Conditional Peak Ground Accelerations in the Canterbury Earthquakes for Conventional Liquefaction Assessment: Part 2

Technical Report Prepared for the Ministry of Business, Innovation and Employment

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This report has been commissioned by the Ministry of Business, Innovation and Employment to provide information on ground motion intensity related to the Canterbury earthquakes. The authors accept no liability for the use of the material contained in this document by third parties. This disclaimer includes Google Earth files providing contours of conditional PGA that are included with this report.

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Executive Summary

This report provides further analysis results from those of a preceding report to the Ministry of Business, Innovation and Enterprise (Bradley and Hughes 2012) related to the development of conditional PGA values observed on alluvial deposits in the greater Christchurch region from the Canterbury earthquakes. Specifically, this report, and appended data files, provide such results for the 16 April (M_w5.0), 13 June 2011 (M_w5.3), and 23 December 2011 (M_w5.8 and M_w5.9) earthquakes. These four earthquakes are in addition to the 4 September 2010 (M_w7.1), 22 February 2011 (M_w6.2) and 13 June 2011 (M_w6.0) events which were examined in Bradley and Hughes (2012).

The theory underpinning the development of the results, and their suggested interpretation is the same as the earlier report, and readers are referred there for further details.

1. Conditional PGA distributions from the Canterbury earthquakes

1.1. Earthquake sources

Figure 1 illustrates the finite faults of major earthquakes in the Canterbury earthquake sequence for which conditional PGA have been developed (in this report and its predecessor). The finite fault models for the September, February, June (2:20pm) and December (2:18pm) events come from Beavan et al. (2012), while those for the April, June (1:01pm), and December (2:18pm) events were obtained in a first-order manner by using the CMT solutions from the GeoNet catalogue (Ristau 2008), and then fault dimensions based on magnitude scaling relationships (Stirling et al. 2007).

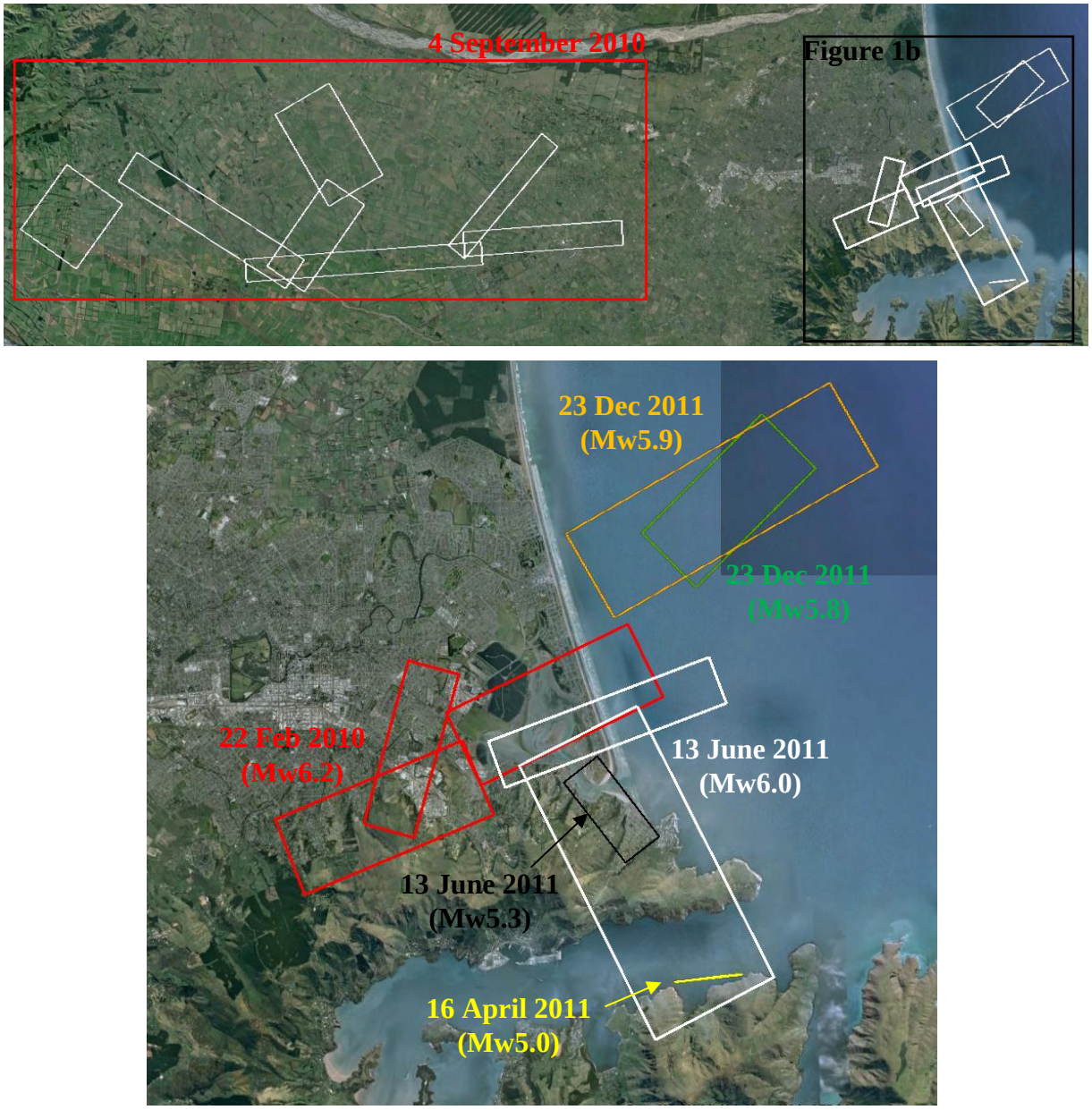

Figure 1: Finite faults from the seven events in this and companion report which have ruptured in the Canterbury earthquakes.

1.2. Peak ground accelerations observed in the Canterbury earthquakes and comparison with empirical predictions

Table 1 provides the numerical values of PGA observed at strong motion stations during the Canterbury earthquakes (see Bradley and Hughes for the remaining three events). A large number of ground motions were observed in these events. This wealth of recorded data helps to provide significant constraint to the predicted PGA values over the entire Canterbury region.

Table 1: Observed values of geometric mean PGA at strong motion stations during the 16 April 2011, 13 June 2011 (1:01pm), and 23 December 2011 (12:58pm and 1:18pm) earthquakes.

Event	16 April 2011 (M_w5.0)	13 June 2011 (M_w5.3)	23 Dec 2011 (M_w5.8)	23 Dec 2011 (M_w5.9)
Station	0.034	0.081	0.073	0.083
CACS	0.070	0.183	0.157	0.210
CBGS	-	-	0.134	0.179
CCCC	0.146	0.199	0.174	0.222
CHHC	0.137	0.159	0.152	0.174
CMHS	0.076	0.173	0.094	0.098
STKS			0.082	0.069
CRLZ	0.161	0.097	0.096	0.119
D14C	0.459	0.187	0.191	0.227
D15C	0.243	0.182	0.220	0.164
GODS	-	-	0.122	0.152
HALS	-	-	0.088	0.123
HHSS	0.148	0.180	0.199	0.264
HPSC	0.676	0.455	0.306	0.439
HVSC	0.052	0.186	-	-
KPOC	0.028	0.026	0.062	0.073
LINC	0.294	0.146	-	0.437
LPCC	0.129	0.232	0.201	-
NBLC	0.156	0.239	-	-
NNBS	0.460	0.148	0.212	0.190
PARS	0.062	0.118	0.116	0.138
PPHS	0.223	0.299	0.290	-
PRPC	0.101	0.188	0.204	0.254
REHS	0.075	0.083	0.159	0.159
RHSC	0.013	0.036	0.102	0.062
ROLC	0.116	0.245	0.262	0.275
SHLC	0.034	0.132	0.066	0.148
SMTC	-	0.059	0.088	0.143
SWNC	0.024	0.037	0.068	0.081
TPLC	0.034	0.081	0.073	0.083

Figure 2-Figure 5 compare the observed and predicted PGA values for the four different earthquakes of concern. For all four events the observed PGA values are largely

consistent with the empirical prediction of Bradley (2010) for locations on the alluvial plains (site class D/E sites). While these events are, on average, consistent with the empirical prediction, there is significant scatter in the observations as a result of complex source, path and site effects.

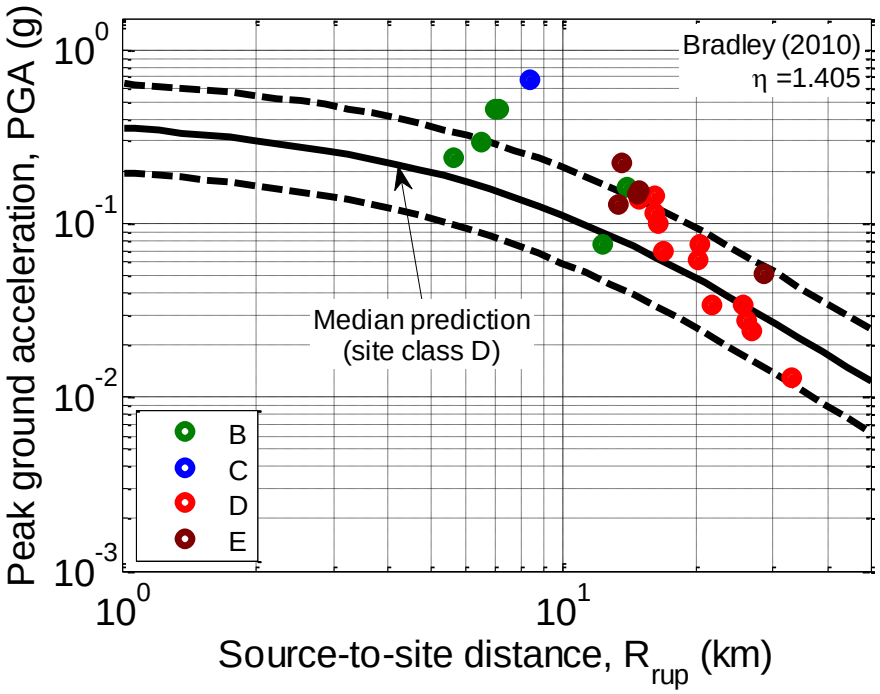

Figure 2: Comparison of observed PGA values with the empirical prediction of Bradley (2010) for the 16 April 2011 earthquake (M_w5.0).

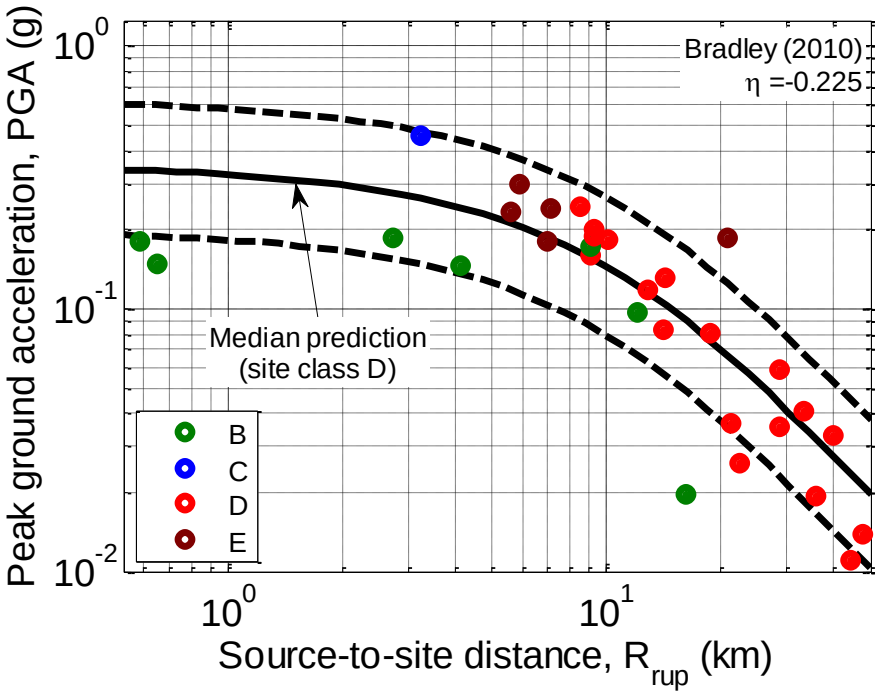

Figure 3: Comparison of observed PGA values with the empirical prediction of Bradley (2010) for the 13 June 2011 (1:01pm) earthquake (M_w5.3).

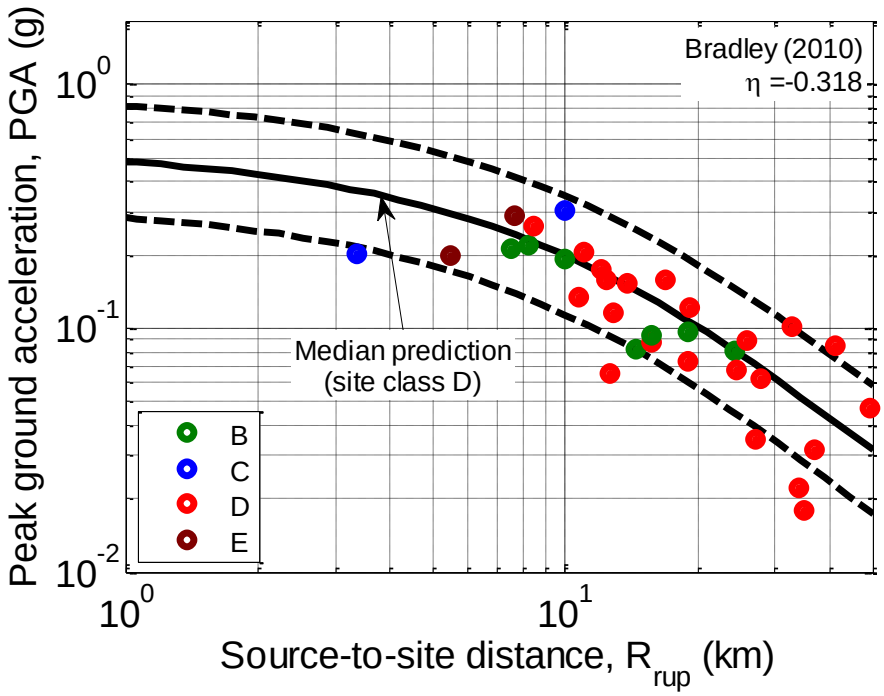

Figure 4: Comparison of observed PGA values with the empirical prediction of Bradley (2010) for the 23 December 2011 (12:58pm) earthquake (M_w5.8).

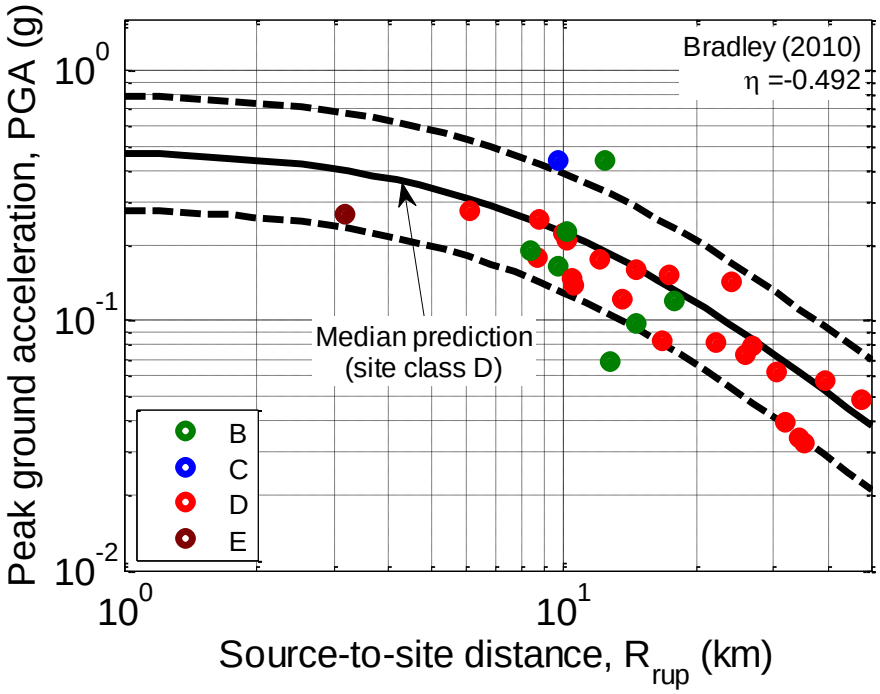

Figure 5: Comparison of observed PGA values with the empirical prediction of Bradley (2010) for the 23 December 2011 (2:18pm) earthquake (M_w5.9).

1.3. Computed PGA distributions in the Canterbury earthquakes

For completeness Figure 6-Figure 12 present the conditional median and conditional standard deviation of PGA for the four events developed in this second report, as well as the three events considered in Bradley and Hughes (2012). As noted in Bradley and Hughes (2012), the conditional distribution of PGA is a lognormal random variable that can be defined via the conditional median and conditional standard deviation.

Several features are worthy of note in the Figure 6-Figure 12:

- The median PGA amplitudes display a typical attenuation in amplitude as the distance from the earthquake source increases.
- In the proximity of strong ground motion stations, the contours can be observed to vary markedly as a result of differences between some observed PGA. This is consistently the case, for example, in Heathcote Valley for all events, due to strong basin-edge effects (Bradley 2012a, Bradley 2012b); and also apparent at Kaiapoi High School, for example, during the 4 September 2010 earthquake as a result of wave-guide effects (Bradley 2012a). However, as shown by the median PGA contours these effects are expected to be localised.
- The conditional standard deviations shown at the bottom panel of each of the figures provide an indication of the level of uncertainty in the conditional median PGA prediction. Near strong motion stations the conditional standard deviations decrease toward zero. This implies that the prediction of PGA is more accurate close to strong motion stations, and less accurate as the distance from strong motion stations increases.

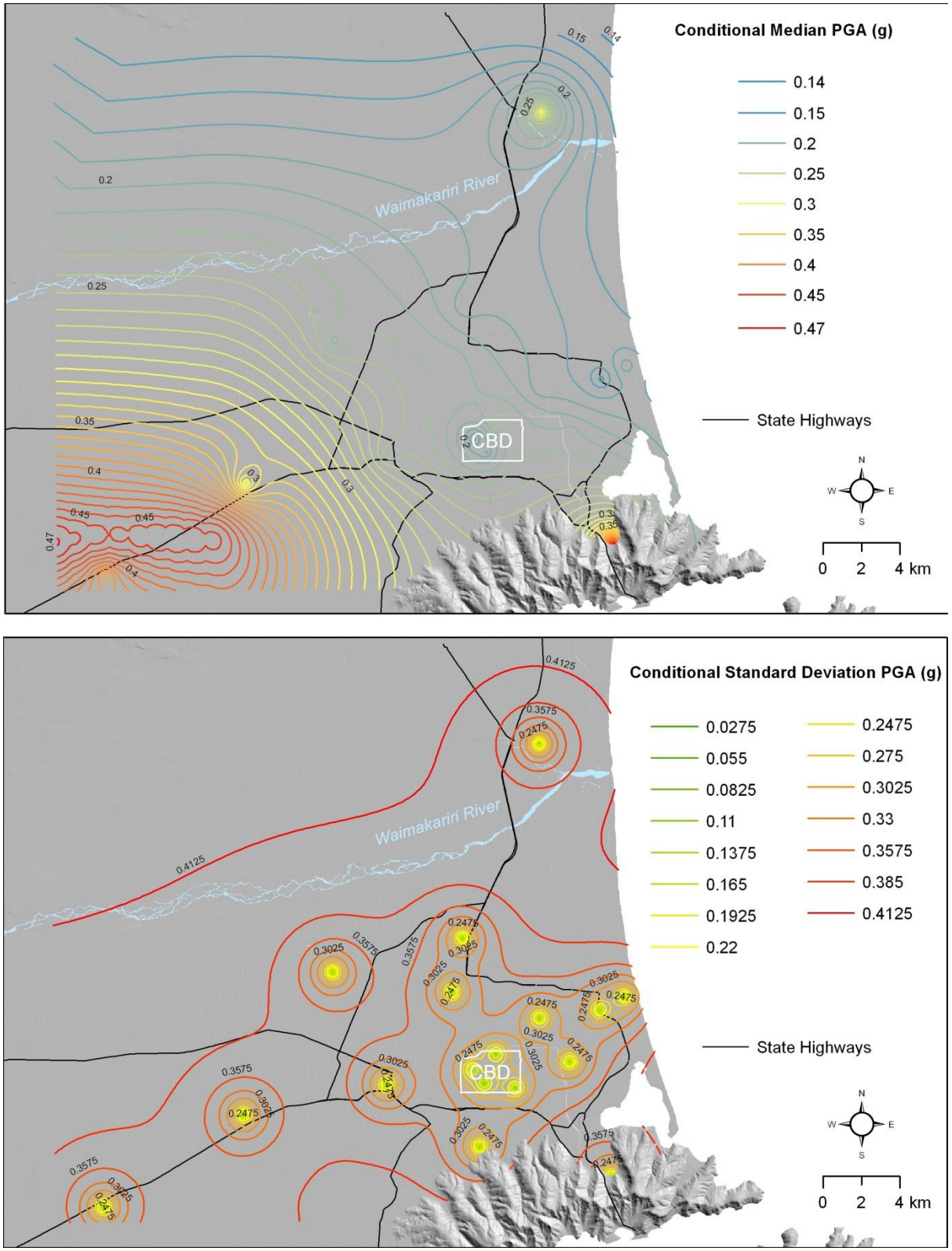

Figure 6: Conditional median (top) and conditional standard deviation (bottom) of PGA predicted in Canterbury from the 4 September 2010 earthquake.

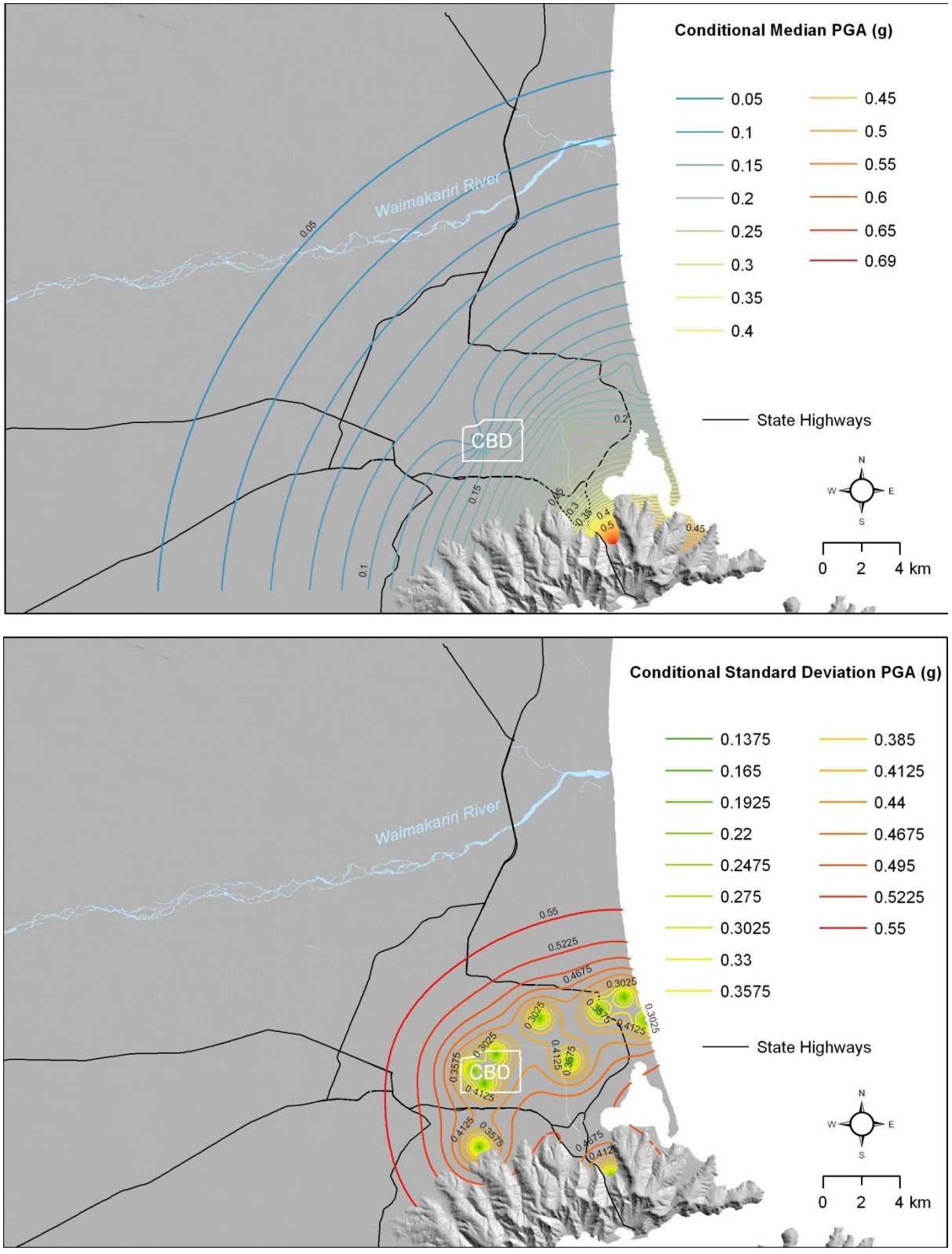

Figure 7: Conditional median (top) and conditional standard deviation (bottom) of PGA predicted in Canterbury from the 16 April 2011 earthquake.

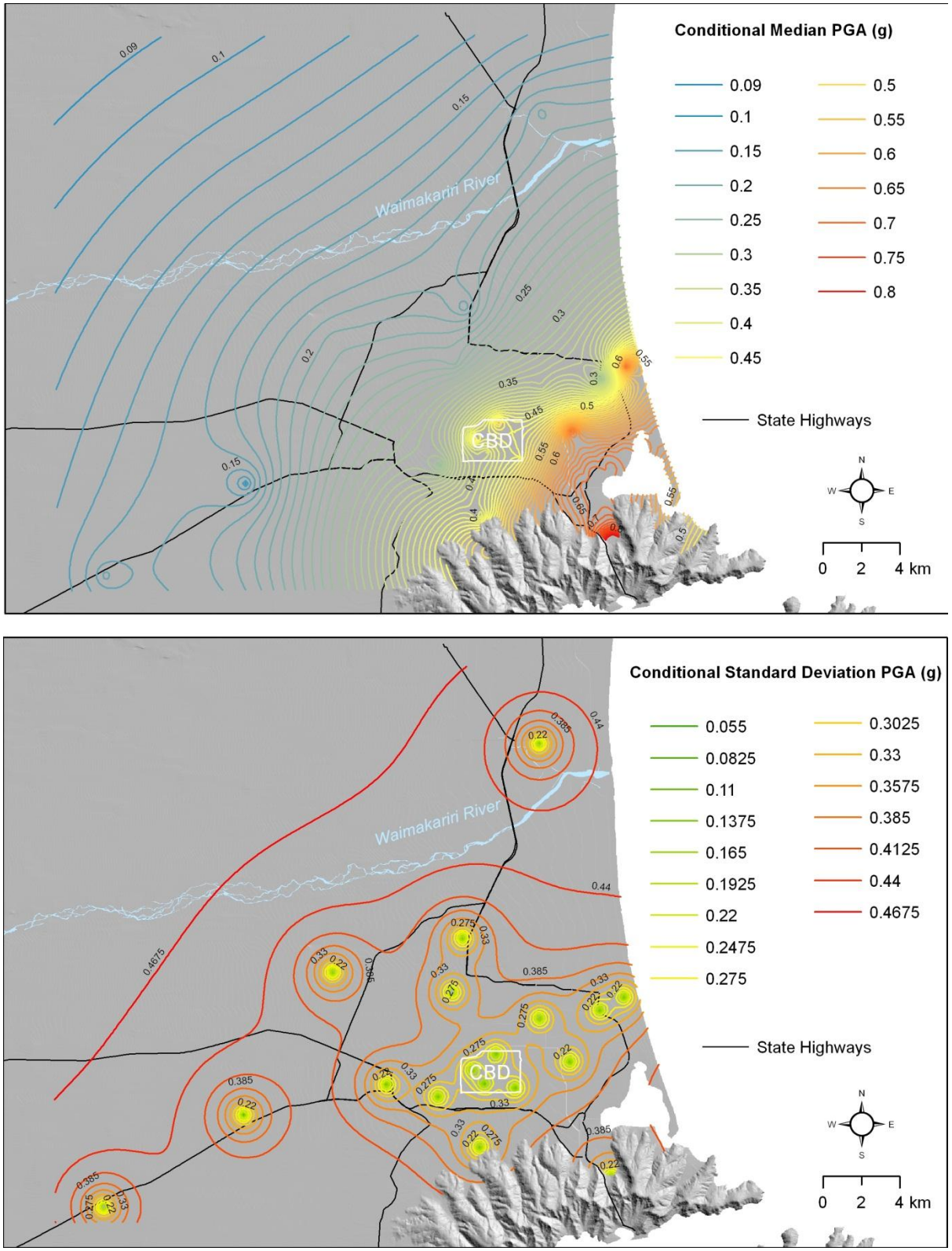

Figure 8: Conditional median (top) and conditional standard deviation (bottom) of PGA predicted in Canterbury from the 22 February 2011 earthquake.

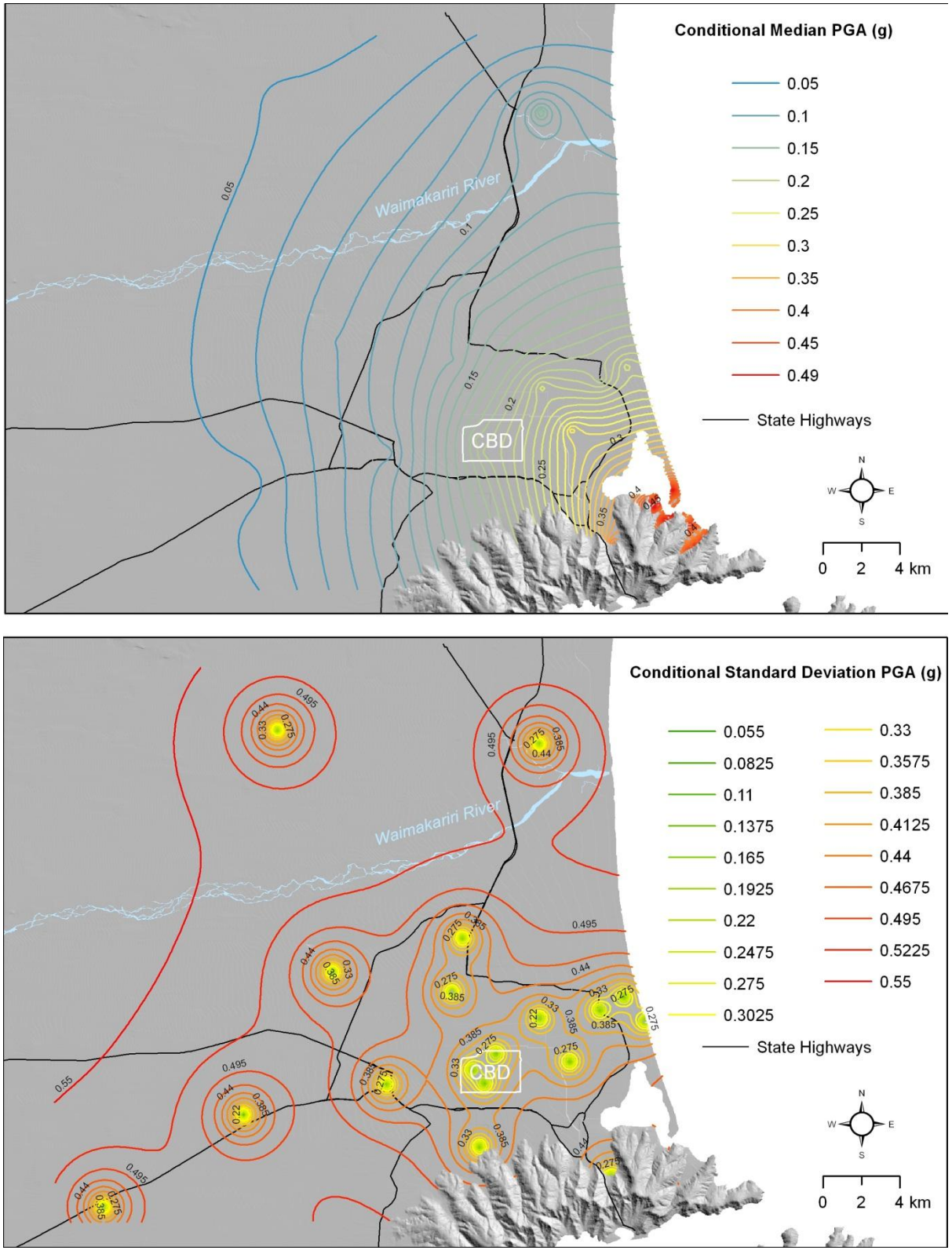

Figure 9: Conditional median (top) and conditional standard deviation (bottom) of PGA predicted in Canterbury from the M_w5.3 1:01pm 13 June 2011 earthquake.

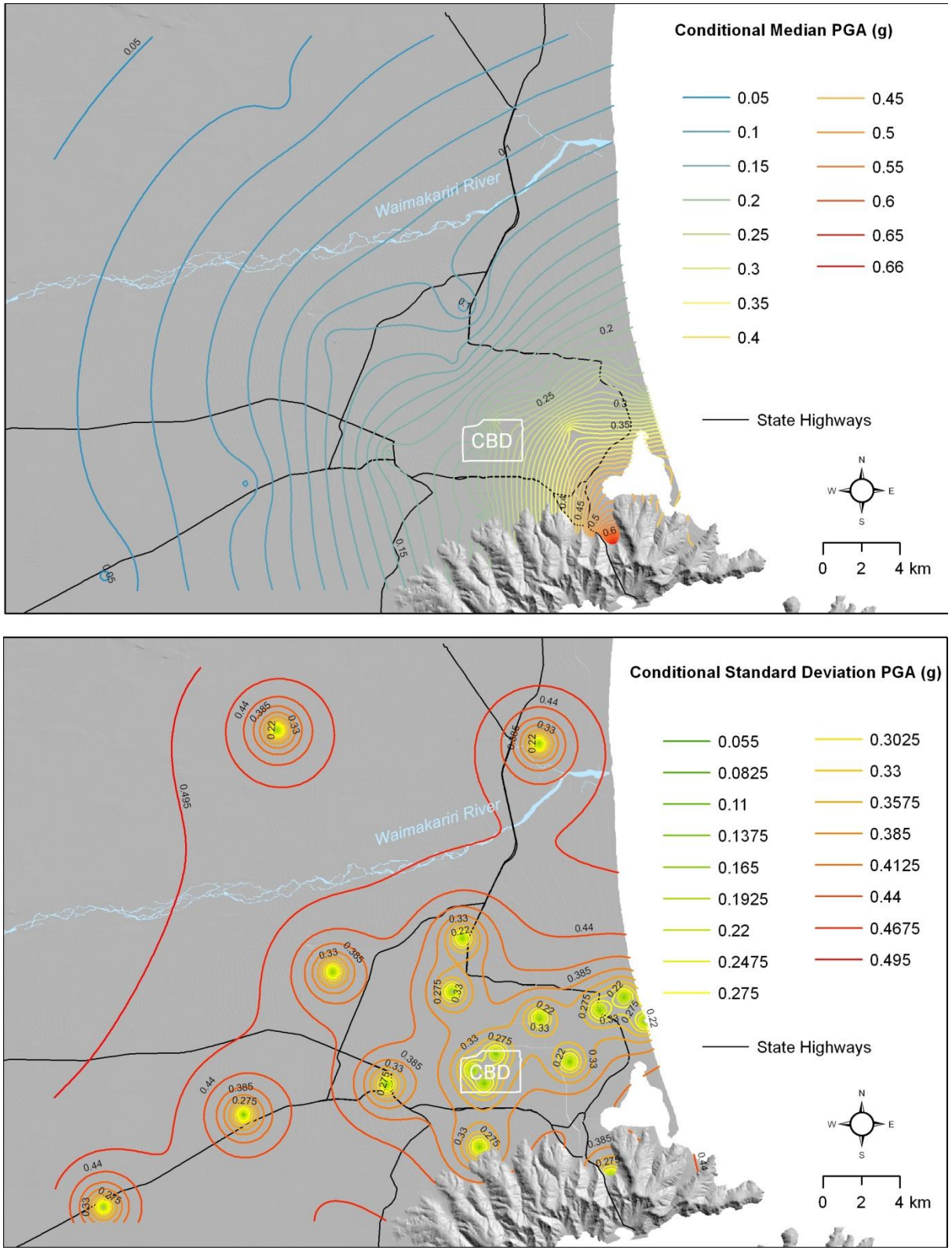

Figure 10: Conditional median (top) and conditional standard deviation (bottom) of PGA predicted in Canterbury from the M_w6.0 2:20pm 13 June 2011 earthquake.

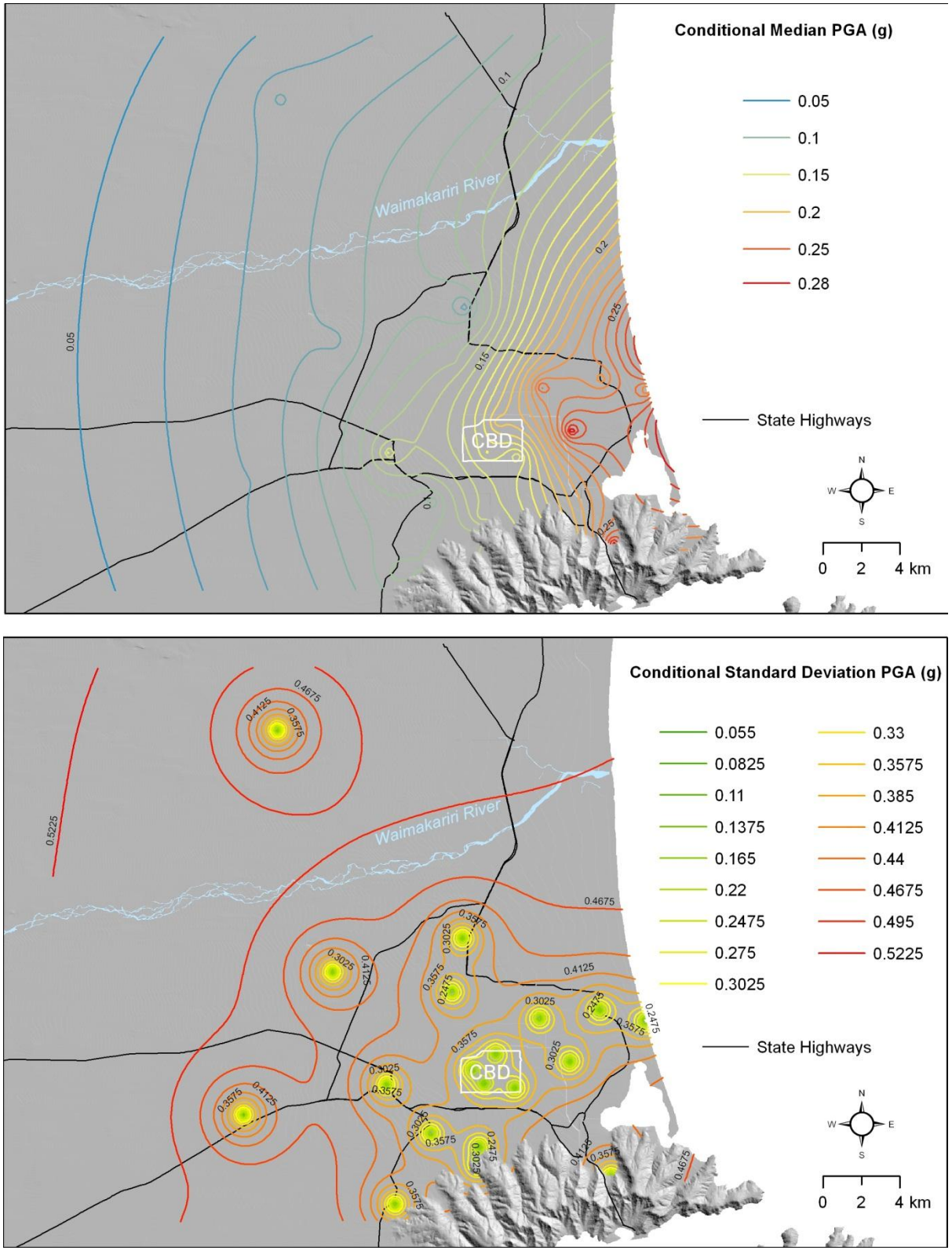

Figure 11: Conditional median (top) and conditional standard deviation (bottom) of PGA predicted in Canterbury from the M_w5.8 12:58pm 23 December 2011 earthquake.

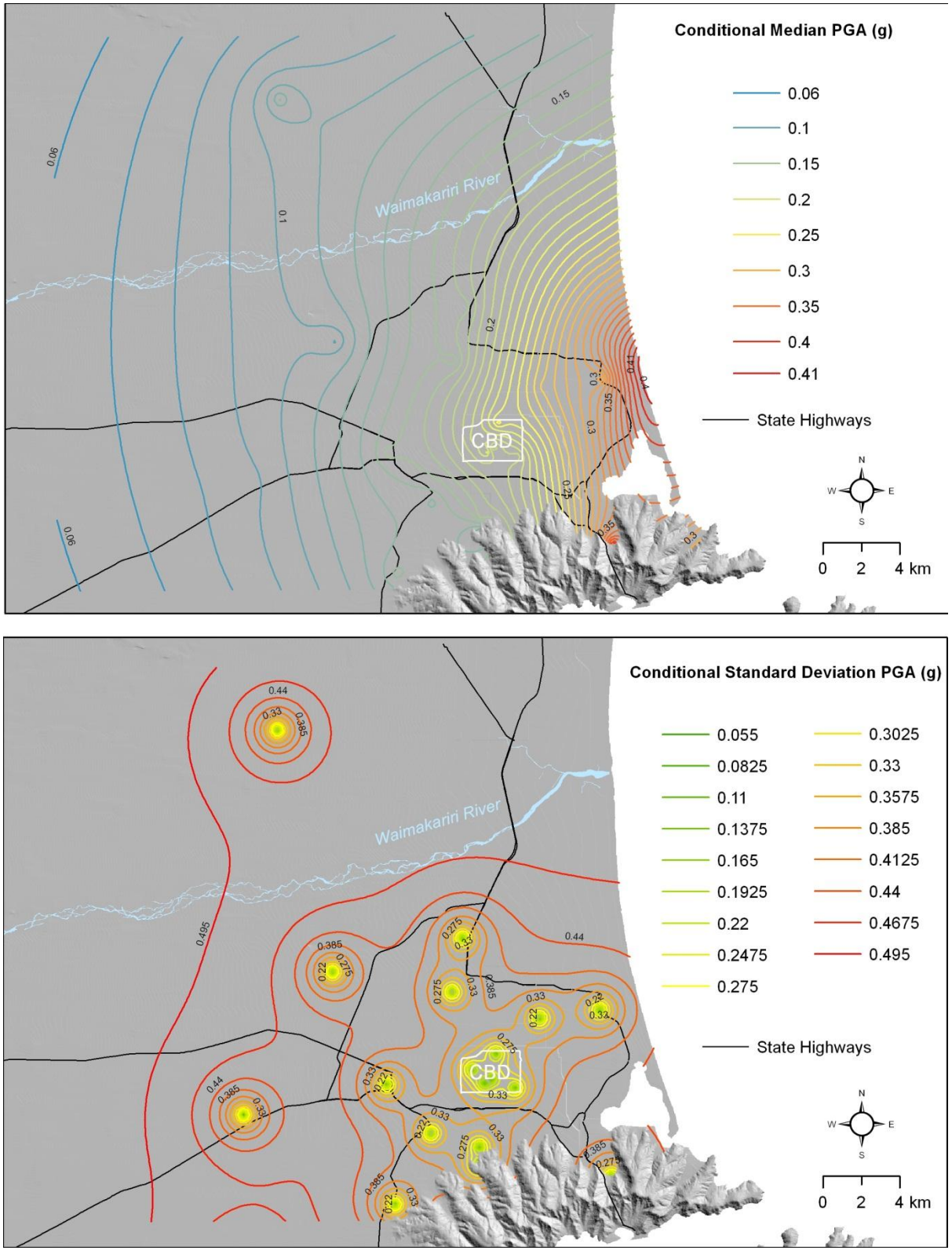

Figure 12: Conditional median (top) and conditional standard deviation (bottom) of PGA predicted in Canterbury from the M_w5.9 2:18pm 23 December 2011 earthquake.

1.4. Google earth files of PGA contours

In order to make use of the contour plots in Figure 6-Figure 12 for a site-specific liquefaction assessment, Google Earth files have been created and are appended with this report. The Google Earth .kmz file "CantEqs_ConditionalMedianStddevPGA" contains all the contour information. Figure 13 illustrates the folder hierarchy of this .kmz file. There is one folder for each of the earthquake events and one sub-folder for the conditional median and conditional standard deviation.

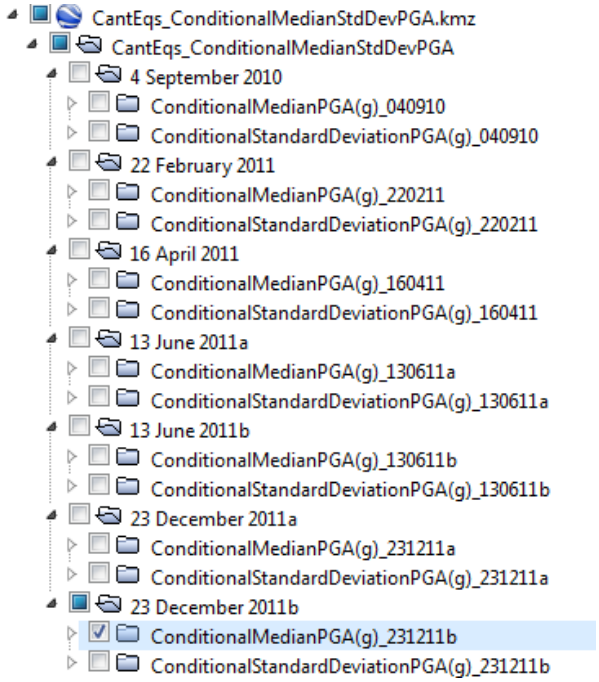

Figure 13: Folder heirarchy of the Google Earth .kmz file.

The specific contour values can be ascertained by clicking on the contour as illustrated in Figure 14. For assessment of the specific values of conditional median PGA and conditional standard deviation PGA at a given location, visual interpolation of contour values can be used, since contour intervals are 0.01g for the conditional median PGA and 0.0275 for the conditional standard deviation.

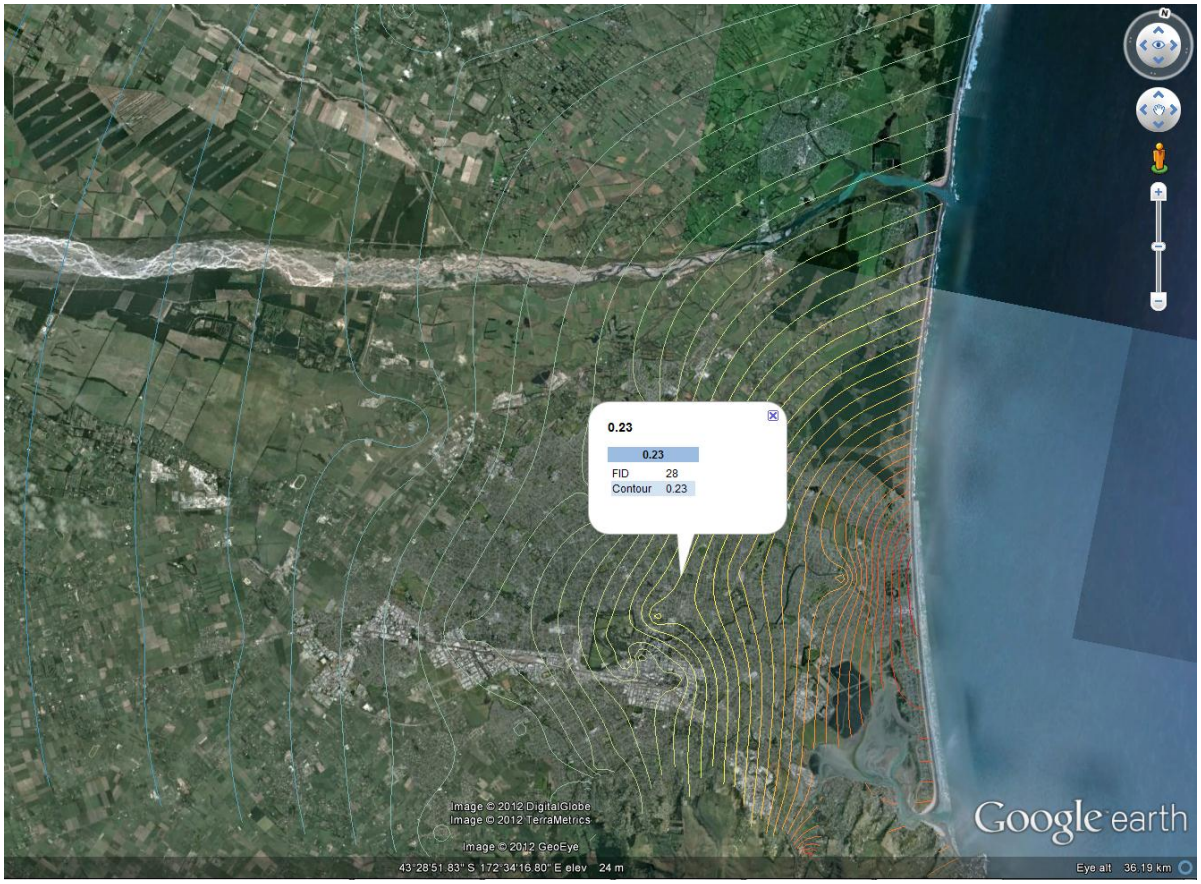

Figure 14: Ascertaining the value of a specific contour. For the case shown the selected contour has a value of median PGA = 0.23g (M_w5.9 23 December 2011 event).

2. Conclusions

This document provides information related to the additional three events which were considered in addition to those of an earlier report (Bradley and Hughes 2012). The results are provided in the form of a google earth .kmz file for use by practising engineers.

3. References

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