Defining Highly Erodible Land for Horizons Regional Council

Mike Page, James Shepherd, John Dymond, Murray Jessen

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Mike Page, James Shepherd, John Dymond, Murray Jessen

Landcare Research NZ Ltd
Private Bag 11 052
Palmerston North
New Zealand

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Prepared for:
Horizons Regional Council
Private Bag 11025
Palmerston North
New Zealand

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Reviewed by:

Alison Collins
Scientist
Landcare Research

Approved for release by:

Maggie Lawton
Science Manager
Rural Land Use

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1. Summary

Following the 2004 Manawatu–Wanganui storm, Horizons Regional Council is examining options to reduce hill country erosion risk. This report, commissioned by the Council, provides improved definitions and guidelines for the assessment of erosion, to help Council staff in the identification of Highly Erodible Land (HEL). HEL as defined by the Council is hill country with a potential for 'severe erosion', or hill country with a potential for 'moderate erosion' but where erosion debris will enter directly into waterways.

This report will help identify HEL at the farm-scale by recognising the types of erosion of concern, and then setting out the criteria for deciding the severity of erosion. At the regional-scale (and as a guide to recognising HEL at the farm-scale) we provide a list of LUC units that fit the HEL criteria and we have prepared a map of HEL. The map is derived from NZLRI data and a 15 m pixel DEM, and accompanies this report (the digital data have been supplied to Horizons). A bibliography is included to provide access to additional information on erosion processes, erosion severity and LUC units.

This report is the first part of a project to help the Council to identify HEL at both farm and regional scales. The second part will provide field guides (together with photographed type-sites) and decision trees for recognition of HEL at the farm scale, and conduct a 3-day training course for Horizons staff.

2. Introduction

The February 2004 storm that struck the Manawatu, Rangitikei, Wanganui and Tararua Districts, caused erosion in hill country, and flooding, sedimentation and stream course changes in the lowlands. The damage is estimated to have cost $355 M. Unsustainable land use of hill country was a major factor contributing to this damage, and is now one of four major issues identified by Horizons Regional Council in their draft Horizons OnePlan. The Council is currently examining options to reduce hill country erosion risk. One of the first tasks is to (better) define and identify land that is highly erodible. This will enable the Council to direct both regulatory and non-regulatory effort towards those parts of the region where land use and/or land management changes may be required. At the farm scale this will include the application of rules for vegetation clearance and land disturbance, and the encouragement of sustainable management practices through a Whole Farm Planning process as currently proposed under the Sustainable Land Use Initiative. Highly Erodible Land (HEL) is regarded by Horizons as hill country with:

1. a potential for severe erosion
2. a potential for moderate erosion, but where eroded sediment will enter a watercourse directly

This report provides guidelines for HEL recognition. The types of erosion are described, criteria for assessing erosion severity are listed, and a table of Land Use Capability units that meet the Horizons criteria for HEL is presented. The guidelines are derived from experience gained during the New Zealand Land Resource Inventory Survey (NZLRI) and a number of specialised larger scale surveys carried out in response to many North Island storms. A regional-scale map showing the distribution of HEL has also been produced.

Definitions of erosion types are adapted from the New Zealand Land Resource Inventory Erosion Classification (Eyles 1985). Definitions of erosion severity were originally set out in the Land Use Capability (LUC) Survey Handbook (Soil Conservation and Rivers Control Council 1971), and subsequently in Eyles (1985). Assessment of erosion severity has been traditionally based on observational evidence collected by experienced assessors. Guidelines have been developed to standardize and increase the objectivity of the assessment procedure, by documenting criteria to be considered in the assessment of erosion severity (Fletcher et al. 1994). These have been refined and employed in the 2nd edition NZLRI survey of the Gisborne-East Coast region (Jessen et al. 1999), and further refined in this report.

A major development has been the inclusion of areal extent guidelines in the assessment of mass-movement and fluvial erosion severity. Areal extent, a readily quantifiable value, provides a preliminary assessment of severity that can then be finalized after considering the other listed criteria. However, even with these guidelines, the judgment and experience of assessors are still important components in the assessment of erosion severity.

This report is the first part of a project to help Council identify HEL. The second is to provide field guides (together with photographed type sites) and decision trees for recognition of HEL at farm scale, and to conduct a 3-day training course for Horizons staff.

3. Objectives

To help recognise HEL within the Horizons Regional Council area by providing:

1. definitions of types of erosion
2. criteria and guidelines for assessing erosion severity
3. a table of LUC units with a potential for severe erosion or moderate erosion where sediment enters a watercourse (i.e. Highly Erodible Land)
4. a regional-scale map of HEL, using NZLRI data and a 15 m pixel DEM
    - with forest excluded,
    - land identified as capable or not capable of delivering sediment to streams,
    - on a per hillslope basis,
    - including riparian areas severely eroded in February 2004 storm,
    - areas of earthflow and slump identified by erosion severity.

4. Methods

Definitions of types of erosion, criteria for deciding erosion severity, and the selection of Highly Erodible LUC units were derived by reference to four main sources (Eyles 1985; Fletcher 1987; Fletcher et al. 1994; Jessen et al. 1999), and from the experience of the authors in erosion mapping and erosion process research.

The regional scale map of HEL was derived as follows:

1. A slope threshold was defined for each LUC unit (Table 10).
2. All pixels in a 15m pixel DEM above the threshold defined by the pixel's LUC was initially assigned to landslide risk (land cover is not considered).
3. The map of initial landslide risk was converted to a hillslope basis by using an aspect-based filter with a 25% risk rule (2ha minimum mapping unit).
4. All land considered at risk was examined to see if it could deliver sediment to a water course or not. Land was considered capable of delivering sediment if it was possible to traverse down DEM streamlines until a watercourse was reached without encountering two consecutive pixels of low slope (i.e. 5 degrees). Earthflow-prone LUC units were mapped as either of moderate or severe risk.

An A3 map accompanies this report, and the regional data were supplied to Horizons in ERDAS Imagine file format at 15m pixel resolution (1:50 000 scale).

5. Results

5.1 Definitions

5.1.1 Erosion types

Definitions of erosion types are adapted from Eyles (1985).

1. Landslide – Ss (aka soil slip, debris avalanche)

A landslide is the movement of a mass of rock, earth or debris down a slope, under the influence of gravity. Landslides usually involve rapid failure along a slip plane at the contact between a more permeable material and an underlying less permeable material. Landslides occur when shear stress forces (shearing) exceed shear strength (resistance). The balance between these forces are influenced by vegetation (root strength, interception, and evapo-transpiration of subsurface water), soil cohesion, internal angle of friction, slope angle, weight of regolith (depth, bulk density), and slope hydrology. When slope materials become saturated, pore water pressures rise, reducing frictional resistance between particles, ultimately leading to failure.

Landslides vary in size and volume from <10 m^3 to >1,000,000 m^3. Typical shallow landslides in pastoral hill country are <1 m deep and between ~150-500m^3. They comprise a scar, and a debris tail that slides or flows down slope as a highly fluid, chaotic mix of soil, regolith and pasture. They are triggered by a variety of agents, from natural; including intense and/or prolonged rainfall, earthquakes, undercutting of slopes by stream or wave action, to human-induced; including slope modifications (especially roading).

Riparian landslides (considered a subset of the landslide class) are recorded where failures are contiguous with, and deliver all sediment to, water courses, and usually result from associated undercutting and oversteepening of slopes.

Slope, aspect and vegetation are important determinants of landslide occurrence. Few landslides occur below 8–20°, and dependant upon rock type and rainfall intensity, mean slope angles are between ~28–35°. Many storm damage assessments (data from reports) show an aspect preference for landsliding that may be influenced by storm direction, or by previous erosion events. Northerly aspects are often more severely affected and this may be because of a more extreme winter wetting/summer drying cycle. Land use change, especially removal of woody vegetation, increases susceptibility to landsliding. Dependant on terrain type, landslide densities under pasture are between 3 and 10 times that under forest (indigenous or exotic).

Landslides occur on a wide variety of terrains and rock types. Mudstone and sandstone hill country are especially susceptible, but loess and tephra covered hills, greywacke hills and ranges, and volcanic mountains and other terrains are also susceptible.

2. Sheet erosion - Sh (aka sheetwash)

Sheet erosion is the removal of surface particles by non-channelised overland flow of water. Areas susceptible to sheet erosion include; bare surfaces such as disked paddocks, unsealed roads and tracks, areas of heavy stock concentration, landslide scars and debris tails. It also occurs in the form of diffuse movement of particles through an incomplete pasture sward. Sheet erosion is caused by a combination of raindrop impact which dislodges fine particles, and overland flow which transports them. Where overland flow concentrates into channel flow, with resulting increase in velocity, rills may develop.

Rills are <60 cm deep and <30 cm wide, that is they are features that can be smoothed out/removed by cultivation using normal farm equipment. In certain circumstances rills may develop into gullies.

Factors that influence susceptibility to sheet erosion include: soil parent material, steep slopes, slope aspect, altitude (especially where freeze and thaw cycles and wind dislodge particles), drought conditions, and overgrazing. Although sheet erosion may occur on a wide variety of terrains, it is most common on seasonally dry hill country, and where tephra deposits occur in upland areas.

3. Streambank – Sb (aka bank erosion, channel erosion)

Streambank erosion refers to the removal of (alluvial) sediment from the bank of a stream or watercourse during or following elevated stream flow. Headward extension of the stream channel and downcutting of the streambed are often associated with lateral bank erosion but are not always recognized separately. Mechanisms of failure include bed and bank scour, which removes support and leads to the toppling of the bank. This generally occurs on the falling stage of a flood event, when the weight of the bank has been increased by uptake of water from the river, and the support of the river has been removed. Water flowing along the bank may also shear off blocks of material by hydraulic action. Lateral bank erosion typically removes 2–50 m of material.

4. Earthflow – Ef

Earthflow erosion is the slow movement of soil and underlying regolith, usually along basal and marginal shear planes, and with internal deformation of the moving mass. The original vegetated surface, although still present, is hummocky and contains numerous tension cracks. The disrupted nature of the surface and high water content of the material impede both surface and subsurface drainage and often result in the development of ponds. Earthflows may be shallow (< 1 m) to deep-seated (>1 m – typically 3–5 m). Deep-seated earthflows typically occur on slopes between 10 and 20° and cover large areas of a hill slope (100s m²), while shallow earthflows are more common on slopes >20°, and are smaller in area.

Movement rates vary from <0.5 m/yr to >2 m/month. Rates and depth of movement are influenced by rock type (usually mudstones and argillites), degree of shearing and crushing, and proportion of associated plastic clays, slope, vegetation cover, and rainfall, which in turn strongly influence pore water pressures. Movement rates within earthflows usually vary, and are often most active where the toes of movements are undercut by streams or roads, or where gullies have developed within an earthflow. Earthflows may show seasonal variation in activity and may reactivate following years of stability.

5. Slump – Su

Slumps are deep-seated failures, usually of large blocks of rock and regolith. They involve rotational movements along failure planes, resulting in a raised lower (toe) slope relative to the upper part of the slope. This often results in the formation of ponds or lakelets at the head of slump. There are strong structural controls on the occurrence of slumps, and most occur in bedded mudstones and sandstones. They often occur in earthflow-prone terrain and earthflow/slump complexes are common.

6. Gully – G

Gullies are formed by the removal of soil, regolith or rock by fluvial incision. They are large, permanent features, >60 cm deep and >30 cm wide. Initially formed through the channelised flow of water and involving headward migration of the channel, gullies may be linear or amphitheatre in shape, depending on rock type, and usually only carry water during rainstorms. In some instances gullies are formed by a complex process of mass movements and sheet erosion in response to oversteepening of gully side walls by channel incision. They may also form through the deepening and coalescing of rills, small usually numerous features <60 cm deep and <30 cm wide, that usually form on bare surfaces during rainstorms.

7. Tunnel gully – T (aka pipe/shaft erosion, under-runners, tomos)

Tunnel gully erosion is initiated by the subsurface concentration and flow of water, resulting in scouring and the formation of narrow conduits, tunnels or pipes. Soluble, dispersive or low strength material is removed, ultimately resulting in collapses, visible either as "holes" in the land surface or as gullies when sufficient collapses coalesce to form continuous linear features (after Lynn & Eyles 1984).

Tunnel gullies form in regolith where subsurface water concentrates above a relatively impervious layer. Land susceptible to tunnel gully erosion within Horizons Regional Council area includes moderately steep hill country where loess deposits (typically >50 cm thick) overlie sandstones and mudstones, colluvial footslopes, and where coarse thick tephra deposits overlie consolidated rock types.

8. Deposition – D (aka siltation, sedimentation)

Deposition refers to sediment, (including vegetation) that has been eroded, transported, and subsequently deposited by running water. The material may be deposited within channels, on flat terrace surfaces by overbanking of streams or rivers or on fans or colluvial slopes during ephemeral flow. Sediment particle size ranges from clay to boulder. Although not an erosion process, deposition is a related process and the end product of erosion.

9. Wind erosion – W

Wind erosion is the detachment, and transportation by saltation (bouncing along the surface) and suspension, of particles (soil, regolith, sediment) by wind action. Wind erosion rates depend on wind velocity and currents, particle size and uniformity, moisture of material, surface roughness, and vegetation cover. Loose, exposed particles begin to move once a critical wind velocity, set by the surface properties, is exceeded. Further detachment is initiated by the impact of saltating particles on the surface.

Wind erosion may occur on flat or sloping land. Where steep bare surfaces are affected by wind erosion, sheet erosion also usually occurs. Wind erosion is the dominant erosion process on sand country, increasing in severity towards the coast where there is little soil development, and on recent volcanic soils above ~600 m asl. on the central plateau.

10. Scree erosion – Sc (aka scree creep)

Scree erosion is the transport and accumulation of coarse, fragmented rock debris on slopes as a result of physical weathering of exposed rock. Scree erosion occurs where rock material is indurated or hard, on steep slopes with shallow soils, and is common at higher altitudes where weathering rates are high and freeze-thaw and frost heave add to fragmentation and movement.

Scree material may be angular as in the case of greywacke, and hard volcanic rocks, or rounded in the case of gravels exposed in terrace scarps. Many screes are relatively stable, long-lived features, and in some cases have developed *in situ* from disintegration of underlying rock rather than from transport and accumulation of material from upslope. The presence of woody vegetation and lichens, and weathering rinds on rock fragments are indications of stability.

5.1.2 Erosion severities

The guidelines and definitions of erosion severity given below are based on Jessen et al. (1999). They are designed to help mappers assess the severity of present erosion. They also help assess the potential for erosion when deciding the LUC unit, because mappers decide whether the criteria are likely to be met in an erosional episode or as a result of significant land-use or land management change.

Surface erosion

Surface erosion processes comprise **sheet, wind and scree erosion.** The severity of surficial erosion is based on areal extent of bare ground and soil loss. Because of the common association of sheet and rill erosion, areal guidelines for the severity of rill erosion are also included here.

Guidelines for assessing present erosion severity are:

Ɵ Erosion is assessed as **nil to negligible** where there is no evidence of present erosion.

1. Erosion is assessed as **slight** where there is recent evidence of topsoil thinning (commonly, but not necessarily relating to soil depletion index 1). The area affected by erosion is <10%. Rill erosion is widely spaced and occupies <1% of the area.

2. Erosion is assessed as **moderate** where there is recent evidence of substantial soil loss (commonly, but not necessarily relating to soil depletion index 2). The area affected by erosion is between 11% and 20%. Rill erosion has an areal extent of between 1% and 5% of the area.

3. Erosion is assessed as **severe** where erosion processes are removing most of the topsoil and some of the subsoil (commonly, but not necessarily relating to soil depletion index 3). The area affected by erosion is between 21% and 40%. Rill erosion is evident on between 5% and 10% of the area.

4. Erosion is assessed as **very severe** where erosion processes are removing all of the topsoil and most of the subsoil (commonly, but not necessarily relating to soil depletion index 4). The area affected by erosion is between 41% and 60%. Rill erosion is evident on >10% of the area.

5. Erosion is assessed as **extreme** where erosion processes are removing all the topsoil and most subsoil over most of the area (commonly, but not necessarily relating to soil depletion index 5). The area affected by erosion is >60%. Rill erosion is evident on >10% of the area.

Table 1. Soil depletion index

Symbol	Description
0	little or no topsoil lost
1	<25% of topsoil depth lost (A horizon)
2	25−75% of topsoil depth lost, subsoil exposed but no significant subsoil lost (B horizon)
3	>75% of topsoil depth lost, subsoil exposed and <50% of subsoil lost, parent material (C horizon) or bedrock exposed
4	soil parent material or bedrock exposed, little subsoil remains (lost >50% subsoil by depth, and/or lost all subsoil <50% of area)
5	soil parent material or bedrock exposed, little subsoil remains (lost >50% subsoil by depth, and/or lost all subsoil >50% of area)

Table 2. Surface erosion severity guidelines

Symbol	Severity	Percentage bare ground
Θ	negligible	<1
1	slight	1−10
2	moderate	11−20
3	severe	21−40
4	very severe	41−60
5	extreme	>60

Assessment of present erosion severity should also take into account:

- indicators of erosion such as exposure of tree roots, splash pedestals, build up of soil downslope behind vegetative barriers and colluvium deposited downslope
- amount of soil profile eroded (Table 1)
- the assessed rate of soil loss
- slope angle and length

- slope angle and length
- soil properties (structure, texture, slaking, dispersion, etc.)
- percentage of the area with complete ground cover or closed canopy vegetation
- condition/type, extent and success of existing soil conservation measures
- the percentage of the area with bare rock resistant to erosion

Mass-movement erosion

Mass-movement erosion comprises landslides, riparian landslides, slumps, earthflows, and rock falls. Severity is based on seriousness – a combination of depth, frequency, potential for further erosion, difficulty of repair, economic effects and the areal extent of bare ground.

Landslides

Table 3. Guidelines for relating bare ground area of scars to landslide erosion severity

Symbol	Severity	Percentage bare ground
Ɵ	negligible	<0.5
1	slight	0.5−2
2	moderate	3−5
3	severe	6−10
4	very severe	11−20
5	extreme	>20

Assessment of present erosion severity should also take into account:

- the size of erosion scars
- the volume of material removed
- the nature of the rock or regolith
- the physical and chemical properties of the soil
- slope angle and length
- position on hillslope, i.e. connectivity of debris with stream channels
- likelihood of reactivation, e.g. undercutting by stream
- the effectiveness of soil conservation measures in other similar situations

Riparian landslides

Table 4. Guidelines for relating bare ground area of scars to riparian landslide erosion severity

Symbol	Severity	Percentage bare ground
Ɵ	negligible	<0.1
1	slight	0.1−0.5
2	moderate	0.6−1
3	severe	2−5
4	very severe	6−10
5	extreme	>10

Assessment of present erosion severity should also take into account:

- length of hillslope channel affected by landslides
- density of affected hillslope channels
- fluvial characteristics of affected hillslope channels
- the size of erosion scars
- the volume of material removed
- the nature of the rock or regolith

- the volume of material removed
- the nature of the rock or regolith
- physical and chemical properties of the soil
- slope angle of riparian slopes
- the effectiveness of soil conservation measures in other similar situations

Earthflow erosion

Table 5. Guidelines for relating earthflow area to earthflow erosion severity

Symbol	Severity	Percentage area affected
Ө	negligible	<1
1	slight	1−5
2	moderate	6−10
3	severe	11−25
4	very severe	26−40
5	extreme	>40

Assessment of present erosion severity should also take into account:

- evidence of ground disruption as indicator of rate of movement
- depth to stable bedrock
- physical and chemical properties of the rock, regolith and soil
- slope angle and slope length
- wetness of earthflow
- average annual rainfall
- processes likely to affect rate of movement, such as removal of toe by stream, presence of springs
- effectiveness of soil conservation measures in other similar situations.

The above guidelines can also be applied to slump erosion.

Fluvial erosion

Fluvial erosion comprises rill, gully, tunnel gully, streambank (and deposition). As with mass movement, severity is based on seriousness – a combination of depth, frequency, potential for further erosion, difficulty of repair, economic effects and areal extent of bare ground.

Gully erosion

Table 6. Guidelines for relating gully area to gully erosion severity

Symbol	Severity	Percentage bare ground
Ө	negligible	<0.1
1	slight	0.1−1
2	moderate	2−5
3	severe	6−10
4	very severe	11−20
5	extreme	>20

Assessment of present erosion severity should also take into account:

- physical and chemical properties of the rock
- length, width and depth of gullies

- number of gullies
- size of runoff-contributing area above gully
- fluvial characteristics of gully channels
- slope of gully walls
- the effectiveness of soil conservation measures in other similar situations

Tunnel gully erosion
Assessment of the severity of tunnel gully erosion is primarily on the basis of the areal extent of tunnel gullies. Cost and technical difficulty of repair must also be taken into account, particularly the depth of tunnel gullies that will dictate cost and feasibility of repair.

Table 7. Guidelines for relating area affected by tunnel gully erosion to tunnel gully erosion severity

Symbol	Severity	Percentage area affected
Ɵ	negligible	<0.5
1	slight	0.5−2
2	moderate	3−5
3	severe	6−15
4	very severe	16−30
5	extreme	>30

Assessment of present erosion severity should also take into account:

- physical and chemical properties of the soil and regolith
- length, width and depth of tunnel gullies
- number of tunnel gullies
- degree of roof collapse
- size of runoff-contributing area above tunnel gullies
- fluvial characteristics of tunnel gully channels
- slope angle
- the effectiveness of soil conservation measures in other similar situations

Streambank erosion
Severity of streambank erosion is assessed on a reach basis. A reach is a length of stream course relatively homogeneous in form (bed slope, sinuosity, bars, width, bank material) and in terms of processes (incision or aggradation, sediment transport).

Table 8. Guidelines for relating area affected by bank loss to streambank erosion severity

Symbol	Severity	Proportion of reach eroded
Ɵ	negligible	lateral bank erosion <10 cm with <1% of reach eroded
1	slight	lateral bank erosion 10−50 cm with 1−5% of reach eroded
2	moderate	lateral bank erosion 50 cm−1 m with 6−10% of reach eroded
3	severe	lateral bank erosion 1−2 m with 11−25% of reach eroded
4	very severe	lateral bank erosion 2−5 m with 26−40% of reach eroded
5	extreme	lateral bank erosion >5 m with > 40% of reach eroded

Where the proportion of lateral bank erosion and proportion of reach eroded do not match a severity category in the above guidelines, the proportion of lateral bank erosion is used to select the severity category e.g. lateral bank erosion of 1−2 m with only 6−10% of reach eroded is classed as severe.

Assessment of the severity of streambank erosion should also take into account:
- length of streambank actively eroding
- height of streambank actively eroding
- lateral distance eroded into terrace
- aggrading or degrading streambed
- proportion of channel affected
- physical nature of streambank materials
- cost and technical difficulty of repair
- frequency of exposure to high energy water action.

Deposition

Table 9. Guidelines for the severity of deposition

Symbol	Description
Ɵ	negligible deposition
1	shallow deposition (<10 cm) of generally fine-textured materials (sand, silt, clay) affecting <5% of area
2	medium depth of deposition (10−50 cm) of fine-textured or fine gravelly materials affecting 5−10% of area; or shallow deposition affecting 10−20% of area
3	deep deposition (>50 cm) affecting >10% of area; or shallow to medium deposition affecting >20% of area

Land subject to more than one erosion process is regarded as highly erodible land if at least three processes are each assessed as having a moderate severity.

5.1.3 Land Use Capability (LUC) units

The guidelines in the previous section are designed to help the assessment of **present** erosion severity. The Land Use Capability system of land classification (Soil Conservation and Rivers Control Council 1971) is designed to identify, by considering physical land characteristics, climate and response to land use and management, where the **potential** for erosion is a limitation to sustainable land use (i.e. land that is highly erodible).

Key features that influence the potential for erosion and therefore the identification of Highly Erodible Land (HEL) are:

- Parent material of soils (rock and/or cover deposits)
- Geological controls (structure, faults, crush zones)
- Slope (angle, length)

Table 10 lists LUC units recorded in the Horizons Regional Council area in hill country that meet HEL criteria. There are three NZLRI Regional Land Use Capability Classifications in the Horizons Regional Council area (Taranaki–Manawatu, Southern Hawke's Bay−Wairarapa, and Wellington), and this made it necessary to provide a correlation of LUC units in Table 10. Table 11 lists LUC units that comprise other areas of HEL within the region (Sand Country, Volcanic Plateau, and Axial Ranges), but these environments are not the main interest of this study, although they are listed to give a full regional view of HEL. Decision trees will be provided to aid recognition of individual LUC units in the field in a future project.

Table 10. LUC units comprising HEL in hill country*

NZLRI region	Taranaki–Manawatu	Southern Hawke's Bay–Wairarapa	Wellington	
Terrain (and main erosion type)	LUC units			Slope threshold (degrees)
Mudstone hill country (landslide)	6e3, 6e4, 6e5, 6e7, 6e8, 6e21 7e1, 7e2, 7e7, 7e9, 7e20, 8e3	6e2, 6e3, 6e7, 6e8 7e1,7e2, 7e12		24
Mudstone hill country (earthflow)	6e19, 6e20 7e12, 7e14	6e10, 6e12 7e6, 7e7, 7e8, 7e9, 8e3		24
Consolidated sandstone hill country (landslide)	6e2, 6e3, 6e4, 6e10, 6e12, 6e13, 6e14, 6e15, 6e17, 6e23 7e3, 7e4, 7e5, 7e11, 7e13, 7e17, 7e23, 8e3	6e9 7e4, 8e1, 8e2		28
Moderate to unconsolidated sandstone hill country (landslide, gully)	6e11, 6e13, 6e14 7e6, 7e16, 8e2			26
Greywacke hill country (landslide, scree)	6e16 7e8, 7e10	6e11 7e10	6e6, 6e8, 6e10 7e1, 7e2	28

Table 11. LUC units comprising HEL – non-hill country*

NZLRI region	Taranaki–Manawatu	Southern Hawke's Bay–Wairarapa	Wellington
Terrain (and main erosion type)	LUC units		
Sand country (wind)	6e24, 7e15, 8e1	6e14, 7e14, 8e4	6e5, 7e3, 8e1
Taupo flow tephra terraces and basins (gully, streambank)	6e26, 7e19, 8e2		
Upland plains and plateaux (wind, sheet)	7e24, 7e25, 7e26, 8e10		
Greywacke ranges (landslide, scree)	8e4, 8e7, 8e8, 8e9	8e5, 8e6	7e5, 8e3, 8e4, 8e5
Greywacke ranges (sheet, wind, scree)	6e27, 7e21, 7e22, 8e5, 8e6, 8e8, 8e9		
Volcanic ranges (landslide)	7e18, 8e4, 8e7		
Volcanoes (scree, wind, sheet)	8e8, 8e9		

*Classes 7 and 8 LUC units have a potential for severe or greater erosion, and Class 6 units have a potential for moderate erosion. Class 6 LUC units comply with HEL only when they have the potential to deliver sediment into watercourses.

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