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Appendix G – Sector 7 Modeling Results

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Sector 7 Huntsbury

1. Site Description

Hillsborough is the northern most point on the Port Hills and is neighbored by Huntsbury to the west and Ferrymead to the east. The rockfall issue in Hillsborough arises from the lower slopes of the Port Hills directly south of Hillsborough. The eastern side of Hillsborough, immediately west of the Avoca Valley, is affected by rockfall from the slopes forming the western side of this valley. The western section of the sector is affected by rockfall from the sides of Glenelg Spur. At both sites the hazard arises as a result of the large number of houses at the base of the slopes.

The area considered in this report is shown in Figure 1 below, an area in excess of 3.5km^2.

Figure 1 - Sector 7 site location showing the study area within (south of) the yellow outline

The slopes west of Hillsborough rise steeply from near sea level up to in excess of 250m in elevation and are typically between 25˚ to 45˚. The predominant source of rock fall comes from a series of near vertical cliff faces that run the majority of the length of Hillsborough. The main bluff features are located towards the top of the slopes and in places are up to 15m high.

The eastern side of Hillsborough is mostly affected by a series of smaller bluffs and outcrops scattered over much of the upper slopes. These outcrops have released a number of large boulders during recent ground shaking events. This site has fewer houses at risk of rockfall however the energies of falling boulders in this area are significant.

2. Geotechnical Environment

The area is characterized by steep slopes with a number of basalt cliffs along the crest and upper part of the slopes, with lesser amounts of bluffs and outcrops further down slope, followed by more or less vegetated talus slopes continuing towards the valley floor. The rock outcrops are the predominant source of boulders and are therefore identified by the PHGG as potential or known outcrop zones in this sector. Houses and roads are mainly located at the base / lower area of the slopes.

The rock bluffs are typical basalt with intermittent lava flows and ash and scoria lenses. These tend to suffer differential weathering resulting in unstable columns and blocks of typically strong, competent rock. The average rock volume (as recorded by the PHGG) is 1.2m3 with a maximum volume of 210m3. Block shape is variable.

A number of causes initiate failure including weathering over time but also excessive ground shaking as has been recently witnessed.

3. Slope Instability

Assessment of slope stability and in particular the stability of the basalt cliffs was not part of the scope of this study and therefore has not been taken into consideration at this stage of the report. However it should be noted that there is extensive evidence of past and recent rockfalls of various scales on these slopes.

4. Rockfall Hazards

Rockfall is the only hazard considered in this present study. Rock falls into the investigated area can be powerful events consisting of numerous different size boulders and small rock avalanches as documented in the boulder inventory. The rockfall hazard along Hillsborough area originates predominantly from the main bluffs located approximately mid-slope.

Additionally there is evidence of limited rockfall originating from the main summit area however analysis of these upper rock slopes has revealed rockfall from these areas has little impact on the residential areas at the base of the slope. It should be noted though that for the purpose of this report we considered both these source areas contributing to the hazard, directly by releasing material immediately from the rock face and also indirectly in the form of blocks from past rock releases that have been arrested mid slope. All slopes that are steeper than 45 degrees assumed to be sources.

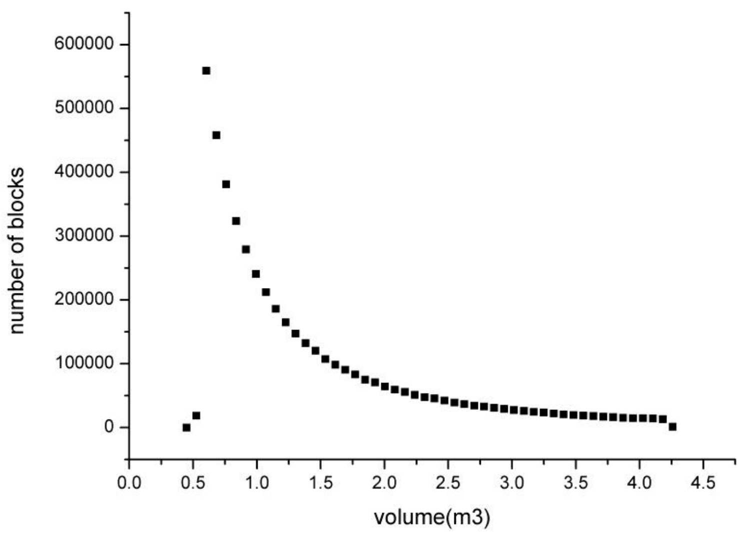
5. Modeling Results

The entire Sector 7 was modeled in 3D using HyStone. The results of this modeling are shown here. In order to check the model for accuracy reasons 2D rockfall modeling was also carried out in some areas. For the purpose of the modeling all vegetation was stripped from the model. For the purpose of the modeling all vegetation has been completely removed from the ground model. While larger vegetation can sometimes have a positive effect on reducing the hazard for the sake of this report any vegetation cannot be considered effective in the long term (i.e. there is a real risk of fire removing the vegetation).

Variables that have been entered include rock type, size and shape (from the PHGG database), slope angles (from the DEM), surface roughness and surface stiffness/hardness (rock, soil). This data is adjusted for each Sector and where necessary calibrated by either 2D modeling or real life one to one boulder rolling exercises.

For the modeling an exponential boulder size distribution was used with a minimum boulder size of 0.3 m³ and a maximum boulder size of 4.25 m³. This distribution curve is represented below in Table 1.

Table 1 - Boulder size distribution used for modeling



Note - this distribution covers all Sectors on the Port Hills. Individual Sectors may vary.

Analysis of the results show that bounce heights are typically below 3m but in places they are in excess of 5-6m high. The highest recorded bounce heights (7m) are on Line 14 at approximately 350m along the line. This is probably due to the large vertical cliffs located midway down the slope in this area. The boulders have relatively high velocities by the time they reach the cliffs which results in high bounce heights as they travel over the bluffs.

Impact velocities for this sector vary throughout the study site but are typically around 1000kJ. The highest energies are recorded on Lines 11, 12 and 14 where energies average around 2000kJ. Approximately 50% of this Sector has energies less than 500kJ. As with other sectors gullying is widespread and source areas are significant in size. This can be seen in the Total Number of Boulders image shown below. The gullying has a positive effect on remedial option design as the highest concentrations of boulders occur in very localized areas. Mitigation structures can be located in these areas meaning smaller (shorter) structures, while outside these areas lower levels of treatment, in some cases none, are required. However the effects of these concentrations may impact on design loadings if they occur in short time spans, e.g. following an earthquake.

Some anomalies do occur and they usually relate to platey or slabby boulders which often traverse slopes parallel to contour lines. It is inevitable that there will always be a small percentage of boulders that do not match the model.

6. Recommendations

In our approach to define solutions for Sector 7 we had three major constraints to consider:

1. **Scale** – Sector 7 is over 3.5km^2 in area with multiple source areas and runnout zones. Rockfall velocities are varied throughout this area. Combined with the topographical scale is the extent of residential development and/or roads below the rockfall source areas, resulting in over 20% of the study area requires protection.

2. **Topography** – the site is typified by steep slopes and multiple bluffs/source areas. This leads to constraints on construction methods due to access and the provision of a safe and stable working platform.

3. **Land use** – the area is moderately densely populated with over 100 houses likely affected by rock fall. The extent of development in the area spreads to very close beneath the base of the slopes below the rock fall source areas, restricting the type or protection available.

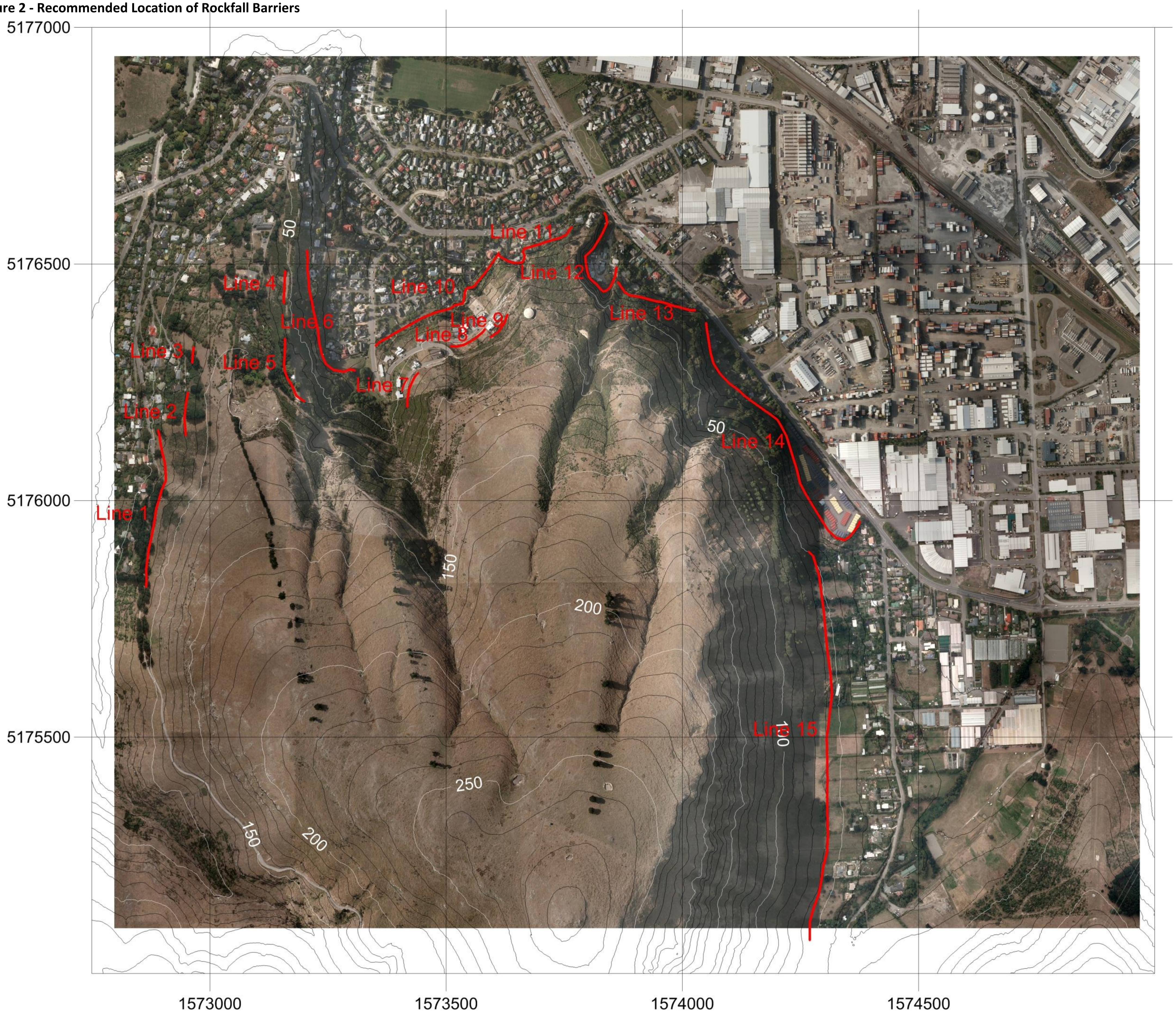
In accordance with Option 4 in the main report text it is recommended that the installation of rockfall barriers is the most suitable means of remediating the rockfall hazard in Sector 7. The size and lengths of the barriers are outlined in Table 2 below while the locations are shown in Figure 2. The results of the modelling are presented in the following graphics.

Table 2 - Recommended Barriers for Sector 7

Sector (#)	Barrier (ETAG27)	Rating (kJ)	Height (m)	Length (m)
7	1	500	3	200
		100	3	137
	2	500	3	90
	3	500	3	32
	4	500	3	67
	5	500	3	146
	6	500	3	180
		1000	4	80
		500	3	51
	7	1000	3	76
	8	1000	3	84
	9	500	3	60
	10	500	3	344
	11	2000	6	70
		500	3	128
	12	1000	5	70
		Active Stabilisation	A	140
		2000	5	55
	13	1000	5	180
	14	1000	3	120
		500	3	200
		2000	7	50
		1000	5	251
	15	500	4	380
		1000	3	80
		500	3	372

For Sector 7 the decision to recommend barriers over bunds is predominantly due to topographical constraints. For the purpose of protecting property there is no suitable land area available for the construction of large earth bunds.

Figure 2 - Recommended Location of Rockfall Barriers




N
0
0.2
0.4 km
arrested_blocks
Fallen blocks
50
100
150
200
250
Sector7, northern
focus area -
Hillsborough

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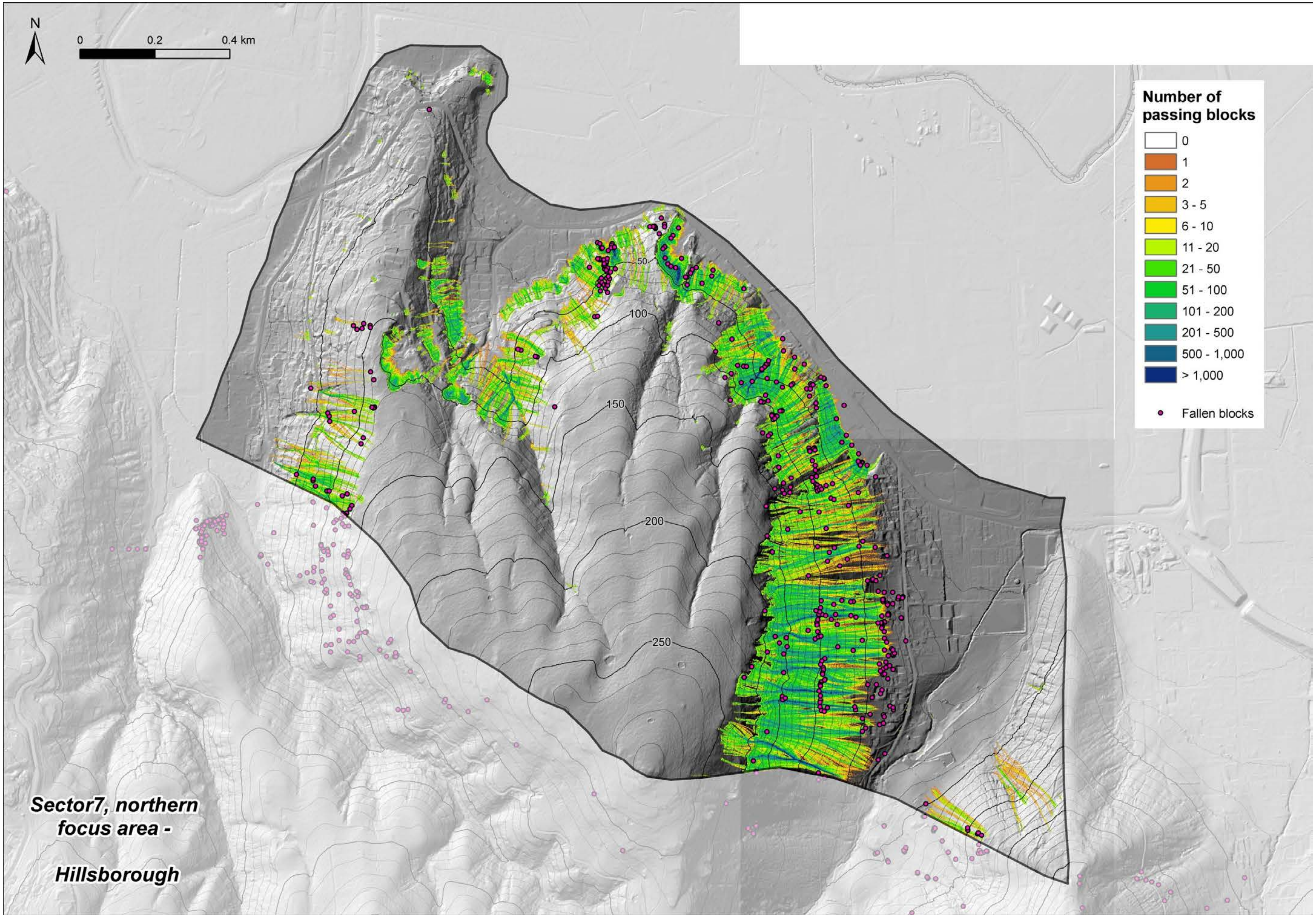
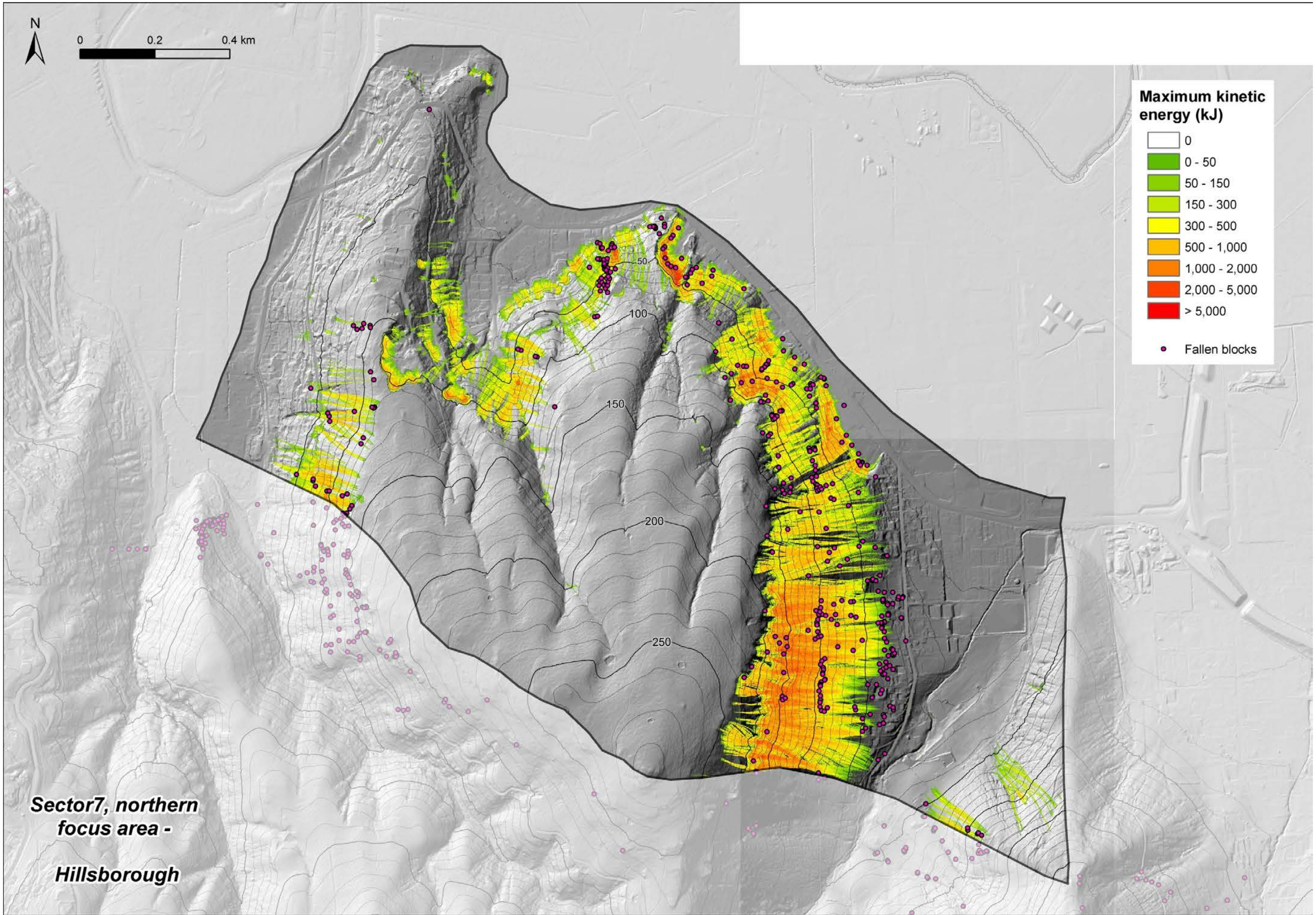
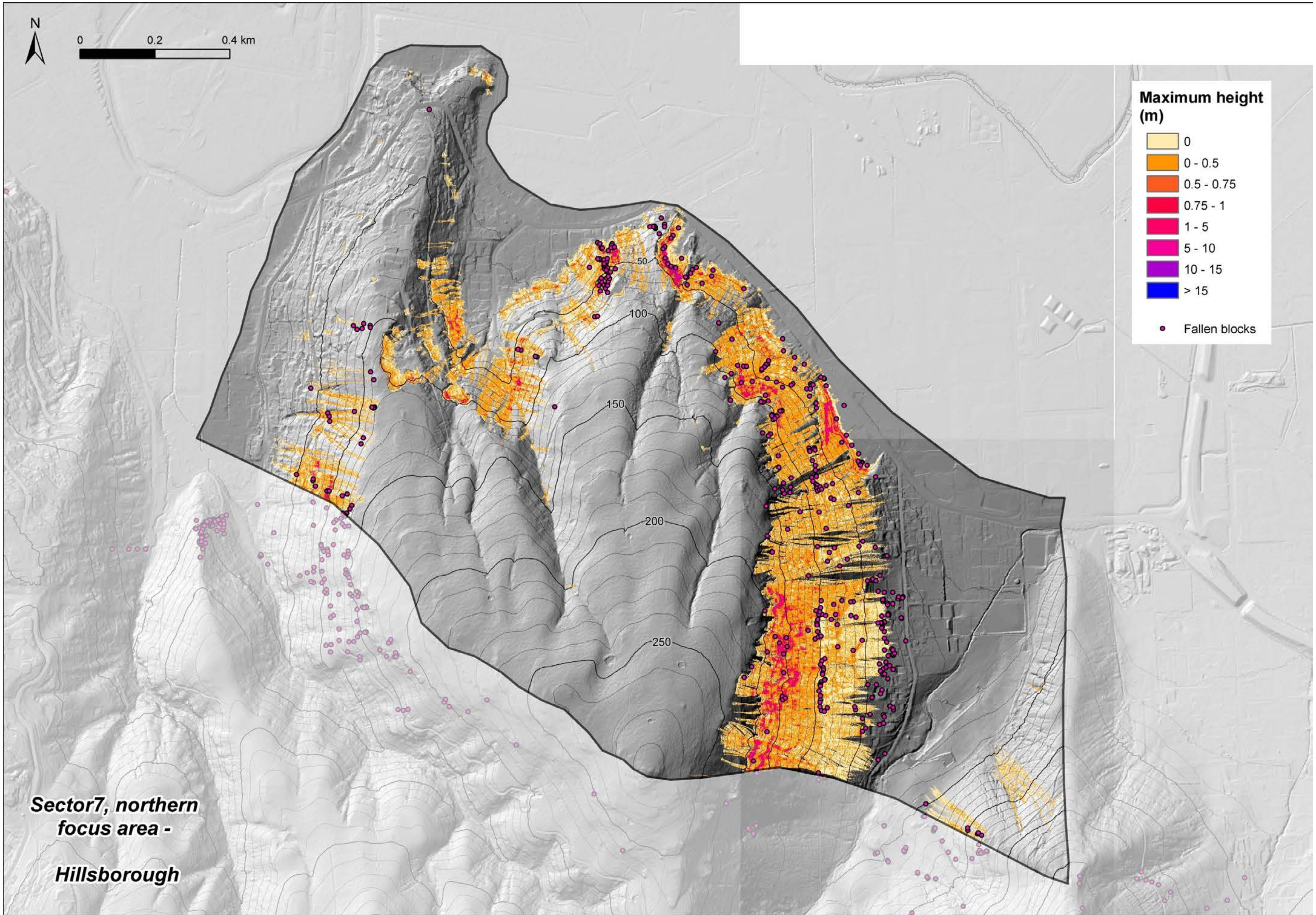
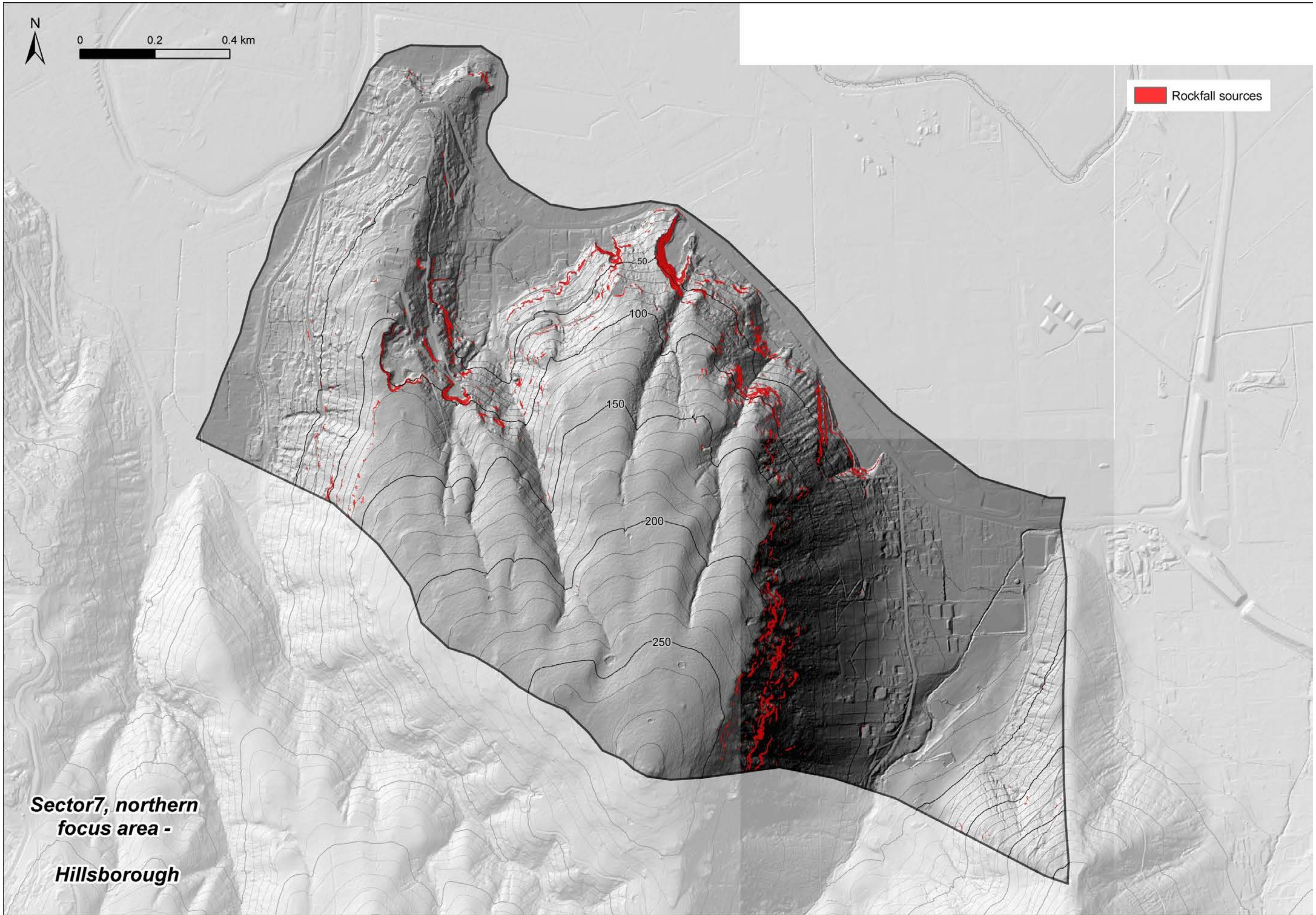

N
0
0.2
0.4 km
Number of passing blocks
0
1
2
3 - 5
6 - 10
11 - 20
21 - 50
51 - 100
101 - 200
201 - 500
500 - 1,000
> 1,000
Fallen blocks
50
100
150
200
250
Sector7, northern focus area -
Hillsborough


N
0
0.2
0.4 km
Maximum kinetic energy (kJ)
0
0 - 50
50 - 150
150 - 300
300 - 500
500 - 1,000
1,000 - 2,000
2,000 - 5,000
> 5,000
Fallen blocks
50
100
150
200
250
Sector7, northern focus area -
Hillsborough


N
0
0.2
0.4 km
Maximum height (m)
0
0 - 0.5
0.5 - 0.75
0.75 - 1
1 - 5
5 - 10
10 - 15
> 15
Fallen blocks
50
100
150
200
250
Sector7, northern focus area -
Hillsborough


N
0
0.2
0.4 km
Rockfall sources
50
100
150
200
250
Sector7, northern focus area -
Hillsborough