Yorkshire Peat Partnership Technical Specification 2

Large Gully and Hag Stabilisation and Re-vegetation

1. Introduction

Peat as a land surface without a vegetative cover is unstable to the extent that the erosive forces of wind, water and livestock poaching easily facilitate the rapid stripping off of peat, often down to the subsoil/mineral/bedrock. Eroded peat is usually washed into watercourses along with silt from any mineral base material that has become exposed as the peat is removed. Peat is a very important carbon sink, once it is in solution in a water body the carbon becomes dissolved and may eventually be released into the atmosphere, probably contributing to the build-up of greenhouse gases in the atmosphere. Peat in upland watercourses also causes problems for water supply companies as large quantities of peat have to be removed from drinking water supplies at very great cost to them and ultimately the consumer. Silt getting into streams as a result of erosion is settling out in reservoirs and presenting serious problems for water companies as the siltation depths build up. There is also a widely held view that siltation of watercourses is damaging aquatic habitats for some species and is a major contributory factor when floods occur in areas downstream of the uplands.

Exposed bare peat in upland regions is caused by a number of factors including; livestock poaching and overgrazing, vehicle damage, peat extraction for fuel use and the most widespread cause – fire.

The initial impact of these factors can lead to areas where the exposed edges of a peat block (hags – see Figure 2.1) are continually eroded away due to the combined effects of freeze-thaw action, cantilever collapse of large blocks followed by desiccating wind erosion during drier periods. In many cases, these eroding edges are often either side of a flow of water (gullies – see Figure 2.1) where a grip has eroded, cracks in the peat have widened or sub-surface channels have collapsed followed by nick-point erosion upstream. Hags and gullies together with flatter areas of bare peat often combine to create extensive areas of heavily degraded eroding peatland.

Actively eroding and exposed hags and gullies create an extremely hostile environment for plants to grow and they need to be stabilised before vegetation can then be re-established. This document sets out a range of methods for restoring gullies and hags to a stable, re-

vegetated condition to prevent further ongoing erosion and eventually to restore hydrological conditions that enable active peat-forming habitats to be re-established.

2. Stabilisation

2.1. Reprofiling to a stable slope angle

2.1.1. Hag & Gully classification

2.1.1.1. YPP now classifies hags & gullies based on 4 variables:

(i) Depth in metres in 5 categories (from top of sloping edge to base of gully):
≤1m
>1m≤2m
>2m≤3m
>3m≤4m
>5m

(ii) Width in metres in 5 categories (gullies only) (from top of sloping edge on one side to top of sloping edge on other side).
≤1m
>1m≤2m
>2m≤3m
>3m≤4m
>5m

(iii) Angle of sloping side in 4 categories.

Vertical (V) = >75^{o}
Severe (Sv) = >45^{o}≤75^{o}
Moderate (M) = >33^{o}≤45^{o}
Stable (St) = ≤33^{o}

(iv) Base substrate in 6 categories.

Bare deep peat (≥0.3m)
Bare shallow peat (<0.3m)
Bare mineral
Vegetated deep peat (≥0.3m)
Vegetated shallow peat (<0.3m)
Vegetated mineral

2.1.2. Achieving the correct slope angle

2.1.2.1. The ideal aim of eroded hag and gully stabilisation is to achieve a hag or gully edge that has no more than about a 33^{o}–35^{o} stable slope and is well vegetated. With hags this may or may not be combined with dams, sediment traps or flow reduction baffles particularly where it is not possible to achieve a 33^{o}–35^{o} slope.

2.1.2.2. Basic trigonometry can be used to work out the base length for each slope angle and depth and therefore the minimum gully width for each slope type (see Table

1). This then can be used to determine which gully depths and widths can achieve a re-profiled stable slope angle of 33º–35º (see Table 2).

2.1.2.3. This analysis shows that only those gullies that are ≤1m deep and >3m wide can be re-profiled to a stable slope angle. A ≤1m deep and >2m≤3m wide and a >1m≤2m deep and >4m wide gully could be re-profiled to a Moderate slope but would need additional stability to provide a base for re-vegetation. No other gullies can be re-profiled without losing material into the central watercourse unless combined with dams or sediment traps which are generally ≤1m in height.

Table 1 Base dimensions and minimum gully widths for different depths and slope angles of eroding hags and gully sides.

	33º		45º		75º	
Depth	Base (m)	Min gully (m)	Base (m)	Min gully (m)	Base (m)	Min gully (m)
≤1m	1.54	3.08	1	2	0.3	0.6
>1m≤2m	3.08	6.16	2	4	0.54	1.08
>2m≤3m	4.62	9.24	3	6	0.8	1.6
>3m≤4m	6.16	12.32	4	8	1.07	2.14
>5m	7.70	15.40	5	10	1.34	2.68

Table 2 Matrix showing which combinations of gully depth and width can be reprofiled to achieve stable or moderate slope angles.

		Width					
		≤1m#	>1m≤2m	>2m≤3m	>3m≤4m	>4m≤5m	>5m
Depth	≤1m	X	X	45º	33º	33º	33º
	>1m≤2m	X	X	X	X	45º	45º
	>2m≤3m	X	X	X	X	X	X

#Note: YPP reprofile all gullies ≤1m as standard regardless of slope dimensions

2.1.2.4. As a result of the above:

Gully management:

(i) All gullies ≤1m deep will be re-profiled but those ≤3m wide will also require sediment traps or dams to prevent the loss of peat through the central water channel (see Technical Specification 1). Edges of re-profiled gullies >3m wide may also need to be re-vegetated as described in sections 2.2 & 2.3.

(ii) Gullies >1m≤2m deep can also be re-profiled to a moderate slope if they are >4m wide but they will need to include additional measures to support the unstable slope as described in section 2.2. Again, the re-profiled slopes may also need to be re-vegetated as described in section 2.3.

(iii) For bare gully sides exposed to the prevailing wind additional measures to stabilise the bare peat surface will be needed as described in section 2.2.

(iv) It may be possible to carry out stabilisation works on other larger gullies but this would need to be determined on a case by case basis requiring detailed surveying and site-specific measures.

Hag management:

(v) All eroding hags ≤3m high should be re-profiled to a stable 33º–35º slope angle.

(vi) For larger hags there may be insufficient material to reprofile to a 33º–35º slope and these should be re-profiled to a moderate 45º slope angle if possible. In these circumstances stabilisation will also need to include additional measures to support the unstable slope as described in section 2.2. The re-profiled slopes may also need to be re-vegetated as described in section 2.3.

(vii) For bare peat hags exposed to the prevailing wind additional measures to stabilise the bare peat surface will be needed as described in section 2.2.

(viii) It may be possible to carry out stabilisation works on other larger hags but this would need to be determined on a case by case basis requiring detailed surveying and site-specific measures.

(ix) All hag and gully works should be completed as soon as possible after the bird breeding season and grouse-shooting season have finished ideally in late summer or autumn when weather conditions are generally more favourable.

2.1.3. Suggested re-profiling method

2.1.3.1. A 1-2m length of vegetation on the top of the hag should be “rolled” back or undermined (to a depth that retains the root structure of the vegetation) far enough to enable the underlying peat to be removed to create a stable 33^0 sloping bank or, in some cases, a moderately stable 45^0 sloping bank from the top of the hag to the base (see Figure 2.2).

2.1.3.2. The vegetation should then be rolled back and compacted to cover the newly profiled slope.

2.1.3.3. For 45^0 slopes further stabilisation may be needed using the techniques outlined in section 2.2.

2.1.3.4. Where the vegetation does not completely cover the newly re-profiled slope and natural re-vegetation is considered unlikely further treatment of the bare peat using the techniques outlined in section 2.3 will be required.

2.2. Stabilising peat surfaces

2.2.1. Protecting the toe

2.2.1.1. Where a gully is not being blocked using dams or sediment traps the toe of an eroding or re-profiled 45^{o} sloping gully edge should be protected from the erosive impact of the central water flow using a bund consisting of either;

(i) random gritstone (150 - 400mm) approximately 75cm high and 75cm in transverse width with the side facing into the gully sloping at the same angle as the re-profiled gully side (see Figure 2.3a), or;

(ii) a double row of coir logs laid one on top of each other sloping into the bank along the base of the gully and staked into the slope using 1m long, wooden stakes (e.g. chestnut paling) at 0.5m intervals (see Figure 2.3b), or;

(iii) a double row of 1.2m long x 0.8m high heather bales along the base of the gully and staked into the slope using 1m long, wooden stakes (e.g. chestnut paling) at 3 stakes per bale (see Figure 2.3c).

2.2.2. Covering with geojute

2.2.2.1. For eroding or re-profiled 45^{o} sloping gully edges and/or stable slopes that are exposed to the prevailing wind geo-textiles should be applied to stabilise the peat surface (Figure 2.4).

2.2.2.2. The main materials used are Geo-jute which is manufactured by a number of different companies. It is an open weaved bio-degradable “net” with a weight of 500-600g/m^2 and should degrade within 2-5 years on moorlands. It is usually supplied in cuts 1.2 metres wide and 50 or 70 metres long. There are between eight and ten cuts per bale which is 500 or 560 linear metres or 600 or 672metres^2.

2.2.2.3. The net is fixed directly to the bare peat areas or gully sides using a variety of different types of pegs. Yorkshire Peat Partnership recommends the use of timber pegs from an FSC approved supplier. The net should be fixed using at least 3 pegs per linear metre with additional pegs needed for securing around topographical features. The whole net should be walked over and pressed down into depressions and any protruding lumps of peat stamped down into the net. The top and side edges of the net should ideally be secured underneath existing vegetation.

2.2.2.4. Geo-textiles should be applied in the autumn/winter after re-profiling and prior to seeding to ensure that seed lime and fertiliser are trapped in the net to enable rapid vegetation establishment.

2.2.2.5. The area of geo-textile required is calculated using a Geographical Information System (GIS) through analysis of aerial photographs.

2.2.2.6. Table 3 gives the number of widths required for each type of gully/hag.

2.2.2.7. Pegs are forced from the ground in winter due to frost heave. They should be inspected in the spring and reinstalled if necessary.

Table 3 Number of geo-textile widths required to stabilise different hag/gully slope dimensions

Depth (m)	Slope angle	Length of slope (m)	Widths of geo-textile (n)
≤1m	33º	1.84	2
	45º	1.41	2
>1m≤2m	33º	3.67	3
	45º	2.83	3
>2m≤3m	33º	5.51	4
	45º	4.24	4
>3m≤4m	45º	5.66	4
>4m≤5m	45º	7.07	5

2.2.3. Spreading bryophyte rich heather brash to stabilise bare peat surfaces

2.2.3.1. For stable slopes a bryophyte-rich heather brash (double-chopped) cut from a suitable donor site (which must be as local to the restoration site as possible and will be inspected and approved by YPP staff) is spread after re-profiling (see Figure 2.5). The brash must be spread as soon as possible after cutting and should not be left in bags for longer than 2 weeks as any heather seed or bryophyte material is unlikely to be viable after this.

2.2.3.2. The brash is delivered in builders dumpy bags (see Figure 2.6). 1 hectare of bare peat with brash spread to a depth of 5cm requires 780 bags (see Table 4 for quantities for each hag/gully slope).

2.2.3.3. Brash can be spread manually using forks or by specially equipped very low ground pressure vehicles to a depth of 5cm (Figure 2.7)

2.2.3.4. If there is suitable access the brash can be cut close to the restoration site and the dumpy bags can be transported by suitable low ground-pressure vehicles.

2.2.3.5. If brash has to be brought-in from further afield it must be delivered to the site by helicopter to avoid significant ground damage. The bags are flown to the bare gully areas in pairs. (see Figure 2.6)

2.2.3.6. When the bags are emptied they are rolled and parcelled together for removal from the moor. For airlifting, as many bags as possible should be parcelled together to ensure adequate weight to prevent the bags causing helicopter instability.

2.2.4. Establishment of a grass & cotton-grass sward to bind the surface peat

To provide longer-term stability of the re-profiled slopes a grass seed mix is applied. The grass roots bind the peat surface into a stable turf that then forms the basis for other moorland species to colonise into or, where these are absent, for brought-in plants to become established. This is done in several steps:

2.2.4.1. Application of lime:

(i) Eroded peat is very acidic and provides a hostile environment for seeds to germinate. Therefore, granulated lime is applied in February at a rate of 1t/ha (see Table 4 for quantities for each hag/gully type) ideally 6 weeks, but at least 2 weeks prior to adding grass seed to raise the pH to about 5 (See Figure 2.9)

(ii) Bulk lime is usually spread using large self propelled spreaders. The use of such spreaders on peat may be inappropriate due to the likelihood of them getting stuck or damaging habitat on, near or en-route to restoration areas. For small patches of bare peat with reasonable access lime can be spread with small spreaders mounted on ATVs or very low ground pressure tractors or otherwise manually.

2.2.4.2. Application of grass seed:

(i) Grass seed should be heat treated to reduce the instances of pathogens.

(ii) Grass seed (see Table 5 for seed mix) is applied at the same time as a dwarf-shrub seed mix in March at least 2 weeks after the application of lime at a total seed rate of 10kg/ha depending on the site (see Figure 2.9).

(iii) For small patches of bare peat with reasonable access seed can be spread with small spreaders mounted on ATVs or very low ground pressure tractors or otherwise manually.

2.2.4.3. Application of fertiliser:

(i) Peat is naturally very nutrient poor and damaged peat even more so. In order to establish the grass sward and provide favourable conditions for initial dwarf-shrub growth it is necessary to provide a short-lived low dose of nutrients using artificial fertiliser applied in July once the grasses are actively growing.

(ii) Phosphate fertiliser (P_2O_5) should be applied at a rate of 20kg/ha.

(iii) For small patches of bare peat with reasonable access fertiliser can be spread with small spreaders mounted on ATVs or very low ground pressure tractors or otherwise manually.

Table 4 Quantification of materials required to stabilise a kilometre of different hag/gully slope dimensions

Depth (m)	Slope angle	Per kilometre of gully/hag				
		Area of slope (ha)	Bags of brash @ 780 bags/ha (n)	Lime @1tonne/ha per kilometre (tonnes)	Phosphate fertiliser (P_2O_5) @ 20kg/ha (kg)	Moorland seed mix @ 20kg/ha (kg)
≤1m	33º	0.18	141	0.18	3.6	1.8
	45º	0.14	109	0.14	2.8	1.4
>1m≤2m	33º	0.37	289	0.37	7.4	3.7
	45º	0.28	218	0.28	5.6	2.8

Table 5 Moorland grass mix species composition.

Species (Latin)	**Species (English)**	**% of seed mix**
Agrostis capillaris	Common bent	**20**
Festuca ovina	Sheep's fescue	**20**
Deschampsia flexuosa	Wavy hair grass	**30**
Eriophorum vaginatum	Hare's-tail cotton-grass	**30**

2.3. Re-establishing blanket bog vegetation to stabilised slopes

2.3.1. Dwarf-shrub seeds

2.3.1.1. In some circumstances it will be desirable to introduce dwarf shrub seed to the stabilised slopes. YPP recommends using a dwarf-shrub seed mix of 50:50 *Calluna vulgaris:Erica tetralix* applied at a rate of 1.5kg per hectare.

2.3.1.2. Small amounts of other species (e.g *Vaccinium myrtillus*, *Vaccinium vitis-idaea* or *Empetrum nigrum*) can be added if required although these are generally better applied as plug plants as they require additional seed treatment to ensure decent germination rates.

2.3.1.3. Seed should be heat treated to reduce the instances of pathogens.

2.3.1.4. For small patches of bare peat with reasonable access seed can be spread with small spreaders mounted on ATVs or very low ground pressure tractors or otherwise manually.

2.3.1.5. The dwarf-shrub seed should be applied in March at the same time as the grass seed and fertiliser.

2.3.2 Dwarf-shrub & cotton-grass plugs.

2.3.2.1 Young Cotton-grass and dwarf-shrub plants are available from a limited number of suppliers as “plugs”. These are used by YPP to increase the long-term stability of the sloping sides and bases of gullies and hags through targeted planting in areas that are similar to the natural conditions these species are normally grown in.

2.3.2.2 The plugs are usually planted by hand using a standard manual tool.

2.3.2.3 Common cotton-grass (*Eriophorum angustifolium*) or if not available Hare’s-tail cotton grass plugs should be planted in lines 1m apart along the lowest 0.3m of the gully/hag slope or in blocks on wetter flat areas behind the top of the gully at 1 plug per m^2 (See Figure 2.11). If cotton-grass is naturally colonising within 1 metre of the re-profiled gully no additional plugs are needed.

2.3.2.4 Where wider gullies have not been completely blocked with dams or sediment traps and flow reduction baffles have been used instead, cotton-grass plugs can be planted in groups either side of the baffles to increase the sediment trapping abilities of the baffles.

2.3.2.5 Crowberry (*Empetrum nigrum*) is also very effective at binding peat particularly around the apex or shoulder at the top of the re-profiled slope.

2.3.2.6 Crowberry plugs should be planted 1m apart in three rows in a dice pattern with one row on the flat areas 0.5m behind the apex of the slope, one row on the apex itself and one row on the first 0.5m of the slope (See figure 2.11).

Figure 2.1 Photos of eroding gully sides and an eroding hag

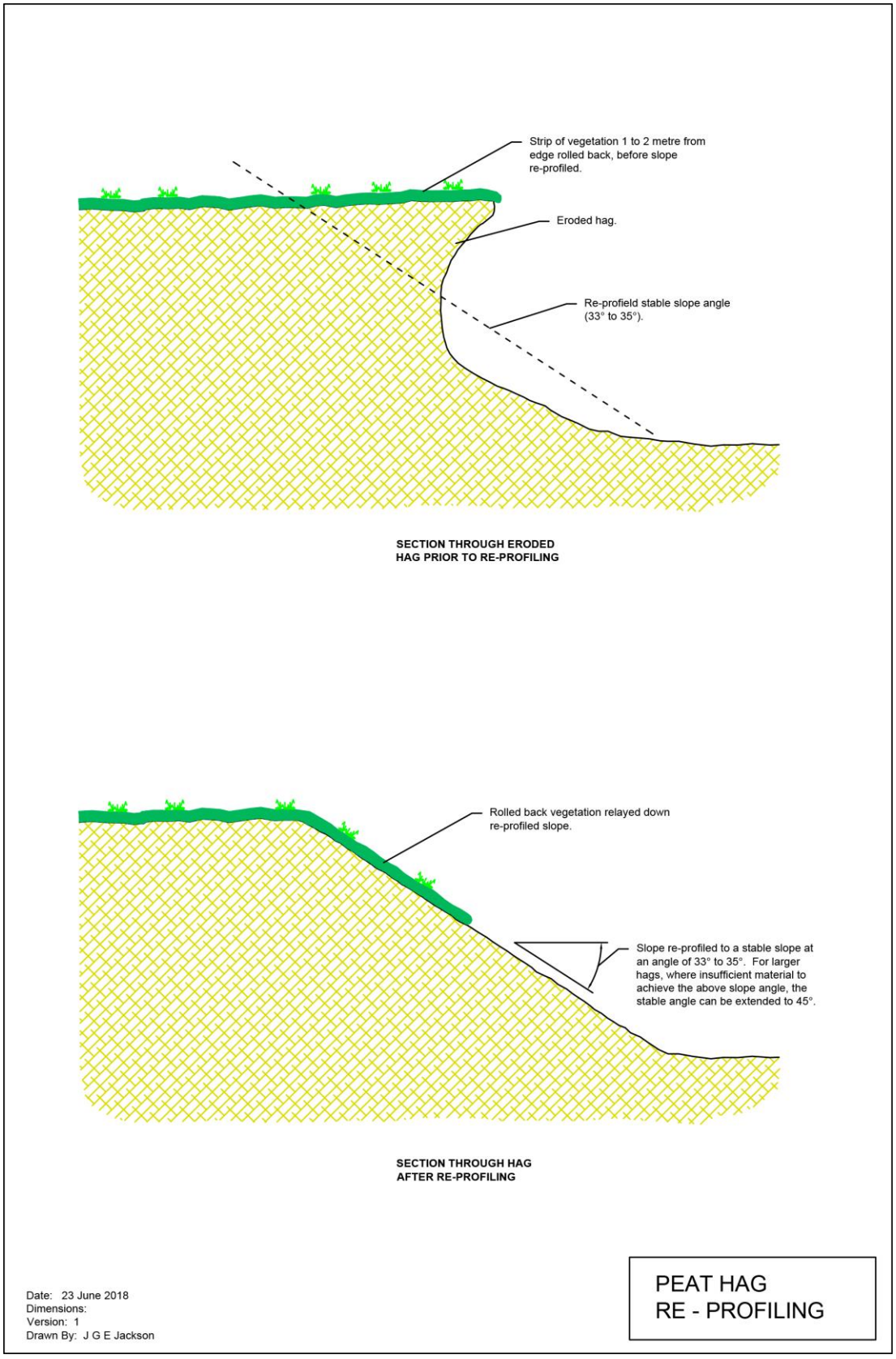
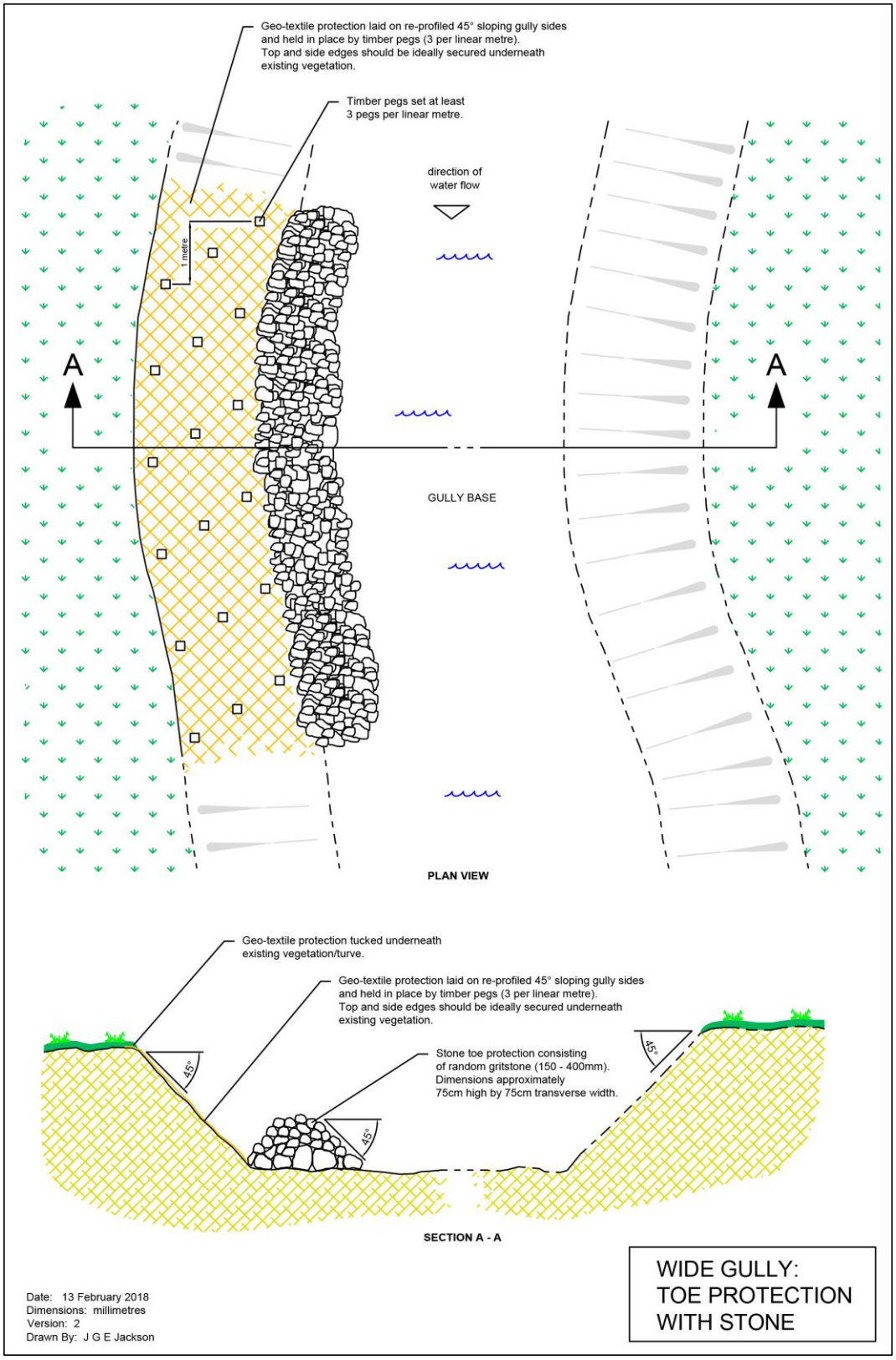
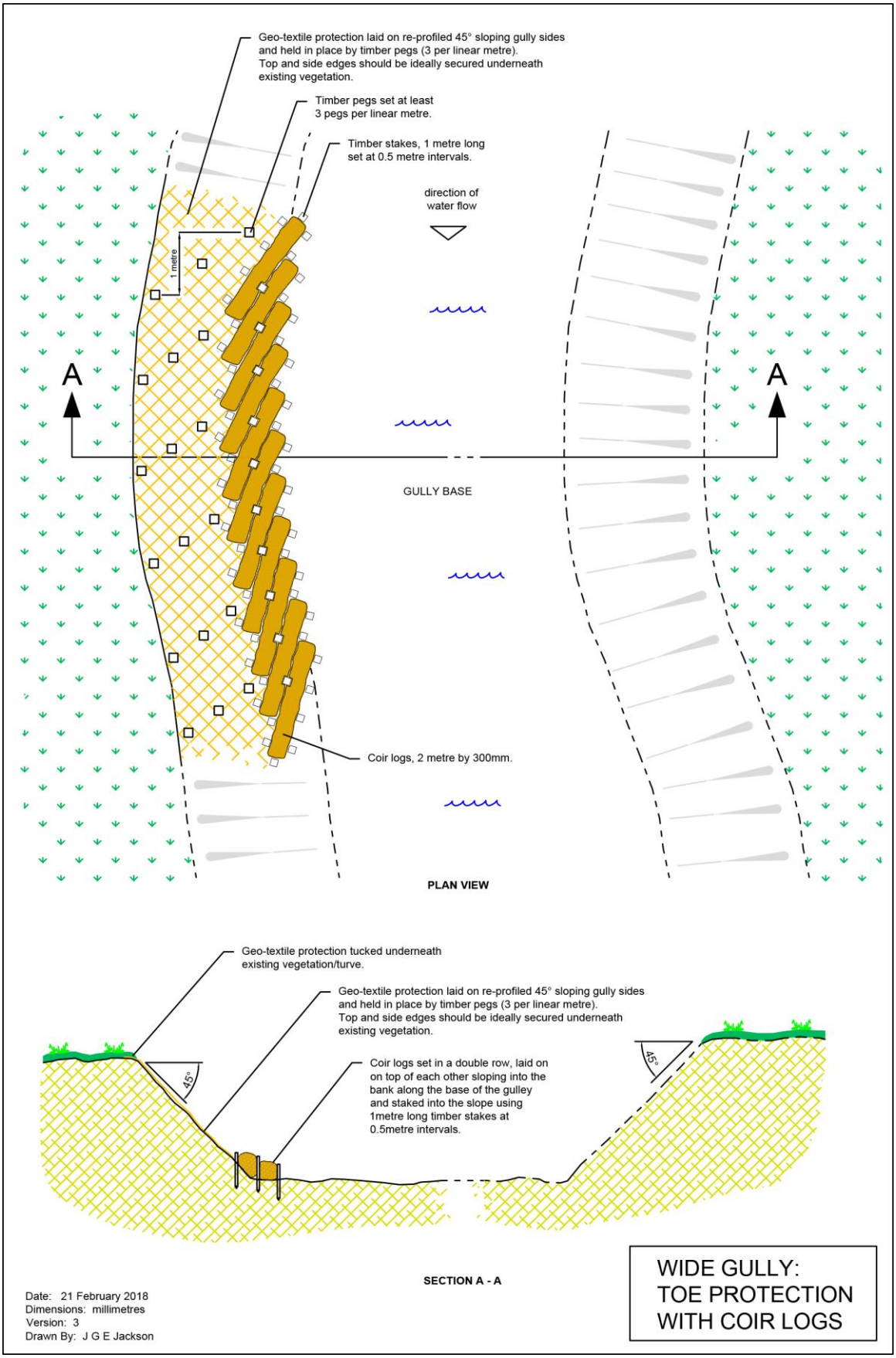


Figure 2.2: Reprofiling large eroding hags or hagged gullies

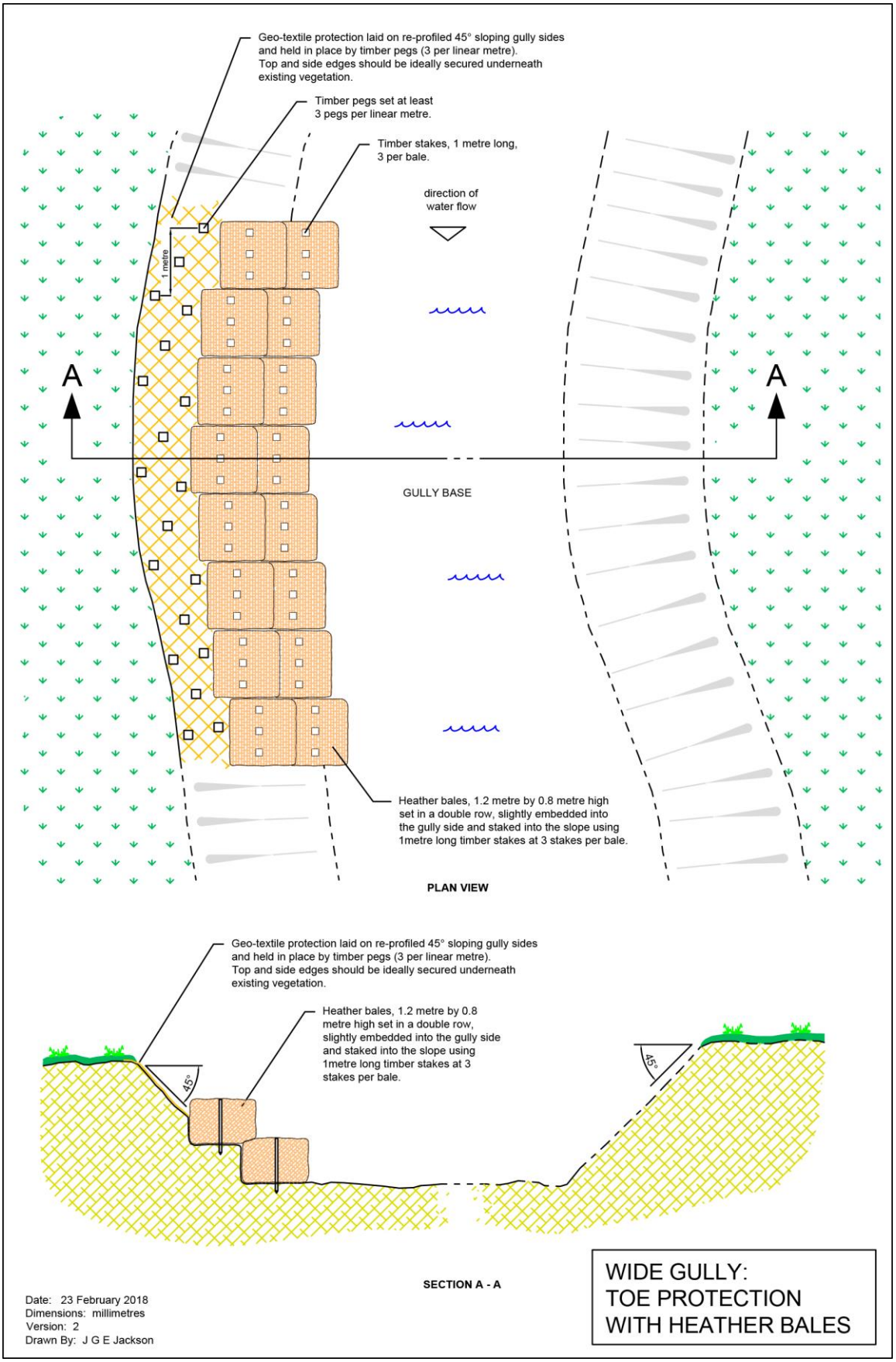
Figure 2.3 Protecting eroding gully toe reprofiled to 45º



a. With stone



b. With coir logs



c. With heather bales

Figure 2.4 photo of a geo-textile treated slope

Figure 2.5 Photo of a well-brashed 33 degree slope

Figure 2.6 Photo of brash dumpy bag being lifted by helicopter

Figure 2.7 Photo of brash being spread to correct depth

Figure 2.8 Photo of lime applied to bare peat

Figure 2.9 Photo of germinating grass seed

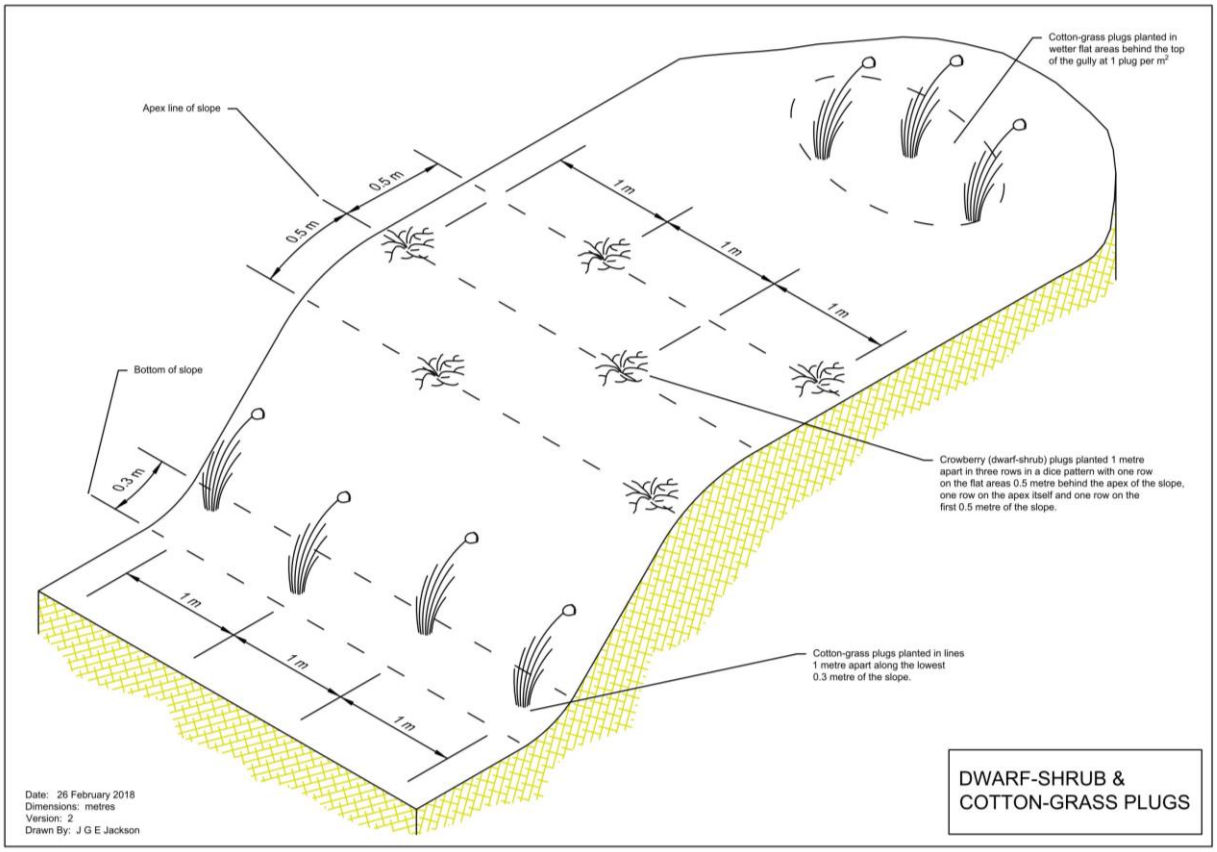


Figure 2.11 Diagram of plug-planting zones on gully sides