line is a location on poorer soils, and the red line is a location on very poor soil. Generally, the spectral response curves are constrained within the design spectra, though we do see an exception for one location in the middle of Seattle. For a building to fall, we would expect the design spectra to be far exceeded and in this case it is not. Most of the buildings in the region experienced accelerations that were well below their design level, with a few exceptions, and there was damage in some cases.



If we look at the damage characteristics for the Nisqually earthquake we see that it was unreinforced masonry buildings that experienced most of the damage. Chimneys were also very heavily impacted, as would be expected. Liquefaction was also very significant in the port area and near some of the airport facilities. The map in the middle shows the Seattle area in terms of liquefaction susceptibility. The orange represents very high susceptibility and the yellow represents high susceptibility. The photo at the top of the slide shows an unreinforced masonry building that had a failure. You can also see that it is in one of the areas that had poor soil. The kind of failure seen in this structure was rather common. These unreinforced structures have parapet walls at the top. If you are standing on the roof of one of these structures there is a small unreinforced wall that extends up above the top of the building to keep you from walking off the roof. This wall fails because it has no lateral support. In this case when the wall fell off the top of the building it also took a lot of the front of the building with it causing extensive damage to the structure and to the cars below.

The lower photo shows some of the liquefaction that happened in the port area. A couple of ZIP Codes in the Seattle region experienced significant liquefaction. Landslides also occurred during the Nisqually earthquake. They caught a lot of media attention as they covered roads in a few places but generally landslides were relatively isolated events. There were not any significant landslides. Though it had been an exceptionally wet year in the Pacific Northwest, which is already a rather wet place making it prone to landslides, most of the landslides were modest in size.

NISQUALLY EARTHQUAKE: LOSS ESTIMATIONS

- In the days following the earthquake, a series of loss estimates for insured property was generated.
- These decreased as information on the ground motion characteristics of the event became better defined.
- The final estimate five days after the event was for gross losses between $0.7 and $1.4 billion.
- Preliminary estimates by the Property Claims Service of the Insurance Services Office were for insured losses of $330 million.

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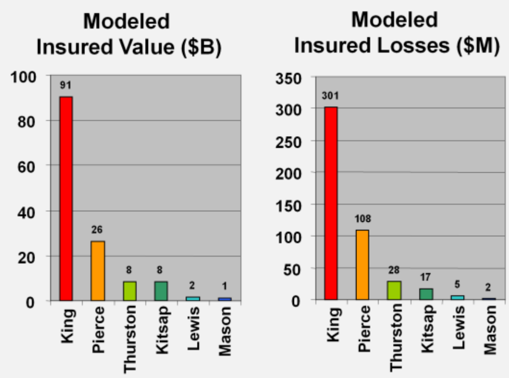
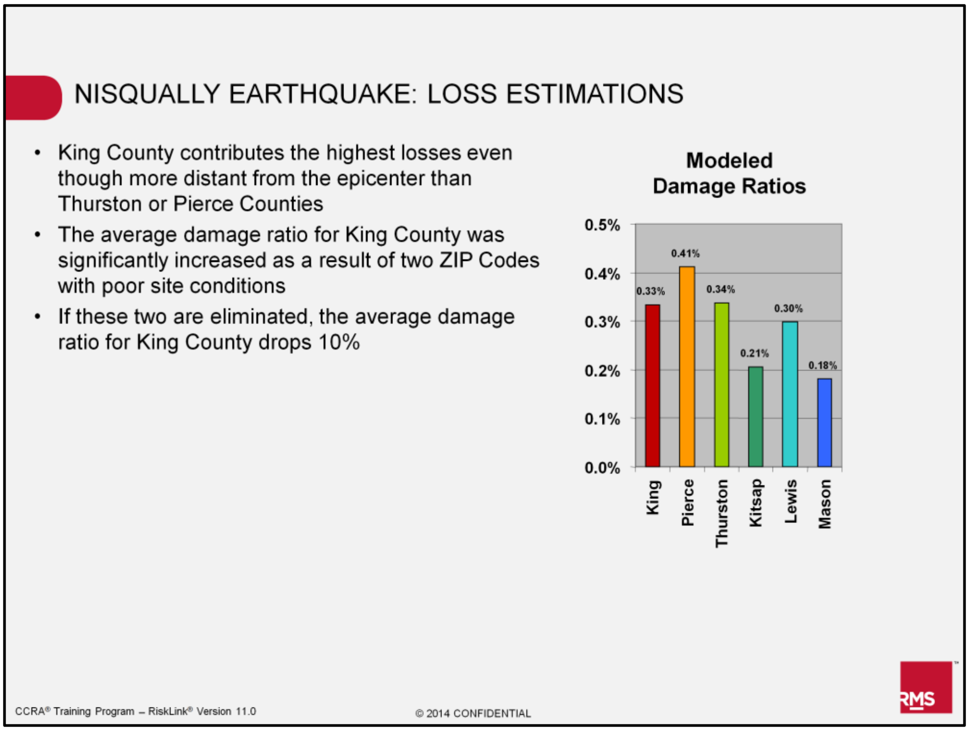
Because we were overestimating the ground motions for the Nisqually event and we were getting more information about the ground motions as the days went by, the loss estimations decreased with time. The final loss estimation we came up with took about five days and was in the range of $0.7 to $1.4 billion. The large range of uncertainty in this loss estimation is driven by the fact that a lot of the damage was at a very low level. There was a large area over which the damage states for buildings were low, and this means there is a very high uncertainty when you look at two structures side by side. We talked about this earlier in the course; at lower damage states the uncertainties are much higher in terms of understanding exactly how buildings will be damaged.

NISQUALLY EARTHQUAKE: LOSS ESTIMATIONS

- Examined the contribution of the six counties declared federal disaster areas to the best-estimate losses
- King County, which includes the city of Seattle, represents almost 50% of the total insured exposure in Washington



Looking a little deeper at what was driving the loss estimations, we looked specifically at the six counties that were declared federal disaster areas to get the best estimate we could on losses. When we look at these six counties, 50% of the exposure is in King County. The bar chart on the left shows the modeled insured value. You can see most of it is in King County and the other counties do not contribute much. Pierce County is where Tacoma is located so there is some exposure there but the other four counties are rather insignificant in terms of insured value.



When we looked at the losses in King County more closely, we realized that though King County is farther away from the epicenter than Thurston or Pierce Counties, it had much higher loss levels. This is due to the fact that two of the ZIP Codes in King County had very poor soil conditions, providing 10% of the loss in King County. If we look at the damage ratio results for each of the individual counties, we see that because Pierce and Thurston are actually closer, their damage ratios are higher before liquefaction is added in.

NISQUALLY EARTHQUAKE: LESSONS LEARNED

- Modeled loss estimates using ground motion relationships that better reflect the observed data show better agreement with the PCS loss level.
- Losses in the Nisqually earthquake were dominated by low ground motions and were inherently difficult to model because of the sensitivity of loss to input parameters.
  - Exposure concentrations can make aggregate losses sensitive to the prediction of ground motion parameters within a few regions.
  - Higher deductibles and lower penetration rates would significantly lower the modeled industry losses.
  - The coefficient of variation on losses is higher for low mean damage ratios.
  - Client data are crucial for calibration of losses at low ground motion intensities, especially when deductibles are involved.

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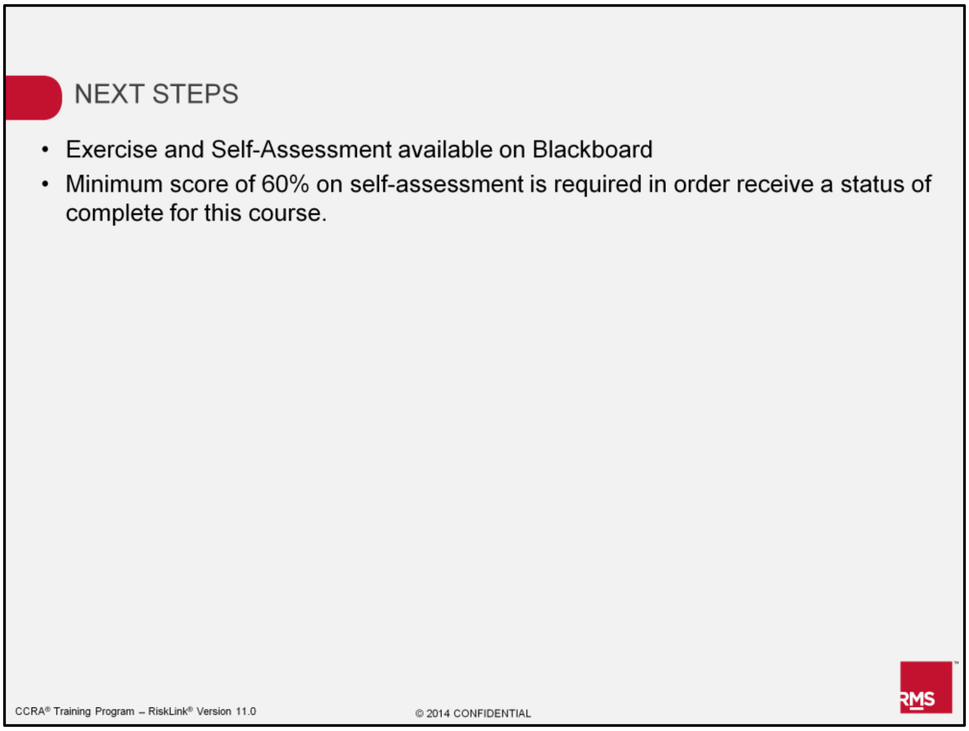
Finally, what were the lessons learned from the Nisqually earthquake? Clearly there were some issues with the way the ground motions were being modeled, and since then there has been a reassessment of ground motion in the Pacific Northwest for these types of events. The Nisqually earthquake was an example of where low ground motions really dominated the losses so it gave us an opportunity to have a better look at these low loss levels and get a better sense of how to quantify them. The exposure concentrations were very sensitive because the ground motions were varied in different places. So if you had exposure on the high ground motion areas, usually connected to the site conditions, you could see very different losses or different damage ratios from place to place. Because of the extremely low loss levels, the modeled loss results are very sensitive to how the financial model is defined in terms of how high the deductibles were as well as what penetration rates were used in the industry exposure that was analyzed. It is also important to note that the CVs were higher because of these low damage ratios. So it was really important for us to try to collect as much client data as possible to get a sense of how best to deal with these low ground motion losses.

UNIT 5 POST-EVENT LOSS ESTIMATION
KEY CONCEPTS

- Post-event loss estimation comprises both a short and long-term response time line.
- The post event loss estimation process is an iterative process that includes stochastic event, footprint, and user-defined analyses.
- Observed damage characteristics from the field provide key information on variability in vulnerability, hazard, and site response.

This slide highlights the key points from Unit 5 of this course. We encourage you to review these topics to ensure that you have a good understanding of each bulleted item before proceeding to the exercise.



In order to fully complete the course work for this peril, complete the exercise and self-assessment available on the Blackboard. You must score a minimum of 60% on the self-assessment in order to receive credit for completing this course.

Completion of three peril model courses is mandatory in order to be eligible to sit for the CCRA® exam.